Balanced Flexible Pavement (Asphalt) Mixture Design
West Virginia Fun Facts!

- George Brett and Jerry West are from WV
- Mother’s Day first celebrated in Grafton, WV in 1908
- Home to largest steel arch bridge
  - (3000’, New River Gorge)
- In Alderson, WV, lions, tigers, and other “large” felines have to be leashed when going for a walk!
Discussion Items

• Understand the concept of Balanced Mixture Design.
• Review the most common performance tests (rutting and cracking) for BMD.
• Learn the current national state of practice for BMD.
• Learn how you can prepare for the future of asphalt mixture design.
• Discuss theory and reality pertaining to mix design.
Balanced Mix Design

Mix design based on balancing mix rutting and cracking performance instead of conventional recipe, restrictive specifications.
Selecting the Correct Mix

• Understand the concept of Balanced Mixture Design.

• Don’t design a Ferrari, if a Pinto will do the job!

• But if a Ferrari is needed, don’t provide a Pinto!
Did You Know…..

- 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
Main Pavement Distresses Observed in the Field

- Moisture Damage
- Permanent Deformation
- Fatigue Cracking
- Thermal Cracking
- Reflection Cracking
- Top-down Cracking
What Distress Does Your State Want to Address with Performance Testing?

<table>
<thead>
<tr>
<th>Answers (DOT)</th>
<th># (%) Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fatigue cracking</td>
<td>40 (88%)</td>
</tr>
<tr>
<td>Rutting</td>
<td>33 (70%)</td>
</tr>
<tr>
<td>Thermal cracking</td>
<td>30 (64%)</td>
</tr>
<tr>
<td>Reflection cracking</td>
<td>29 (62%)</td>
</tr>
<tr>
<td>Moisture damage</td>
<td>28 (60%)</td>
</tr>
<tr>
<td>Raveling</td>
<td>23 (49%)</td>
</tr>
<tr>
<td>Others (block cracking, slippage, etc.)</td>
<td>22 (51%)</td>
</tr>
</tbody>
</table>

Source: NCAT Survey
What are the Most Common Performance Tests (Rutting and Cracking) for BMD?
Rutting Tests

Logging Trucks, Olympic Peninsula, 1947

Source: University of Washington Libraries
Rutting Tests

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

- Hamburg Wheel Test (HWT)
- Asphalt Pavement Analyzer (APA)
- IDT - HT
- AMPT Flow Number / Dynamic Modulus

Most commonly used tests. Hamburg gaining popularity due to moisture susceptibility analysis.
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**
- Bending Beam Fatigue
- Texas Overlay Test

**Bottom Up / Top Down**
- SCB
  - LTRC – Jc
  - IFIT

**Bottom Up**
- Direct Tension Cyclic Fatigue, S-VECD

**IDEAL CT**
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)
IFIT Background Information

Flexibility Index (FI) = \( G_F \times \frac{1}{\text{abs}(m)} \)

- Peak Load
- Slope at Inflection Point (m)
- Work of Fracture (W)
- Critical Displacement (u_c)
- Final Displacement (u_{fin})
IDEAL CT Background Information

- Similar to IFIT
- Uncut!
- 62 mm height specimen

https://www.youtube.com/watch?v=OB4pQDB2Yfs

Texas A&M Transportation Institute

Indirect Tension Asphalt Cracking Test (IDEAL-CT)
NCHRP IDEA Project 195: Development of an IDEAL Cracking Test for Asphalt Mix Design, Quality Control and Quality Assurance

Time View: 0:40 to 1:40
Balanced Mix Design

**MIX PERFORMANCE CURVES**

- Rutting
- Cracking

**MIXTURE PERFORMANCE SPACE DIAGRAM: APA vs IFIT**

- Good Performance
- Better Rutting Performance
- Better Cracking Performance

- Rutting Performance Threshold
- Cracking Performance Threshold
- Acceptable Binder Content Range

20 | Americas Materials - Performance
Mix Testing – IFIT Results

![IFIT Graph]

- **STOA OPT. - 0.5**: 3.9
- **STOA OPT 0**: 7.2
- **STOA OPT. + 0.5**: 14.6
- **STOA OPT 8**: 4.4
- **STOA OPT. - 0.5**: 8.3
- **STOA OPT 35**: 17.7
- **STOA OPT. + 0.5**: 3.7
- **STOA OPT 8**: 5.2
- **STOA OPT. + 0.5**: 10.1

**Average of FI**

**FLEXIBILITY INDEX**

- 0
- 2
- 4
- 6
- 8
- 10
- 12
- 14
- 16
- 18
- 20

**INDICATORS**

- BINDER
- REJUVENATOR
- RAP
Performance Space Diagram (Hamburg vs IFIT)

**MATERIALS COST**

- 25% RAP
- 35% RAP
- 45% RAP

<table>
<thead>
<tr>
<th>Mix</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>25%0/OPT</td>
<td>$26.71</td>
</tr>
<tr>
<td>25%0/OPT+0.5%</td>
<td>$29.38</td>
</tr>
<tr>
<td>35%0/OPT</td>
<td>$24.91</td>
</tr>
<tr>
<td>35%0/OPT+0.5%</td>
<td>$27.57</td>
</tr>
<tr>
<td>45%0/OPT</td>
<td>$22.47</td>
</tr>
<tr>
<td>45%0/OPT+0.5%</td>
<td>$25.14</td>
</tr>
<tr>
<td>65%0/OPT</td>
<td>$27.80</td>
</tr>
</tbody>
</table>

* 4 mixes w/ acceptable performance w/ costs varying from $27.57 to $32.04
* Performance + Cost Data = Knowledge
* Knowledge leads to good decisions
Mix Testing – IDEAL CT Results

Average of CT Index 5

IDEAL CT

<table>
<thead>
<tr>
<th>OPT.</th>
<th>OPT. - 0.5</th>
<th>OPT. 0</th>
<th>OPT. + 0.5</th>
<th>OPT. - 0.5</th>
<th>OPT. 8</th>
<th>OPT. + 0.5</th>
<th>OPT. - 0.5</th>
<th>OPT. 8</th>
<th>OPT. + 0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAP</td>
<td>51.5</td>
<td>81.5</td>
<td>160.3</td>
<td>50.2</td>
<td>86.2</td>
<td>205.3</td>
<td>35.0</td>
<td>69.9</td>
<td>142.8</td>
</tr>
</tbody>
</table>
Performance Space Diagram (Hamburg vs IDEAL CT)

**MATERIALS COST**

- **Low Rutting, High Cracking**
- **Low Rutting, Low Cracking**
- **High Rutting, High Cracking**
- **High Rutting, Low Cracking**

*~4 mixes w/ acceptable performance w/ costs varying from $27.57 to $32.04
* Performance + Cost Data = Knowledge
* Knowledge leads to good decisions

CRH
Takeaway:
Can use IDEAL CT during production as a quicker control tool.
NCAT BMD Survey Results

Current Use of BMD Approaches
NCAT BMD Survey Results – State Interest in BMD

34 States Interested

[Map showing states interested in BMD]
Illinois Balanced Mix Design

- **Phased implementation**
  - 26 Pilot projects 2016/2017
  - All Interstate projects 2019
  - **Full implementation 2020**

(1) Hamburg Wheel Test Criteria. The maximum allowable rut depth shall be 0.5 in. (12.5 mm). The minimum number of wheel passes at the 0.5 in. (12.5 mm) rut depth criteria shall be based on the high temperature binder grade of the mix as specified in the mix requirements table of the plans.

<table>
<thead>
<tr>
<th>PG Grade</th>
<th>Number of Passes</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG 58-xx (or lower)</td>
<td>5,000</td>
</tr>
<tr>
<td>PG 64-xx</td>
<td>7,500</td>
</tr>
<tr>
<td>PG 70-xx</td>
<td>15,000</td>
</tr>
<tr>
<td>PG 76-xx (or higher)</td>
<td>20,000</td>
</tr>
</tbody>
</table>

(3) I-FIT Flexibility Index (FI) Criteria. The minimum allowable FI shall be as follows:

<table>
<thead>
<tr>
<th>Minimum Flexibility Index (FI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA</td>
</tr>
<tr>
<td>SMA</td>
</tr>
</tbody>
</table>
Louisiana Balanced Mix Design

- Louisiana DOT implemented BMD in the 2016 Standard Specifications for all DOT projects.

Hamburg research began prior to 2000
- SCB research began in 2004
New Jersey Balanced Mix Design

- NJDOT High RAP Design incorporates BMD

<table>
<thead>
<tr>
<th>Test</th>
<th>Surface Course</th>
<th>Intermediate and Base Course</th>
</tr>
</thead>
<tbody>
<tr>
<td>APA @ 8,000 loading cycles (AASHTO T 340)</td>
<td>≤ 7 mm</td>
<td>≤ 7 mm</td>
</tr>
<tr>
<td>Overlay Tester (NJDOT B-10)</td>
<td>≥ 200 cycles</td>
<td>≥ 100 cycles</td>
</tr>
</tbody>
</table>
Texas DOT Balanced Mix Design

- TxDOT currently uses BMD for selected specialty mixes.
- New SS 344 developed for Superpave BMD.

Special Specification 344
Superpave Mixtures - Balanced Mix Design

1. DESCRIPTION

Construct a hot-mix asphalt (HMA) pavement layer composed of a compacted Superpave (SP) mixture of aggregate and asphalt binder mixed hot in a mixing plant utilizing a Balanced Mix Design (BMD) approach.

- SS 344 allows TxDOT Districts to use on a case by case basis.
  - Delta Tc (<6C) and Methylene Blue (<10) requirements
  - Grade “dumps” reduced
  - Simplified recycle material requirements

From Robert Lee (TxDOT, Now CRH)
Texas DOT Balanced Mix Design Performance

Table 11A
Hamburg Wheel Test Requirements

<table>
<thead>
<tr>
<th>High-Temperature Binder Grade</th>
<th>Test Method</th>
<th>Minimum # of Passes @ 12.5 mm² Rut Depth, Tested @ 50°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG 64 or lower</td>
<td>Tex-242-F</td>
<td>10,000°F</td>
</tr>
<tr>
<td>PG 70</td>
<td>Tex-242-F</td>
<td>15,000°F</td>
</tr>
<tr>
<td>PG 76 or higher</td>
<td>Tex-242-F</td>
<td>20,000</td>
</tr>
</tbody>
</table>

1. When the rut depth at the required minimum number of passes is less than 3 mm, the Engineer may require the Contractor to lower the Ndesign level to no less than 35 gyrations.
2. May be decreased to no less than 5,000 passes when shown on the plans.
3. May be decreased to no less than 10,000 passes when shown on the plans.

Table 11B
Overlay Test Requirements

<table>
<thead>
<tr>
<th>Mixture Property</th>
<th>Test Method</th>
<th>Surface Mixtures</th>
<th>Intermediate and Base Mixtures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical Fracture Energy (CFE), 1 in²-lb/in² Min</td>
<td>Tex-248-F</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Crack Progression Rate (CPR), Max</td>
<td></td>
<td>0.45</td>
<td>0.55</td>
</tr>
</tbody>
</table>

1. If the requirement is not met, the Engineer may approve the mix if the average number of cycles is ≥300 cycles.

From Robert Lee (TxDOT, Now CRH)
Oklahoma DOT Balanced Mix Design Performance

Table 708:11a
Hamburg Rut Test Requirements\(^{a,b}\)

<table>
<thead>
<tr>
<th>Binder Grade</th>
<th>Minimum Number of Passes to 12.50 mm Rut Depth, Tested at 122 °F (50°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG 64</td>
<td>10,000</td>
</tr>
<tr>
<td>PG 70</td>
<td>15,000</td>
</tr>
<tr>
<td>PG 76</td>
<td>20,000</td>
</tr>
</tbody>
</table>

Table 708:8
Mix Design Properties of Laboratory Molded Specimens

<table>
<thead>
<tr>
<th>Property</th>
<th>Superpave</th>
<th>SMA</th>
<th>PFC</th>
<th>RBL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PG64</td>
<td>PG70</td>
<td>PG76</td>
<td>PG76</td>
</tr>
<tr>
<td>Cantabro</td>
<td>Report Only</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-FIT</td>
<td>≥ 8.0</td>
<td>≥ 8.0</td>
<td>≥ 8.0</td>
<td>---</td>
</tr>
</tbody>
</table>

Notes:
Hamburg + IFIT @ 7% voids, Cantabro @ 4%
Short term aging used (R30)
BMD Activities at the 2018 NCAT Test Track

- Balanced Mix Design is a key focus area
  - TXDOT (2 sections)
  - Texas Bit Mix (Materials)
  - OKDOT (2 sections)
  - APAC Central (OK) Mix Design and Materials
  - Cargill (2 sections)
## Current / Completed State DOT Research

Various State DOTs have research activities focused on BMD.

<table>
<thead>
<tr>
<th>State DOT</th>
<th>Research Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>Simplified <strong>Performance Based</strong> Specifications for Long Life AC Pavements (Funding unknown)</td>
</tr>
<tr>
<td>Idaho</td>
<td>Development and Evaluation of <strong>Performance Measures</strong> to Augment Asphalt Mix Design in Idaho (170K)</td>
</tr>
<tr>
<td>Indiana</td>
<td>Performance <strong>Balanced</strong> Mix Designs for Indiana’s Asphalt Pavements (243K)</td>
</tr>
<tr>
<td>Minnesota</td>
<td><strong>Balanced</strong> Design of Asphalt Mixtures (140K)</td>
</tr>
<tr>
<td>Texas</td>
<td>Develop Guidelines and Design Program for Hot-Mix Asphalts Containing RAP, RAS, and Other Additives through a <strong>Balanced</strong> Mix Design Process (524K)</td>
</tr>
</tbody>
</table>
| Wisconsin | 1. Analysis and Feasibility of Asphalt Pavement Performance-Based Testing Specifications (Funding Unknown, completed)  
2. Regressing Air Voids for **Balanced** HMA Mix Design (150K) |
| Oklahoma | Implement **Balanced** Asphalt Mix Design in Oklahoma (111K) |
| Nebraska | Feasibility and Implementation of **Balanced Mix Design** in Nebraska (120K) |
| Virginia | **Performance Mixture Design** for Asphalt Mixtures: Phase I, Roadmap and Specification Development (456K) |
Balanced Mix Design – The Future

- BMD / Performance Based Mix Design is Coming!
- New Draft BMD AASHTO Standards

Standard Specification for

**Balanced Mix Design**

AASHTO Designation: M XXX-XX
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures

Standard Practice for

**Balanced Design of Asphalt Mixtures**

AASHTO Designation: R xx-xx
Technical Section: 2d, Proportioning of Asphalt–Aggregate Mixtures
So…I’m a Agency Engineer, What to Do to Prepare?

1. Remember, it’s still aggregate, asphalt, and air!
2. Be aware of what’s happening
3. Participate in conferences/meetings to learn more
4. Evaluate your readiness (e.g., capabilities / needs). Do you need to more people, training, equipment?
5. Act to increase readiness
6. Establish baseline (test your mixes to see where you are at)
7. Establish appropriate protocols for design and acceptance
8. Embrace the opportunity!
9. Be the leader!

“By failing to prepare, you are preparing to fail.”
- Ben Franklin
So…I’m a Contractor / Producer, What to Do to Prepare?

1. Remember, it’s still aggregate, asphalt, and air!
2. Be aware of what’s happening
3. Participate in conferences/meetings to learn more
4. Understand the impact of BMD on asphalt binder demand, recycle potential / availability
5. Evaluate your readiness (e.g., capabilities / needs). Do you need to more people, training, equipment?
6. Act to increase readiness
7. Establish baseline (test your mixes to see where you are at)
8. Optimize mixes (performance + economics)
9. Embrace the opportunity!
10. Be the leader!
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.
- Must consider testing during production.
- IDEAL CT offers promise in this regard for fast, reliable rutting and cracking performance prediction.
Be Aware of the Total Picture!

- Materials
- Time
- Production
- Economics
- Construction
- Personnel
- Equipment
Theory and Reality

- Avoid measuring with a micrometer, marking with a piece of chalk and cutting with an ax.
- Must consider the “total picture” and not just a part.
- Applied Common Sense MUST be used.
Final Thoughts

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

"Things should be made as simple as possible, but no simpler."
-- Albert Einstein

[Diagram: Engineering Flowchart]

[Image: WD-40 and Price Tag]
Thank you