Caltrans Implementation of PG Specs

PG - Performance Graded

Presentation Overview

- Why, When & How?
- How will it affect YOU?
  - Caltrans
  - Local Agencies
  - Industry
  - Consultants

HMA in California

- ~ 1 Ton HMA/Person/Yr
- ~ 34 Million Tons/Yr
Binder Specifications - Then & Now

**Specification Systems**

- Penetration
- Viscosity
- PBA
- Superpave PG

**Penetration Grading System**

- Introduced in 1918 by Bureau of Public Roads (now the FHWA)
- At least 9 penetration grades
- 1956 - PCCAS formed - Goal was to reduce the number of grades & standardize specs
- 1957 - PCCAS adopted 5 grades

PCCAS = West Coast User-Producer Group
Penetration Grading System

- Based on magnitude of the penetration of a standard needle at 25°C

Penetration Spec

- Classification based on pen at 25°C
- Also considers
  - Penetration at 4°C
  - Flash point
  - Viscosity at 135°C
  - Solubility
  - Thin Film Oven Aging
    - Penetration at 25°C
    - Ductility

Temp Susceptibility

Penetration, 0.1 mm

25°C (77°F) Temp
Viscosity Grading System

**AC**
- Developed in 1960s
- Replace penetration system
- Based on unaged binder consistency at max in-service temp
- AASHTO M226 & ASTM D3381

**AR**
- Caltrans in the 1960s
- Based on aged binder to simulate post-mixing binder consistency

**AC Spec Tests**
- Classification based on vis at 60°C
- Also considers
  - Vis at 135°C
  - Pen at 25°C
  - Flash Point
  - Solubility
  - TFO-aged residue
    - Vis at 60°C
    - Ductility at 25°C
**Viscosity Grades (AC-xx)**

- AC - 2.5
- 5
- 10
- 20
- 30
- 40

**PCCAS and the AR**

1967
1969
1972
1974

RTFOT adopted as alternative to TFOT

Use of RTFOT-conditioned asphalt began

Formally adopted Implementation

**Caltrans Grades & Tests**

- Classification based on aged-residue vis at 60°C
- AR Grades*
  - AR -1000
  - -2000
  - -4000
  - -8000
  - -16000

* Caltrans Std Specs, Section 92 "Greenbook" Section 203-1
Caltrans Grades & Tests

- Also considers tests on RTFO-aged residue
  - Vis at 60°C & 135°C
  - Pen at 25°C
  - % of Original Pen
  - Ductility
  - Properties of unaged asphalt
    - Flash Point
    - Solubility

Comparison of Pen & Vis Grades
Limitations of Pen & Vis Grading Systems

- Penetration: Empirical measurement
- Viscosity: Viscous effect only
- No low temp properties (except PCCAS-pen ratio)
- Long-term aging not considered
- Inadequate for modified binders

PCCAS to the Rescue

- 1987 – Paving Asphalt Committee charged to develop specs for modified asphalts
- Representatives from
  - Industry - Chevron & Golden Bear
  - ODOT
  - Caltrans
**PBA Concept**

- **Performance**
- Rutting, Fatigue & Low Temp Cracking
- **Safety**
- **Environment**
- **Purity**
- **Compatibility**

**Binder Tests**

**Climate**

**PBA Grade**

<table>
<thead>
<tr>
<th>Test Criteria</th>
</tr>
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<tbody>
<tr>
<td>1</td>
</tr>
</tbody>
</table>

**PBA Spec - 1992**

- Precursor to SHRP PG
- Climatic guidelines to select grade
- Conventional tests to relate to performance
- Unique grades
  - PBA (performance-based asphalt)
- Identifies modified binders by grade

**Current PBA Spec - Handout**
"PG" Asphalt Binder System

PG - Performance Graded

PG System

- Developed in 1990s during SHRP in concert with PCCAS
- Fundamental Properties, i.e., stress and strain
- Unmodified binders
- Performance Considerations
  - Rutting, Cracking (Fatigue & Low Temp), & Aging
- Environment

Resources

- FHWA
- Asphalt Institute
  - http://www.asphaltinstitute.org
- NAPA (National Asphalt Paving Assn)
  - http://www.hotmix.org
- NCAT (National Center for Asphalt Tech)
  - http://www.eng.auburn.edu/center/ncat
Viscosity/Stiffness

PG Spec (eg, PG 64-16)

Original

In-Service

Construction

PG Spec
System Based on Climate -
In-Service Pavement Temps

PG XX - YY

Min Pavement Surface Temp (°C)

Average 7-day Max Pavement Temp (°C)

Performance Grade

Determination of Pavement Temp Used in PG Spec

- Determine Project Specific Air Temps
- Compute Design-Specific Pavement Temps from Air Temps
Air Temps
- Superpave Weather Database
  - NOAA ~ 40 years of data
  - 7,900+ stations in US & Canada
  - 308 stations in California
- Uses Annual Air Temps
  - Hottest, consecutive 7-day temp (average & standard deviation)
  - Coldest temp (average & standard deviation)
- Calculated Pavement Temps used in PG Selection

Reliability
- Percent Probability of Not Exceeding Design Temp
- Generated from Site Specific Mean and Standard Deviation

Observed Air Temps
- 50% reliability $= \bar{X}$
- Very hot summer $= \bar{X} + 2\sigma$
- 98% reliability $= \bar{X} + 2\sigma$
- 7-Day Max Air Temps
Observed Air Temps - San Diego (La Mesa)

average winter
very cold winter
-3
-5
5

average summer
very hot summer
35
30
40

ºC

Pavement Temps

Max Air Temp
Calculated Pavement Temp
-3
1
10
54
61

ºC

PG Binders

PG 64-10 (98% reliability)

PG 58-10 (50% reliability)

ºC
PG Spec Testing

Age Conditioning

<table>
<thead>
<tr>
<th>No aging</th>
<th>RTFO (Short Term)</th>
<th>PAV (Long Term)</th>
</tr>
</thead>
</table>

Service Temps

- Low temp properties
- Intermediate temp properties
- High temp properties

Mixing

- DSR
- RV

Temp (°C)

-20 20 60 135

PG Specification – AASHTO M320-04
Current PG Spec - Handout

Tests Used in PG Binder System

- Safety - Flash Point
- Pumpability - RV at High Temp (135°C)
- Rutting - DSR at High Temps
  - Original & RTFOT-Aged; ie. 2 “conditions”
- Fatigue Cracking - DSR at Intermediate Temps
  - RTFOT PAV-Aged; ie. 1 “condition”
- Low Temp Cracking - BBR & DTT (optional) at Low Temps
  - RTFOT PAV-Aged; 1 “condition”

PG Spec Testing
**Safety & Pumpability**

- **Viscosity (η)** ≤ 3 Pa·s at 135°C for the unaged binder

**Pumpability**

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**PG Spec Testing**

- Low Temp Cracking
- Fatigue Cracking
- Rutting
- Pumpability

Test Temp (°C): -20, 20, 60, 135

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- During construction a contractor must be able to pump the binder.
- Viscosity (η) ≤ 3 Pa·s at 135°C for the unaged binder.
Rutting/Permanent Deformation

How the PG Spec Works

Rutting/Permanent Deformation

Addressed by

$G^*/\sin \delta > 1.00 \text{ kPa (unaged binder)}$

$G^*/\sin \delta \geq 2.20 \text{ kPa (RTFO-aged binder)}$

For the early part of the service life
Mass Loss Spec

- Calculate mass loss after RTFO.

\[
\text{Mass loss, } \% = \frac{\text{Original mass} - \text{Aged mass}}{\text{Original mass}} \times 100
\]

- Mass Loss \( \leq 1.0\% \)

Establishing Grades - DSR Data

NB:
1. Stiffness approximately doubles with each 6°C decrease in temp.
2. \( G'/\sin \delta \approx 1.0 \text{ kPa at } 60\text{°C for AC-10} \)

PG Spec Testing

Low Temp Cracking
DTT (optional)
BBR
Fatigue Cracking
DSR
Rutting
Pumpability

-20 20 60 135
Test Temp (°C)
### Fatigue Cracking

- Addressed by stiffness at intermediate temp
- \( \sigma \sin \delta \) on RTFO & PAV-aged binder < 5000 kPa

For later part of pavement service life

### Fatigue Testing

- Long-term performance problem
- Use aged binder
  - Short-term aging (RTFO) + Long-term aging (PAV)
Notes on the Spec

- Assumed strain controlled distress (thin HMA)

- Initially a maximum of 3 MPa
  - Over 50% of binders tested failed
  - Raised to max of 5 MPa; 15% of binders failed

- Basis for limiting to 5 MPa

PG Spec Testing

- Low Temp Cracking
- Fatigue Cracking
- Rutting
- Pumpability

- DTT (optional)
- BBR
- RV

Test Temp (°C)

Low Temp Cracking

- Avg 7-day Max, oC
- 1-day Min, oC
- ORIGINAL
- > 1.00 kPa
- < 5000 kPa
- 20 Hours, 2.07 MPa
- > 2.20 kPa
- 230 °C
- 135 °C
- < 3Ps a.s @ 135 °C
- S < 300 MPa m > 0.300
- Report Value
- > 1.00 %

- PAV Aged
- Dynamic Shear Rheometer (DSR) G*/sin δ
- Bending Beam Rheometer (BBR) "S" Stiffness & "m" value

- (ัส)
**Bending Beam Rheometer**

- Evaluates low temp stiffness
  - Creep stiffness, \( S(t) \)
  - Slope of log creep stiffness curve, "m-value"

![Graph showing log creep stiffness over log loading time]

**PG Spec Testing**

- Low Temp Cracking
- Fatigue Cracking
- Rutting
- Pumpability

![Diagram showing various testing methods]

**Low Temp Cracking**

<table>
<thead>
<tr>
<th>Test</th>
<th>Avg 7-day Max, °C</th>
<th>1-day Min, °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original</td>
<td>10 7 4 25 22 19 16 13 10 7 25 22 19 16 31 28 25 22 19 16 34 31 28 25 22 19 37 34 31</td>
<td></td>
</tr>
<tr>
<td>PAV Aged</td>
<td>20 Hours, 2.07 MPa</td>
<td></td>
</tr>
</tbody>
</table>

- DSR: Dynamic Shear Rheometer
- BBR: Bending Beam Rheometer
- RV: Rotational Viscosity
- FP: Flash Point
- RTFO: Rolling Thin Film Oven

**Report Values**

- CEC: 300 MPa m > 0.300
- PAV Aged < 1.00 %
DTT (optional)

- $\sigma_f$ (no spec criterion)
- $\epsilon_f \geq 1.0\%$

Summary

- Evolution of binder grading systems
  - Penetration ➔ Viscosity ➔ PBA & PG ➔ PG
  - Fundamental properties measured.
  - Quantifies binder contributions to rutting, fatigue & low temp cracking.
  - Considers the effect of aging.

Summary

- PG System - Selection based on climatic conditions at project site.
  - Low temp (min pavement surface temp)
  - High temp (average 7-day max pavement temp)
- Spec requirement remains constant; test temp changes.
Binder Topics

- Needs based on climate
- Used
- Special cases

California Climate ➤ PG “Needs”

CA - High Temp PG “Needs”

High Temp PG (°C)

Locations

50% 98%
CA - Low Temp PG “Needs”

Low Temp PG (C)

Locations

CA - PG “Needs”

Locations

20 PG Binders!

PG Binder Distribution

Locations

279/308 locations

PG Binder
Caltrans Strategy - 2006

- Special Circumstances
  - PBA 6a & 6b for cold regions
  - PBA at discretion of District... with economic justification
  - eg: Dist 9 ⇒ PBA-6b
  - eg: Dist 8 ⇒ PBA-6a*

Caltrans Strategy - 2007

- Regular
  - Conventional PG Binder
- Special Circumstances
  - PG Polymer Modified
Caltrans Binder Selection

<table>
<thead>
<tr>
<th>Region</th>
<th>Conventional Hot Mixed Asphalt</th>
<th>Rubberized Asphalt</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Typical</td>
<td>Special</td>
</tr>
<tr>
<td>Central Coast, North Valley, South Coast</td>
<td>PC 80-10, PG 70-10, PG 64-25PM</td>
<td>PG 64-10, PG 59-34PM</td>
</tr>
<tr>
<td>North Coast, Low Mountain, South Mountain</td>
<td>PC 80-16, PG 64-25FM</td>
<td>PG 64-16, PG 59-34FM</td>
</tr>
<tr>
<td>High Desert, High Mountain</td>
<td>PC 64-22, PG 59-34FM</td>
<td>PG 59-34FM</td>
</tr>
<tr>
<td>Desert</td>
<td>PC 70-10, PG 64-25FM</td>
<td>PG 70-10, See Note c</td>
</tr>
</tbody>
</table>

Caltrans vs AASHTO

<table>
<thead>
<tr>
<th></th>
<th>Caltrans</th>
<th>AASHTO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solubility, min</td>
<td>98.5%</td>
<td>99.0%</td>
</tr>
<tr>
<td>RTFO mass loss, max</td>
<td>0.60%</td>
<td>1.0%</td>
</tr>
<tr>
<td>DSR</td>
<td>Min elastic recovery, max phase angle</td>
<td></td>
</tr>
</tbody>
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Implementation

- 4 unmodified PGs - Jan 06
- Replace modified PBAs with PG - Jan 07
- Asphalt Rubber - base PG by RACTG - Jan 06
- AMRL Certification - Jan 07
- Training (Caltrans, Local Agencies & Industry)
  - Classroom: 12 Locations, Beginning Oct 05
**PG Binders are not a panacea!!**

- Aggregate Characteristics
- Mix Design
- Construction Quality Control

**Other Considerations**

- PG for other applications?
- Mixing PG binders of same grade but from different sources?
- Critical tests for checking binders?
- Mix design approval; effect of asphalt different supplier?
- Effects of PG binders on construction process (e.g., impact on compaction)?
- PG vs AR grades?

**PG for Other Applications?**

- Commercial
  - Parking Lots, Truck Terminals
- Ports
- Airfields
  - Commercial & General Aviation
- Residential
- Hydraulic
- Local Streets & Highways
PG for Other Applications?

- Tack Coats
  - PG 64-10 or PG 64-16
- Surface Treatments, eg, ChipSeals
  - Conventional or polymer modified emulsions
- AC Dikes
  - PG 70-10
- Crack Sealing, Expansion Joints
  - FHWA-RD-03-080

Mixing Binders – Same “PG” But Different Sources?

- Same precautions as taken for AR binders.

Critical Binder Testing?

- Spec tests
  - BBR
  - DSR (Original & RTFO-Aged)
- Use AMRL-Certified Commercial Lab!
**Mix Design - Different Binder Supplier?**

- Same precautions as taken for AR binders ... do another mix design!

**PG Binder Influence on Construction?**

- Potential for stiffer binders may require higher mixing and placement temps.
- Plant production and placement temps ~ 15-20°F higher than traditional AR-graded binders.
- Another test strip?

**Questions?**