Materials for Civil and Construction Engineers

CHAPTER 9

Asphalt Binders and Asphalt Mixtures
Bituminous Materials

Asphalt
- Natural
- Refined from petroleum oil

Tar

Asphalt Cement

Cutback

Emulsion
Source of Asphalt

[Diagram showing the process of extracting asphalt from petroleum and refining it into different forms such as light, medium, and heavy solvents, residue, asphalt cements, cutbacks, emulsions, and air blown asphalt.]
9.1 Asphalt Types Used in Pavement

• Asphalt cement (asphalt binder)
  ➢ Used for HMA, patching

• Asphalt emulsion
  ➢ Used for cold mix & maintenance applications

• Asphalt cutback
  ➢ Used for cold mix & maintenance applications
Asphalt Pavement

Surface
Base
Subbase
Subgrade
Asphalt Cutback

= asphalt cement + solvent

- Hazardous, volatile solvents and hydrocarbons are released
- Cold mix maintenance, patching, chip seals, crack sealing, base and sub-base stabilization, and surfacing low volume roads
Asphalt Emulsion

= asphalt cement + water + emulsifying agent

- Many of the same uses as cutback
  - Safer
  - Environmentally better
  - Cost?
Asphalt binder is a visco-elastic material.

- viscous at high temps, like a fluid
- elastic at low temps, like a solid
- its characteristics depend on both temperature and loading rate

- Complex chemical properties
- Asphalt binder’s specifications based on physical properties
Hot Mix Asphalt

Chip Seal

Fog Seal
9.3 Temperature Susceptibility of Asphalt

• Asphalt is highly affected by temperature
• Slope indicates degree of susceptibility
• Some additives can reduce temp. susceptibility

Too brittle (Thermal cracking)

Too soft (Rutting)
Thermal Cracking

Rutting
Asphalt comes in different grades (soft and hard)

- Soft (low viscosity) asphalt is used in cold climates to avoid thermal cracking
- Hard (high viscosity) asphalt is used in hot climates to avoid rutting
Asphalt Grading

History
1. Penetration grading (pen)
2. Viscosity grading (AC)
3. Aged residue grading (AR)

• Current
Performance grading (PG)
9.5 Superpave & Performance Grade Binders

• After the Strategic Highway Research Program (SHRP)

• Superpave (Superior Performing Asphalt Pavements)
  - mix design method for asphalt concrete
  - performance grading method for asphalt binder specification
9.6 Performance Grade
Binder Characterization

• Control specific distresses
  ➢ Rutting
  ➢ Fatigue cracking
  ➢ Thermal cracking

• Specific aging conditions
  ➢ Unaged
  ➢ Construction
  ➢ Long term
Aging Behavior

Causes
- Oxidation
- Volatilizations
- Physical hardening

Types
- Short-term aging
- Long-term aging

Viscosity vs. Time (years)
1. Construction
2. 1 tank
3. 2 construction – short term
3. 3 use – long term
Simulation of Aging in the Lab

Rolling Thin-Film Oven (RTFO)
Short-term aging to simulate hardening during construction
- 325°F (163°C) for 75 min.

Pressure Aging Vessel
Long-term aging to simulate hardening in service
- aged in the RTFO first, then 20 hrs at 305 psi & 90-110°C
Performance Grading (PG)

Intended to improve pavement performance by reducing the potential to:

- Permanent deformation
- Fatigue cracking
- Low-temperature cracking
- Excessive aging from volatilization
- Pumping and handling
**Performance Grading (PG)**

Based on field performance

- Starts with PG (Performance Graded) followed by 2 numbers – max. & min. pavement service temps. in °Celsius

- Example: PG 52-28 designed for 52°C to -28°C

- High is measured 20 mm (3/4") below pavement surface, low measured at surface
Performance Grading (PG)

PG 64-16, PG 70-10, ...

PG # - #

- Low-temperature grade
- High-temperature grade
- Performance graded
<table>
<thead>
<tr>
<th>High Temperature Grades (°C)</th>
<th>Low Temperature Grades (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PG 46</td>
<td>−34, −40, −46</td>
</tr>
<tr>
<td>PG 52</td>
<td>−10, −16, −22, −28, −34, −40, −46</td>
</tr>
<tr>
<td>PG 58</td>
<td>−16, −22, −28, −34, −40</td>
</tr>
<tr>
<td>PG 64</td>
<td>−10, −16, −22, −28, −34, −40</td>
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<tr>
<td>PG 70</td>
<td>−10, −16, −22, −28, −34, −40</td>
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<tr>
<td>PG 76</td>
<td>−10, −16, −22, −28, −34</td>
</tr>
<tr>
<td>PG 82</td>
<td>−10, −16, −22, −28, −34</td>
</tr>
</tbody>
</table>
High Pavement Temperature

\[ T_{20\text{mm}} = \left( T_{\text{air}} - 0.00618 \text{ Lat}^2 + 0.2289 \text{ Lat} + 42.2 \right) \times (0.9545) - 17.78 \]

\( T_{20\text{mm}} \) = high pavt. design temp. at a depth of 20 mm
\( T_{\text{air}} \) = 7-day average high air temp
\( \text{Lat} \) = geographical latitude

Low Pavement Temperature

Similar equation for predicting the minimum pavement temperature
Selecting Asphalt Binders

PG 64-34 (98% minimum reliability)

PG 58-28 (50% minimum reliability)

Asphalt Binder Grades, Topeka, Kansas
Asphalt Cutbacks

• Graded by curing time and viscosity
  - RC = rapid curing = 5-10 min
  - MC = medium curing = a few days
  - SC = slow curing = a few months

• Viscosity = 30, 70, 250, 800, & 3000 = higher grade is higher viscosity
  - RC-70, RC-250, RC-800, RC-3000
  - MC-30, MC-70, MC-250, MC-800, MC-3000
  - SC-70, SC-250, SC-800, SC-300
Cutback Nomenclature

MC – #

Viscosity

M = medium curing, R = rapid, S = slow
**Emulsion vs. Cutback**

Emulsion is preferred over cutback

- safer
- used with damp aggregates
- might be slightly more economic
- better environmentally
Asphalt Emulsions

Graded by setting time and viscosity

- RS = rapid setting = 5-10 min
- MS = medium setting = several hours
- SS = slow setting = a few months

- Viscosity = 1 or 2 (2 is high viscosity of the emulsion)
- Anionic – negative charge
- Cationic – positive charge
**Emulsion Nomenclature**

CMS – 1 h

- **h** = hard asphalt residue, **s** = soft
- 1,2 = indicates emulsion viscosity
- **M** = medium set, **R** = rapid, **S** = slow
- **C** = cationic, **HF** = high float
9.8 Asphalt Concrete (Hot-Mix Asphalt)

- Asphalt binder + aggregates
- Flexible (HMA) Pavements = 93% of 2 million miles of paved roads in the U.S.
- AC is produced in batch or drum plants
HMA Desirable Properties

- stable – resist permanent deformations under load
- fatigue resistant – under repeated loading
- resistant to thermal cracking – due to contraction at low temps
- resistant to hardening or aging – during production and in service
- resistant to moisture induced damage – stripping asphalt from agg
- skid resistant – by texturing surface
- workable – ease of mixing, placing, compacting
- economical
9.9 Asphalt Concrete Mix Design

1. Selection of design aggregate structure
   - preliminary
     ✓ gradation
     ✓ consensus properties
   - volumetric analysis of mixes

2. Selection of design asphalt content
   ✓ volumetric analysis of design aggregate structure
     at four binder contents

3. Evaluation of moisture sensitivity of mix
Mixing & Compaction Temps

Equiviscosity temperatures for mixing and compacting
Specimen Compaction for Mix Design

Different AC mix design methods use different types of compaction:

- **Superpave Mix Design**
  - Gyratory compactor

- **Marshall Mix Design**
  - Marshall hammer
Volumetric Code Names

G = specific gravity
M = mass
W = weight
V = volume
P = percent

b = binder
s = stone (agg)
a = air
m = mix

a = apparent, stone
a = absorbed, binder
b = bulk
e = effective
m = maximum
Superpave Mix Design

Find asphalt content using available binder & aggregate:

a) Aggregate Selection
b) Binder Selection
c) Determine design aggregate structure
d) Determine design binder content
e) Evaluate moisture susceptibility
a) Aggregate Selection

Source properties – specified by agency
- Soundness
- Toughness
- Deleterious materials

Consensus properties – depends on traffic level and depth
- Coarse agg. angularity – min. % crushed particles
- Fine agg. angularity – measured by unpacked air voids (min.)
- Flat & elongated particles – max.
- Sand equivalency – need clean aggregates
- Gradation – 0.45 power chart
  - curve must pass through control points
  - blend stockpiles

Stockpiles evaluated

Blend requirements
b) Binder Selection

- based on service temps.
- Modify for traffic:
  - High traffic volumes + one grade level for high temperature rating
  - Slow speeds + one grade level for high temperature rating
  - Slow speeds and high traffic volumes + two grade level for high temperature rating

Example – Base grade of asphalt selected based on temperature

- High traffic volumes: PG 64-22
- Slow speeds: PG 70-22
- Slow speeds and high traffic volumes: PG 76-22
Stripping is loss of bond between asphalt & agg.
- several methods differing by specimen preparation, conditioning, and strength requirements
- 2 sets of specimens: control & conditioned
- evaluate strength before and after conditioning
- retained strength = conditioned strength / reference strength
- must have min. retained strength
How to Improve Moisture Susceptibility

- Increase asphalt content
- Higher viscosity asphalt
- Clean aggregate of dust and clay
- Change aggregate gradation
- Add anti-stripping additives
  - liquid
  - portland cement or lime
Types of AC Pavement Failure

- rutting – accumulation of permanent deformation in the wheel path
- fatigue cracking – from repeated bending
- thermal cracking – temperature gradient
- excessive surface roughness – aging
- aging & oxidation of the binder – stiffening
- stripping – loss bond between binder and aggregate from moisture
Superpave Asphalt Mixture Performance Tests

triaxial cell used to simulate vehicle loads in three dimensions
9.12 Recycling of Asphalt Concrete

• High energy prices support recycling

• Advantages of AC Recycling
  ➢ economy – >25% savings in cost of material
  ➢ energy – savings in manufacturing and transportation
  ➢ environment – reduces amount of new materials and solves problem of discarding old materials
  ➢ eliminates problem of reconstruction of utilities, curbs, & gutters associated with overlays
  ➢ maintains bridge & tunnel clearances
9.14 Warm Mix

- Lower mixing and placing temperatures
- Reductions of 25 to 50 °C (50 to 100 °F)
- Advantages
  - Less energy heat the mix
  - Lower greenhouse gases
  - Less oxidation of the asphalt binder
  - Pave at lower temperatures
  - Longer haul distances are possible
  - Extending the paving season since the asphalt can be compacted at lower temperatures
Warm Mix Technology

• Emulsion Technology
  ➢ Evotherm – Mead Westvaco

• Mix additives
  ➢ Aspha-min – Eurovia
  ➢ Sasobit Sasol Int./Moore and Munger
  ➢ Rediset – Akzo-Noble

• Materials Processing
  ➢ WAM-Foam Shell/Kolo Veidekke/BP
  ➢ Low Energy Asphalt Fairco
  ➢ Green WMA Aztec