PAVING MATERIALS

Past, Present and Future

Gerry Huber
Heritage Research Group
Indianapolis, IN
1890 E.G. Love

- Engineering and Building Record
- Articles on paving streets
  - Brick
  - Cobblestones
  - Wood pavers
  - Concrete
  - Asphalt

Philadelphia 1911
Lake Trinidad Asphalt (Barber Co.)

- First HMA (1870’s)
  - Pennsylvania Ave.
- Naturally occurring from lake in Trinidad
Recipe Design
- 70 to 83% sand
- 5 to 15% lime

Sand heated to 150ºC
- Lime added cold
  - Amount adjusted visually
- Asphalt added
Barber Design

- **Cushion Coat (Top Lift)**
  - 14 to 19% Asphalt

- **Surface Coat**
  - 12 to 15% Asphalt

- **Macadam**
1905 Clifford Richardson

- Owner of New York Testing Company
- Published book
  - “The Modern Asphalt Pavement”
- Pavements built in 1890s and 1900s
Typical 1900s Pavement

- Surfacing Mix
- Asphaltic Concrete
- Stabilized Aggregate
Surfacing Mixture

- 100% passing #10 sieve
- 15% passing #200 sieve
- 9 to 14% asphalt
Pat-Paper Test

- Brown paper from store
- Mixture in pan dumped on to paper
- Asphalt fluidity judged visually
Asphaltic Concrete Mixture

- 7.4% asphalt
- 0(%)% air voids
- 13.2% VMA

Not suitable for Surface

40-mm nominal maximum size
Hubbard Field Mix Design

- Developed in 1920s by the Asphalt Association
- Fredrick Field
  - Chemist from Calgary, AB
  - Asphalt Institute 1924 to 1947
Hubbard Field Mix Design

- Compact Mixture with rammer
- Specifications
  - Air voids
  - Voids in compacted aggregate
  - Hubbard Field Stability
Marshall Method of Mix Design

- Developed in 1930s
- Adopted by Corps of Engineers
  - WW II
- 1943 joined Corps to “civilianize”
Marshall Mix Design

- Used drop hammer instead of hand rammer
- Calculated air voids
- Similar stability test
  - Different geometry
- No VMA Added in
- No absorption 1960s
Strategic Highway Research Program

- Performance Based Asphalt Binder
- Performance Based Mixture Spec
- Mix Design System
Result of SHRP Research

- Performance Based Asphalt Binder Spec
- Performance Based Asphalt Mixture Spec
- Performance Based Mix Design System
Understanding How Asphalt Mixture Works

Listen, it’s only $1800 for the fuel pump. It could have been the transmission!
HOT MIX ASPHALT

- Hard elastic particles
  - carry load

- Visco-elastic, visco-plastic asphalt binder
  - hold rocks together
  - resist raveling
  - carry shear
Mix Properties

- Effected by
  - Asphalt binder properties
  - Aggregate properties
  - Proportion of each
Effect of Temperature
How hard is the water?
Visco-elasticity

Applied Load

Resulting Deformation

Lag time

time

time
ASPHALT BINDER

Solid Behavior

Liquid Behavior

Stiffness

Solid Behavior
EFFECT OF TEMPERATURE

- Liquid Behavior
- High Temperature
- Solid Behavior
- Low Temperature
SUPERPAVE Asphalt Binder

- Performance Based
  - Temperature
  - Time of Load

PG 64-22

- Performance Grade
- High Temperature
- Low Temperature
Packing of Aggregates

- Gradation
- Shape
- Texture and Angularity
- Type of Compaction
- Amount of Compaction
- Hardness
Percent Crushed Particles

0% Crushed

100% with 2 or More Crushed Faces
Fine Aggregate Angularity

Natural sands: typically 37 to 44

 Manufactured sands: typically 42 to 52
Effect of Gradation on Packing

Sieve Size (mm) Raised to 0.45 Power

Primary Control sieve (PCS)

Fine part of Fine Aggregate

Coarse Aggregate

Fine Aggregate

Fine

Coarse

% Passing

Sieve Size (mm) Raised to 0.45 Power
### Effect of Design Compaction

<table>
<thead>
<tr>
<th>Asphalt Content</th>
<th>125 gyrations</th>
<th>100 gyrations</th>
<th>75 gyrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>125 gyrations</td>
<td>5.78%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 gyrations</td>
<td></td>
<td>5.74%</td>
<td></td>
</tr>
<tr>
<td>75 gyrations</td>
<td></td>
<td></td>
<td>5.72%</td>
</tr>
</tbody>
</table>
## Effect of Design Compaction

<table>
<thead>
<tr>
<th>VMA</th>
<th>125 gyrations</th>
<th>100 gyrations</th>
<th>75 gyrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>125 gyrations</td>
<td>15.22%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100 gyrations</td>
<td></td>
<td>15.40%</td>
<td></td>
</tr>
<tr>
<td>75 gyrations</td>
<td></td>
<td></td>
<td>15.31%</td>
</tr>
</tbody>
</table>
# Rutting Resistance (Flow Number)

<table>
<thead>
<tr>
<th>21°C 200 kPa</th>
<th>125 gyrations</th>
<th>100 gyrations</th>
<th>75 gyrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>125 gyrations</td>
<td>151</td>
<td>131</td>
<td>103</td>
</tr>
<tr>
<td>(7.5% air)</td>
<td></td>
<td>(7.1% air)</td>
<td>(7.4% air)</td>
</tr>
<tr>
<td>100 gyrations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>75 gyrations</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Asphalt Mixture Properties

- Linear Elastic
- Non-linear Elastic
- Visco-elastic
- Plastic
MIX PROPERTIES

- **Linear Elastic**
- **Non-Linear Elastic**
- **Visco-Elastic**
- **Plastic Behavior**

**% Behavior**

- **Cold Temperature**
- **Hot Temperature**

- **Fast Loading Rate**
- **Slow Loading Rate**
Rut Resistance

% Behavior

Cold Temperature

Hot Temperature

Linear Elastic

Non-Linear Elastic

Visco-Elastic

Plastic

OK
Low Air Voids

Shift Curves

% Behavior

0%

100%

Cold Temperature

Hot Temperature

Linear Elastic

Non-Linear Elastic

Visco-Elastic

Plastic
Rut Resistance

% Behavior

Cold Temperature

Hot Temperature

Plastic

Non-Linear Elastic

Visco-Elastic

Linear Elastic

NOT OK

0%

100%
LOW TEMPERATURE CRACKING

- Linear Elastic
- Non-Linear Elastic
- Plastic
- Visco-Elastic

% Behavior

Cold Temperature

Hot Temperature

OK
Fatigue (Spring)

Stress

No Fatigue

Strain
Asphalt Mixture Fatigue

Stress

Strain
Asphalt Mixture Healing

Kim, Lee, and Little (AAPT 1997)
Superpave

- Elastic Properties
  - Asphalt binder properties
  - Aggregate

- Non-linear Elastic Properties
  - Aggregates
    - Particle Shape, Texture, Gradation, etc
    - Compaction
Superpave

- Visco-elastic Properties
  - Asphalt binder
  - Aggregate

- Plastic
  - Air voids
  - Aggregate
    - Particle Shape, Texture
Future?

Viscoelastoplastic Continuum Damage (VEPCD) Model

- Elastic-Viscoelastic Correspondence Principle
- Work Potential Theory
- Viscoplastic Model
- Time-Temperature Superposition with Growing Damage

Linear Viscoelastic Effects
Microcracking Related Degradation
Permanent Deformation Growth
Time-Temperature Effects
The Future??
The Future of Testing (AMPT)
**Test Methods Exist (almost)**

Proposed test method under review before submitting to AASHTO Subcommittee on Materials

**Proposed Standard Method of Test for**

Determining the Damage Characteristic Curve of Asphalt Concrete from Direct Tension Cyclic Fatigue Tests

AASHTO Designation: PP XX-XX

1. **SCOPE**

   1.1. This test method covers procedures for preparing and testing asphalt concrete mixtures to determine the damage characteristic curve via direct tension cyclic fatigue tests.

   1.2. This standard is applicable to laboratory prepared specimens of mixtures with nominal maximum size aggregate less than or equal to 37.5 mm (1.48 in.).

   1.3. This standard may involve hazardous material, operations, and equipment. This standard does not purport to address all safety problems associated with its use. It is the responsibility of the user of this procedure to establish appropriate safety and health
What else?

- Aging
- Effect of Moisture
When will Future be Here?

Will be a while yet!