Balanced Asphalt Mixture Design: A Formula for Success
Southeastern Asphalt User/Producer Group Annual Meeting November 14 – 16, 2017 Jacksonville, Florida

What is Balanced Mix Design (BMD)?

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.”

• Use the right mix for the right job!

History of Mix Design

1890
Barber Asphalt Paving Company
Asphalt cement 12 to 15% / Sand 70 to 83% / Pulverized carbonic 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

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, never implemented)

Discussion Items

1. What is Balanced Mix Design (BMD)?
2. Why the need for BMD?
3. What are the most common performance tests (rutting and cracking) for BMD?
4. What is the current national state of practice for BMD?
5. How does a BMD compare with a volumetric mix design?
6. What is the future of BMD?

Selecting the Correct Mix

• Using the right mixture for the right job
• But if a Ferrari is needed, don’t provide a Pinto
• Don’t design a Ferrari, if a Pinto will do the job!

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.”

• Use the right mix for the right job!
Why the need for BMD?

Problems:
- Dry mixes exist in some areas.
- Volumetrics alone cannot adequately evaluate mix variables, such as recycle, warm-mix additives, polymers, rejuvenators, and fibers.

Solutions:
1. Recognize performance issues related to dry mixes in some areas. (Note: Many performance issues are caused by factors outside the mix design.)
2. Increase understanding of the factors which drive mix performance
3. Design for performance and not just to "the spec."
4. Start thinking outside of long held "rules and constraints"
5. Innovate!

Why the Need for a New Mix Design Approach?

- Problems:
  - Dry mixes exist in some areas.
  - Volumetrics alone cannot adequately evaluate mix variables, such as recycle, warm-mix additives, polymers, rejuvenators, and fibers.
- Solutions:
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  3. Design for performance and not just to "the spec."
  4. Start thinking outside of long held "rules and constraints"
  5. Innovate!

Pavement Performance General Overview

Achieving Balanced Mixture Performance is Key to a Long Lasting Pavement

What Type Distress Is Occurring?

Durability / Cracking Dominates

Source: Oldcastle Internal Survey

Superpave system is becoming unrecognizable with specifications changing rapidly as agencies search for ways to improve durability
- Specifications have become convoluted and confounded
- Existing specified items compete against each other
- New requirements get added and nothing gets removed
- Establishing true "cause and effect" is impossible

Agencies Are Searching for Solutions: Spec Changes

What is the Main Key to Enhancing the Durability of Asphalt Mixtures?

"Volume of Effective Binder (Vbe) is the primary mixture design factor affecting both durability and fatigue cracking resistance."

Vbe = VMA – Air Voids

Source: Oldcastle Internal Survey


Enhancing the Durability of Asphalt Pavements

Source: Oldcastle Materials

November 14-16, 2017

Jacksonville, Florida
What are the most common performance tests (rutting and cracking) for BMD?

Main Pavement Distresses Observed in the Field

- Moisture Damage
- Permanent Deformation
- Fatigue Cracking
- Thermal Cracking
- Reflection Cracking
- Top-down Cracking

Source: NCAT

Test Mixtures in the Lab to Help Ensure Field Performance

- Mixtures need to be evaluated in the lab during design to help ensure the required field performance can be achieved.

What Distress Does Your State Want to Address with Performance Testing?

- Moisture Damage
- Permanent Deformation
- Fatigue Cracking
- Thermal Cracking
- Reflection Cracking
- Raveling

Source: NCAT Survey

Stability Testing (Rutting)

- Rutting can be evaluated with several available tests based on the user preference.
- Hamburg Wheel Test (HWT)
- Asphalt Pavement Analyzer (APA)
- AMT Pile Number

Most commonly used tests. Hamburg gaining popularity due to moisture susceptibility analysis.
Durability Testing (Cracking)

- Durability/cracking evaluation is substantially more complicated than stability with aging being one main variable.
- No general consensus the best test(s) or the appropriate failure threshold.
- MANY different tests are available with more being developed.
- Main question is “What is the anticipated mode of distress?”

Durability/Cracking Evaluation

First Question for Durability Testing: What is the Anticipated Mode of Distress for Testing?

- Many tests are available with each targeting a specific specimen response (i.e., field distress)
- Various empirical and mechanistic tests are available for use.
- Match apples to apples, not apples to oranges!

GOALS
1. MATCH THE TEST TO THE DISTRESS
2. SET APPROPRIATE FAILURE THRESHOLDS

Fatigue (Bottom Up or Top Down) Related Cracking Tests

- Bending Beam Fatigue
- Texas Overlay Test
- SCB – Jc
- Fatigue, S-VECD

Thermal Cracking Tests

- IDT Creep Compliance
- TSRST
- SCB at Low Temp
- Disk Shaped Compact Tension (DCT)

Reflection (Reflective) Cracking Tests

- Disk Shaped Compact Tension (DCT)
- Texas Overlay Test
- SCB (FIT)
**Performance Tests**

- Empirical tests will tend to have monotonic loading + high strains and can be conducted in a shorter time period.
- Mechanistic tests will tend to have cyclic loading + low strains and will require a longer test time.
- Each test is developed to evaluate a certain mixture response.
- Multiple tests may be needed.
- Use caution when trying to relate one test to another (e.g., IFIT vs DCT).

**Key Test Considerations**

1. Strong relationship to performance
2. Sensitive to mix variation (e.g., binder, aggregate, grading, etc.)
3. Practical: cost, time, complexity
4. Repeatable, reproducible

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**Performance Space Diagrams**

- Performance testing within a BMD allows an improved visualization of mix performance relative to economics.
- Allows for effective mix optimization!

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**BMD Approaches**

- Three general mix design approaches.
  1. Volumetric Design w/ Performance Verification
  2. Performance Modified Volumetric Design
  3. Performance Design

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**Agency Practices For Balanced Mix Design**

What is the current national state of practice for BMD?

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**Volumetric Design w/ Performance Verification**

- 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

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**Example Data for Illustration Purposes**

What is the current national state of practice for BMD?

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**Graphic Developed by Kevin Hall (FHWA BMD Task Force), 2016**
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. The final volumetric properties may be allowed to drift outside existing AASHTO M323 limits.

Example States: 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

Innovation Potential = Low / Medium / High

A number of SHAs have begun to either explore or adopt BMD approaches.

<table>
<thead>
<tr>
<th>State</th>
<th>Mixture Design</th>
<th>Design Type</th>
<th>Testing Type</th>
<th>Volumetric Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>Performance Mod. Volumetric</td>
<td>Design w/ Performance Verification</td>
<td>Hamburg Wheel Tracking Test (HWTT) AASHTO T 324</td>
<td></td>
</tr>
<tr>
<td>Illinois</td>
<td>Volumetric Design w/ Performance Verification</td>
<td>RVT</td>
<td>Hamburg</td>
<td></td>
</tr>
<tr>
<td>Louisiana</td>
<td>Volumetric Design w/ Performance Verification</td>
<td>Aggregate Penetration</td>
<td>Texas Overlay Test [T 324]</td>
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<tr>
<td>New Jersey</td>
<td>Volumetric Design w/ Performance Verification</td>
<td>Asphalt Pavement Penetration</td>
<td>Asphalt Pavement Analyzer</td>
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<tr>
<td>Texas</td>
<td>Volumetric Design w/ Performance Verification</td>
<td>Asphalt Pavement Penetration</td>
<td>Asphalt Pavement Analyzer</td>
<td></td>
</tr>
<tr>
<td>Wisconsin</td>
<td>Volumetric Design w/ Performance Verification</td>
<td>Hamburg Tension Test</td>
<td>Texas Overlay Test [T 324]</td>
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</tbody>
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Within this acceptable range (5.3 to 5.8 percent), the mixture at the selected asphalt content must meet the Superpave volumetric criteria.

Ongoing National Research: NCHRP Project 20-07/Task 406

- Development of a Framework for Balanced Asphalt Mixture Design
  - 1 yr. / 100k Project, Started May 2017
- The objective of this research is to develop a framework that addresses alternate approaches to devise and implement balanced mix design procedures incorporating performance testing and criteria.
- The framework shall be presented in the format of an AASHTO recommended practice and shall encompass a wide variety of testing procedures and criteria.

Framework for Balanced Mix Design NCHRP 20-07/Task 406

- BMD is a very "hot" topic nationally!
- Various State DOTs have current research activities focused on BMD related activities

Ongoing State DOT Research

<table>
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<tr>
<th>State</th>
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<tr>
<td>California</td>
<td>Simplified Performance Based Specifications for Long Life AC Pavements</td>
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<tr>
<td>Idaho</td>
<td>Development and Evaluation of Performance Measures to Augment Asphalt Mix Design in Cold Climates</td>
</tr>
<tr>
<td>Indiana</td>
<td>Performance Balanced Mix Designs for Indiana's Asphalt Pavements</td>
</tr>
<tr>
<td>Minnesota</td>
<td>Balanced Design of Asphalt Mixtures</td>
</tr>
<tr>
<td>Texas</td>
<td>Develop Guidelines and Design Program for Hot Mix Asphalt Containing RAP, RAS, and Other Additives through a Balanced Mix Design Process</td>
</tr>
<tr>
<td>Wisconsin</td>
<td>1. Analysis and Flexibility of Asphalt Pavement Performance-Based Testing</td>
</tr>
<tr>
<td></td>
<td>2. Developing Air Void of Balanced Hot Mix Design</td>
</tr>
</tbody>
</table>
How does a BMD compare with a volumetric mix design?

Volumetric Mix Design vs Balanced Mix Design (Example)

VOLUMETRIC
BALANCED

What's the future of BMD?

The Path Forward for Balanced Mix Design

- Long term effort with ups/downs, but we must start now.
- Utilize available, proven approaches to find effective, implementable solutions.
- Completion of 20-07 Task 406 and the developed AASHTO recommended practice will aid use / implementation.

What Should You Do To Get Ready For BMD?

1. Establish a DOT & Industry task group
2. Discuss the need
3. Discuss the advantages and disadvantages of potential tests
4. Try to reach consensus on which tests are most likely to succeed
5. Discuss how to deal with reheating and mix aging
6. Purchase equipment and get trained
7. Test and evaluate current mixes (lab and plant produced)
8. Determine the best ways to improve mixes
9. Determine appropriate criteria based on collected data
10. Plan and execute pilot projects

List Source: NCAT

Don’t fail to do anything, because you can’t do everything.

Final Thoughts

- 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”
Thank You / Questions

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