# Balanced Asphalt Mixture Design: A Formula for Success


Southeastern Asphalt User/Producer Group
Annual Meeting
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## 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?

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## What is Balanced Mix Design (BMD)?

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## 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!

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## Selecting the Correct Mix

- Using the right mixture for the right job!

- Don't design a Ferrari, if a Pinto will do the job!

- ***But*** if a Ferrari is needed, don't provide a Pinto!

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## 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)

Stability

**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

Stability + Durability

**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**

Stability + Durability

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

http://asphaltmagazine.com/history-of-asphalt-mix-design-in-north-america-part-2/

## Why the need for BMD?

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## Why the Need for a New Mix Design Approach?

- **Problems:**
  - Dry mixes exist in some areas.
  - Volumetrics alone can not 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!**


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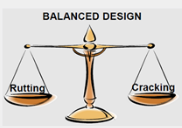
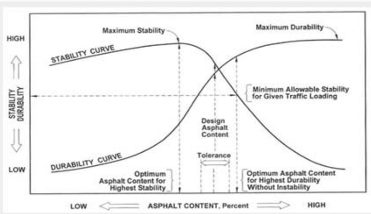
## Pavement Performance General Overview

- Achieving Balanced Mixture Performance is Key to a Long Lasting Pavement

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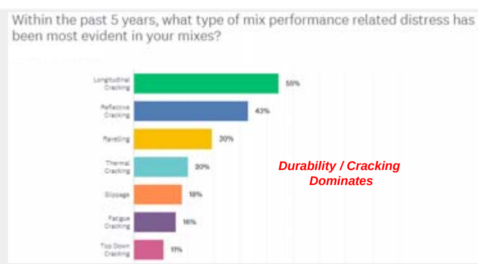
## What Type Distress Is Occurring?

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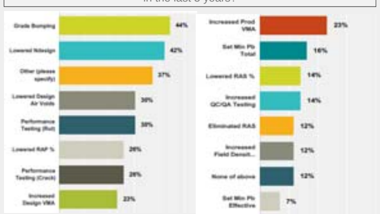
Source: Oldcastle Internal Survey

## Agencies Are Searching for Solutions: Spec Changes

- 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**

Which of the following specification changes has your DOT implemented in the last 5 years?



Source: Oldcastle Internal Survey

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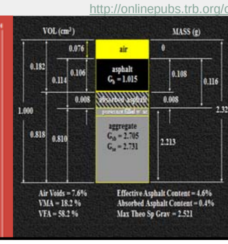
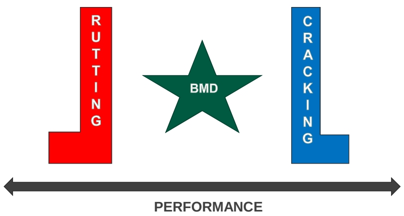
## What is the Main Key to Enhancing the Durability of Asphalt Mixtures?

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

http://onlinepubs.trb.org/onlinepubs/circulars/ec186.pdf


## What are the most common performance tests (rutting and cracking) for BMD?

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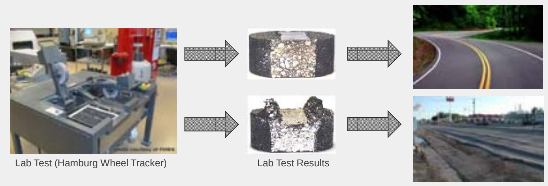
## Test Mixtures in the Lab to Help Ensure Field Performance

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



Lab Test (Hamburg Wheel Tracker) Lab Test Results Expected Field Performance

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## Main Pavement Distresses Observed in the Field


Source: NCAT

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

| Answers (DOT) | # (%) Response |
|---|---|
| Fatigue cracking | 40 (88%) |
| Rutting | 33 (70%) |
| Thermal cracking | 30 (64%) |
| Reflection cracking | 29 (62%) |
| Moisture damage | 28 (60%) |
| Raveling | 23 (49%) |
| Others (block cracking, slippage, etc.) | 22 (51%) |

Source: NCAT Survey


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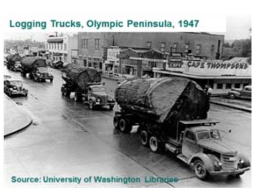
## Stability Testing (Rutting)

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## Rutting Tests

- Rutting can be evaluated with several available tests based on the user preference.

Hamburg Wheel Test (HWT)

Asphalt Pavement Analyzer (APA)

AMPT Flow Number

Most commonly used tests. Hamburg gaining popularity due to moisture susceptibility analysis.

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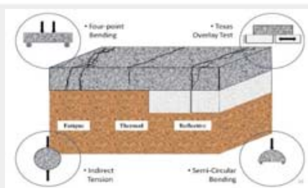
## Durability Testing (Cracking)

## Durability/Cracking Evaluation

- 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?**"


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

- Many test 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!



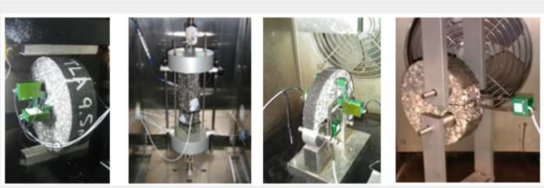

GOALS
1. MATCH THE TEST TO THE DISTRESS
2. SET APPROPRIATE FAILURE THRESHOLDS

## Fatigue (Bottom Up or Top Down) Related Cracking Tests

| Bottom Up | Bottom Up | Bottom Up / Top Down | Bottom Up |
|---|---|---|---|

| Bending Beam Fatigue | Texas Overlay Test | SCB<br>- LTRC – Jc<br>- IFIT | Direct Tension Cyclic Fatigue, S-VECD |
|---|---|---|---|

## Thermal Cracking Tests



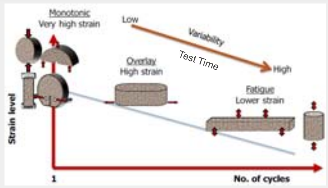
IDT Creep Compliance | TSRST | SCB at Low Temp | Disk Shaped Compact Tension (DCT)

## Reflection (Reflective) Cracking Tests

Disk Shaped Compact Tension (DCT) | Texas Overlay Test | SCB (IFIT)

## 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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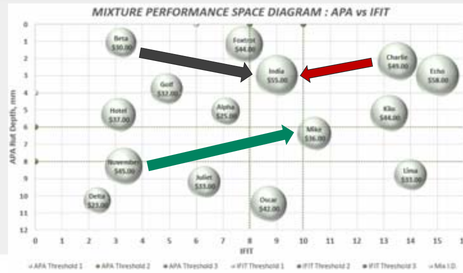
## Performance Space Diagrams

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




Example Data for Illustration Purposes

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**What is the current national state of practice for BMD?**

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## Agency Practices For Balanced Mix Design

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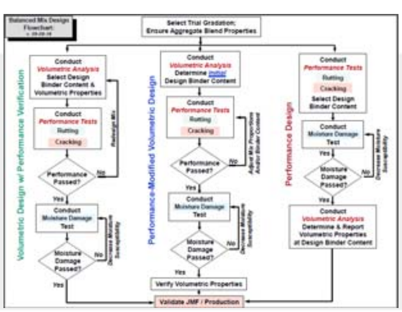
## BMD Approaches

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




*Graphic Developed by Kevin Hall (FHWA BMD Task Force), 2016*

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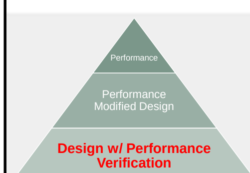
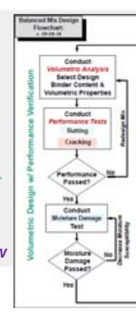
## Volumetric Design w/ Performance Verification




***Innovation Potential = Very Low***




- **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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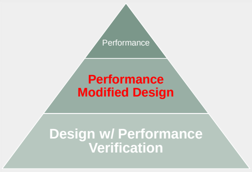
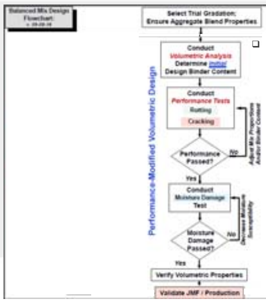
## Performance Modified Volumetric Design



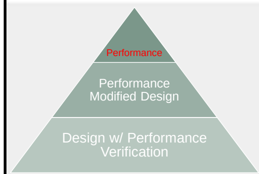

*Innovation Potential = Low*



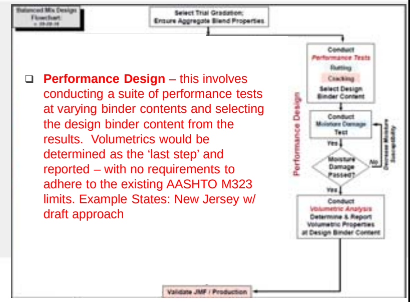

- **Performance-Modified Volumetric Design** – the initial design binder content is selected using AASHTO M323/R35 prior to performance testing; the results of performance testing could 'modify' the mixture proportions (and/or) adjust the binder content – and the final volumetric properties may be allowed to drift outside existing AASHTO M323 limits. Example State: California



## Performance Design




*Innovation Potential = Medium / High*




- **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



## State Agency Practice – Mixture Design

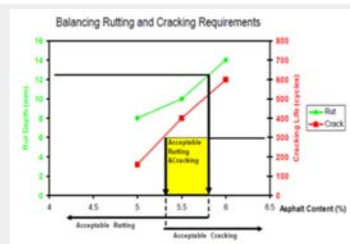
- A number of SHAs have begun to either explore or adopt BMD approaches.

| State | Design Approach | Stability Test | Durability/Cracking Test |
|---|---|---|---|
| California | Performance Mod Vol Design | SST Repeated Shear, Hamburg | Bending Beam Fatigue (BBF) |
| Illinois | Vol Design w/ Performance Verification | Hamburg | Semi Circular Bend (IFIT) |
| Louisiana | Vol Design w/ Performance Verification | Hamburg | Semi Circular Bend (LTRC) |
| New Jersey | Vol Design w/ Performance Verification | Asphalt Pavement Analyzer | Texas Overlay Test (OT) |
| Texas | Vol Design w/ Performance Verification | Hamburg | Texas Overlay Test (OT) |
| Wisconsin | Vol Design w/ Performance Verification | Hamburg | Disc Shaped Compact Tension + SCB (IFIT) |



## 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.

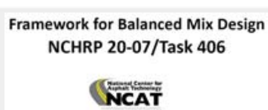



**Within this acceptable range (5.3 to 5.8 percent), the mixture at the selected asphalt content must meet the Superpave volumetric criteria.**



## 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.**





Standard Practice for
Balanced Design of Asphalt Mixtures
AASHTO Designation: R xx-xx
Technical Section: 2d, Proportioning of Asphalt-Aggregate Mixtures
AASHTO



## Ongoing State DOT Research

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

| State DOT | Research Title |
|---|---|
| California | Simplified Performance Based Specifications for Long Life AC Pavements |
| Idaho | Development and Evaluation of Performance Measures to Augment Asphalt Mix Design in Idaho |
| Indiana | Performance Balanced Mix Designs for Indiana's Asphalt Pavements |
| Minnesota | Balanced Design of Asphalt Mixtures |
| Texas | Develop Guidelines and Design Program for Hot-Mix Asphalts Containing RAP, RAS, and Other Additives through a Balanced Mix Design Process |
| Wisconsin | 1. Analysis and Feasibility of Asphalt Pavement Performance-Based Testing Specifications<br>2. Regressing Air Voids for Balanced HMA Mix Design |

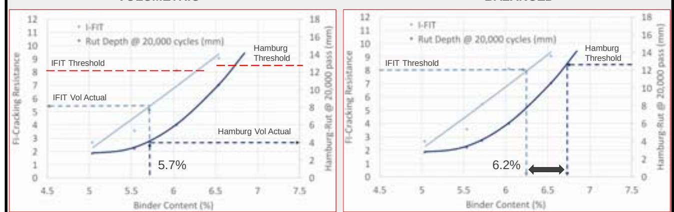
Caltrans · Idaho Transportation Department · Indiana Department of Transportation · Minnesota Department of Transportation · Texas Department of Transportation

## How does a BMD compare with a volumetric mix design?



## Volumetric Mix Design vs Balanced Mix Design (*Example*)

VOLUMETRIC | BALANCED




Note: Example for Illustration Purposes.

*Source: NCAT Balanced Mix Design Training Course*

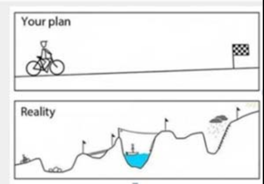


## What's the future of BMD?




## 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***


***"By failing to prepare, you are preparing to fail."***

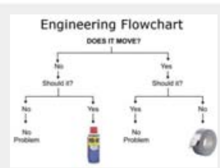
*- Ben Franklin*



***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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