Evolution of Asphalt Mix Design Systems

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Our Visit Today

Part 1: The GOAL of Mix Design
Part 2: A Look Back at our Past
Part 3: The Superpave Revolution
Part 4: Hot Challenges because of Warm Mix

CHANGE:
The dogmas of the quiet past are inadequate to the stormy present... as our case is new, so we must think anew and act anew.
What is the GOAL?

- A Good mix provides?
- A Bad mix does not provide?

The GOAL is...

Getting this to Carry this without To much of this.

Professor Carl Monismith

- Design of an asphalt-aggregate mixture consists of...
  1. Select the type and gradation of mineral aggregate
  2. Select the type and grade of asphalt binder, with or without modification
  3. Select the amount of asphalt binder to satisfy the project-specific requirements...

Properties of a Good Asphalt-Aggregate Mixture

- Stiffness
- Durability
- Fracture Resistance
- Workability
- Permeability
- Stability
- Fatigue Resistance
- Low Skid
- Permeability
A Look Back at our Past

Early Design Methods

- T.L.A.R.
- W.A.G.
- S.W.A.G.

History

- Asphalt Paving in the United States
  - 1870 in Newark, New Jersey
  - 1871 in Washington, DC

Early Mix Design (1940-1960)

- Dominated by World War II... Korean War
- 1950’s Most Prevalent Systems, developed by:
  - Francis Hveem
  - Bruce Marshall
- Others:
  - Hubbard-Field, Smith Triaxial, & Texas Gyratory
Early Design Methods

- **State of California DOT Method**
  - Driver: Poor Performance
  - Key: lab *kneading* compaction

- **Francis Hveem**
  - Engineer CA Division of Highways
  - Hveem Method
    - Circa 1930’s thru 1942, 1985

- **Texas Gyratory Press**
  - Kneading compaction

- **US Army Corps of Engineers Method**
  - Driver: Poor Performance
    - 100 psi tires on WWII aircraft
    - Korean War introduced 200 psi tires
    - Impact Hammer (Compaction)

- **Bruce Marshall**
  - Vicksburg, Mississippi
  - Highway Research Board 1949

- **Gyratory Test Machine**
  - Floating 2-point system
  - Kneading Compaction, w/ a measure of stability
Early Design Methods

• 1950’s, US Corps of Engineers
  – John McRae

• 1st NCAT Track

European Methods

• Early 1960’s, LCPC, France
  – Texas-type gyratory press
  – French rut tester

LCPC Gyratory Compaction

• Early 1960’s, LCPC, France
  – Texas-type press
  – 1968, 2nd prototype
  – 1973, PCG1
  – 1985, PCG2
  – 1997, PGC3

Francis Moutier (LCPC)

• Early 1960’s, LCPC, France
  – Texas-type press
  – 1968, 2nd prototype
  – 1973, PCG1
  – 1985, PCG2
  – 1997, PGC3
LCPC Gyratory Compaction

• Early 1960’s, LCPC, France
  – Texas-type press
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The Superpave® Revolution

SHRP
5 years to boldly go where...

• 1987, United States Congress authorized the Strategic Highway Research Program
• 1987, Focus on asphalt binder research
• 1990, Expanded to include research on mix
A rose by any other name...

• But the Monk fish used to be called the Slime fish?

• And MiDAS became...

Superpave® System
Performance-Based
Purchase Specification
Design and Analysis Tool

Focus on Limiting Distress (Failure Modes)

Rutting

Dr. Damian Kulash
SHRP Executive Director

SHRP Researchers Working Hard
And many others...

Refinement, Jnr

Developed as Table 3 for AASHTO M 320-09

Matrix Approach, versions A-1

- The challenge is to develop a "purchase" specification...
- It has to be implement-able, — Both from an Agency and from an Industry standpoint

Dr. Dave Anderson
SHRP Researcher
Penn State

Standard Test Procedure developed for AASHTO TP70-09
SHRP... Mix Design

• SHRP mixture research, building on:
  – NCHRP 9-06, AAMAS
    • Report Number 338, published 1991
    • Von Quintus, Brent Rauhut Engineering
  – LCPC in France

SHRP

• NCHRP 9-06, AAMAS
  Asphalt-Aggregate Mixture Analysis System
  – US Corps GTM
  – Texas gyratory shear test machine

SHRP Gyratory Compactor

• 1990, FHWA Demo Project No. 90
  “Innovative Asphalt Mix Laboratory Techniques”

• AAMAS
• SHRP (MiDAS)

FHWA Modified Gyratory Shear Test Machine

• Fixed Angle
  – Variable 0.5° to 3.0° at 0.25° increments
• 4” Specimens
• 30 rpm
• Height recordation
AAMAS Workshops

- April 1991 in Atlanta, Georgia
- FHWA proposed a hybrid gyratory

Harman & D’Angelo

Asphalt Institute
SHRP A-005 Contractor

- Fall of 1991
- Building on LCPC
- Mod. TX Gyratory
- 6” specimens
- 1° angle
- 30 rpm
- Height recordation

An Alternative Path

- SHRP Intense Debate
- University of California – Berkeley
  – Promoted
  Rolling Wheel compaction

Superpave Gyratory Compactor Calibration
Making Superpave Mixtures Consistent
**Superpave® Mix Design**

1. **Selection of Materials**
2. **Selection of a Design Aggregate Structure**
3. **Selection of the Design Binder Content**
4. **Evaluation of Moisture Sensitivity**
   - Modified Lotman, AASHTO T 283
5. **Asphalt Mixture Performance Test(s)**

**A Simple Performance Test(s)**

- **NCHRP 9-19**
  - E*
  - Flow Number, Fn
  - Flow Time

**TP-62  Determination of Dynamic Modulus, E***

- 9-29: HMA Performance Tester
- TP 62 Dynamic Modulus E*
  - Accommodate HMA Performance Tester
  - Separate Std for sample preparation
  - Separate Std. for master curve

**Asphalt Mix Performance Tester**

- NCHRP 9-29
- Evaluate mixture fatigue and response (E*) rutting (Fn)
- Published as TP 79 also PP 60, PP 61, and PP 62
- Relatively inexpensive and ease of use
- Provides key MEPDG input
Asphalt Mix Performance Tester

Flow Number (Fn)

- Developed as indicator of rutting potential
- 9-33 relationship flow number/maximum traffic with lab mixes (field mix issue-age)
- Issues
  - High temperature 50% reliability PG LTPPBind 3.1
  - Confined/unconfined
  - Load: various levels have been used

Asphalt Mix Performance Tester

(2009/2010)

- Develop pooled fund for training and equipment purchase of the equipment
- Technician training for operation of the equipment (AAT contractor/NCAT Lab)
- Remaining issue with determination Flow Number, Fn

Future of Mix Design??

Hot Challenge because of Warm Mix

Warm Mix Asphalt

- WMA encompasses a wide range of enabling technologies that enhance asphalt production and/or lay-down properties...
**Q. Which project is which?**

A: Hot-Mix Asphalt (HMA)?
B: Warm Mix Asphalt (WMA)?

**Project No. 1**

**Project No. 2**

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**What is WMA?**

<table>
<thead>
<tr>
<th>Relative Production Temperature (°F)</th>
<th>Zone</th>
<th>Driver</th>
<th>WMA Technology Category...</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA</td>
<td></td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>- 40°</td>
<td></td>
<td>A lot</td>
<td></td>
</tr>
<tr>
<td>- 60°</td>
<td></td>
<td>Maybe</td>
<td></td>
</tr>
<tr>
<td>- 80°</td>
<td></td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>- 100°</td>
<td></td>
<td>Unlikely</td>
<td>n/a</td>
</tr>
</tbody>
</table>

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**Q. From an Agency perceptive, what Driver is most important?**

<table>
<thead>
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<th>Relative Production Temperature (°F)</th>
<th>Zone</th>
<th>Driver</th>
<th>WMA Technology Category...</th>
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<tbody>
<tr>
<td>HMA</td>
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<td></td>
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<tr>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- 100°</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**I.C. = I.P.**

- The BAD mix with GOOD density outperformed the GOOD mix with POOR density.
Memorable Message

• I.C. = I.P.
  Improved Compaction = Improved Performance

• F.E.W. key benefits...
  – Fuel
  – Emissions
  – Worker Comfort

**Advantages will only be realized by optimizing production operations and utilizing best practices**

Currently Twenty Two (22) Technologies Marketed and Available in the US.

Economics of WMA
Start Up to Operating

• Foaming Systems...
  – $35 to $100k Start Up
  – Water is basically free.
  – If a liquid antistrip is needed, ~ $1 to $2 / ton

• Additive Systems...
  – $7 to $60k Start Up
  – $1.75 to 2.50 / ton of mix

• Factor in fuel savings
  Net cost ~ Zero to $1.50 / ton

Mike Acott
President, National Asphalt Pavement Association

“WMA is the future of flexible pavements in the U.S. ... lowering our production and paving temperatures promises improved energy consumption, operations, and quality.”
**Interstate Highway WMA Usage**
as of March 2010 - WMA Interstate Projects Only

**What will Laboratory Mix Design Require for WMA?**

- **DRAFT R35**
  - Simulate the WMA technology...
    - Blending of additive
    - Foaming unit, $30k
    - Etc.

**Q. What if we treat WMA Different?**

- **GOAL** should be to have a performance-based mixture design process with criteria that applies to plant mix asphalt –

- Regardless of the temperature it is produced!

**Evolution of Mix Design Recipe**

- **Recipe – TLAR**
- **Empirical**
- **Volumetric – Strength Tests**
- **Volumetric – Performance Tests**
- **Performance Indicators & Tests?**
### Performance-Driven Asphalt Mixture Design

<table>
<thead>
<tr>
<th>Property</th>
<th>Concern</th>
<th>Available Tools</th>
<th>State-of-the-Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work-ability</td>
<td>Segregation</td>
<td>Uniformity / Density / IR Camera</td>
<td>?</td>
</tr>
<tr>
<td>Low-Skid</td>
<td>Safety</td>
<td>Polish Factor / AIMS...</td>
<td>PF</td>
</tr>
<tr>
<td>Permeability</td>
<td>Moisture Damage</td>
<td>FH Permeometer / Volumetrics / Lotman / Hamburg...</td>
<td>Va, VMA, T-283</td>
</tr>
<tr>
<td>Durability</td>
<td>Premature Failure</td>
<td>LA Abrasion / Micro Duval / VMA / MSCR-binder...</td>
<td>LA, VMA</td>
</tr>
<tr>
<td>Stability</td>
<td>Rutting</td>
<td>Volumetrics / Hamburg / APA / AMPT (FN) / MSCR</td>
<td>Va + ???</td>
</tr>
<tr>
<td>Fatigue Resistance</td>
<td>Cracking</td>
<td>Volumetrics, CP Beam, TP Beam, Semi-circular Notched Specimen</td>
<td>VMA</td>
</tr>
<tr>
<td>Facture Resistance</td>
<td>Cracking</td>
<td>BBR-binder...</td>
<td>PG-grade</td>
</tr>
<tr>
<td>Tied to Structural Design</td>
<td>Right Mix – Right Application</td>
<td>AMPT (E*) + MEPDG</td>
<td>???</td>
</tr>
</tbody>
</table>

### However...

- Mix Design provides... LTMF
- Mix Verification, during production, provides... JMF
Thank You!