Polyphosphoric Acid
What really is it

Review of the PPA workshop April 2009
and recent studies

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Definition - Asphalt

A high molecular weight, thermoplastic hydrocarbon constituent, found in a large number of petroleum crude oils. Although some asphalts do occur naturally, asphalt as we know it, and as discussed herein, is derived from fractional distillation of petroleum crude oil.
UTI of Performance Grade Asphalts

- A PG 64-22 would have a UTI of 86 °C
- A PG 58-28 also has a UTI of 86 °C
- If we needed a PG 76-22, which has a UTI of 98 °C - how is this accomplished?
- As a “rule of thumb”, to achieve a UTI of >92 °C, the asphalt has to be “modified”.
- Depending on crude source, some binders with more narrow UTI’s of 86 and 89 °C may also require modification
For a given crude, asphalt grade is defined by refinery processing conditions.
Phosphoric Acid Modification of Asphalt Binder
Definition – Polyphosphoric Acid

- Inorganic Polymer
- Obtained by Condensation of Monophosphoric Acid or by Hydration of P$_2$O$_5$
- 0%wt of Free water
- Viscous liquid (25°C) from 840 cP (105%wt) to 60 000 cP (115%wt)
- Crystallisation temperature below 0 to 15°C
- Medium strong acid: Acidity function (Hammet) = 6 (ref H$_2$SO$_4$ = 12)
- Highly soluble in organics
- Non oxidant compound
### PG76-22 from Saudi Asphalt

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<tr>
<th>PG Grade Achieved</th>
<th>76-22</th>
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PG76-22 from Venezuelan Asp
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<td>82.50%</td>
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PG76-16 from CA Valley
PPA reaction with binder and Polymers

- PPA reaction with binder is binder specific.
  - Stiffening effect varies for different binders.
- PPA appears to improve SBS elastomeric response.
Moisture Sensitivity

- Does adding a hydrophilic material like phosphoric acid impart moisture sensitivity to the binder?
Hamburg Moisture testing

- FHWA Research study
- Mathy study
FHWA

NuStar with Maryland Sandstone sever stripper.
Moisture Sensitivity: Hamburg

EFFECT OF PPA AND ANTI-STRIP
E-1 LIMESTONE MIX, HAMBURG (50°C, 158 LB, WET), 7% AIR VOIDS

- PPA performs well with proper anti-strip.
- Need to test all mix components.
Conclusions – Hamburg Testing

- Test is only an indication and was with limited asphalt
- PPA increased moisture sensitivity of the neat binders for one AC
- Action of amine and phosphate ester anti-strips is aggregate specific- PPA may increases moisture sensitivity with certain Amine’s
- With lime treated aggregates the moisture sensitivity is unaffected or improved by PPA modification
- Users need to test each asphalt/aggregate/anti-strip combination.
PPA and Fatigue

- Review of several studies.
Bending Beam Fatigue
Short Term Aged

Ref: Tom Bennert and J.V. Martin – TRB 2008 CD
Long Term Aged

Ref: Tom Bennert and J.V. Martin – TRB 2008 CD
NCAT Test Track Description

- 1.7 mile Closed Loop Facility
  - Consists of Forty-Six 200 ft. Test Sections
  - Each Section Cooperatively Funded
  - Operation and Research Managed by NCAT
PPA/SBS Binder for NPTT-2000

- 2000 Test Track Formulation
  - SuperPave™ PG76-22
    - Venezuelan Crude Source
    - 3.5 Weight Percent SBS Block Co-Polymer
    - 0.25 Weight Percent Polyphosphoric Acid (105)
    - 0.05 Weight Percent Amine Anti-Stripping Agent
Construction of 2000 Test Track

- Eighteen Sections Contained PPA/SBS Modified PG76-22
- Various Aggregates
  - Limestone
  - Slag
  - Gravel
  - Granite
  - Marble Schist
  - Combinations of the Above
Construction of 2003 Test Track

- Twenty-Three of the Existing Sections were left to Extended Traffic
  - Nine Sections Left to Extended Traffic Utilized PPA/SBS Modified PG76-22
- Twenty-Two New Sections Built
  - Nine Sections Reconstructed or Partially Reconstructed Using PPA/SBS Modified Binder
  - Six PG76-22 and Three PG70-22
Permanent Deformation
2000/2003 Test Tracks

Extended bars represent additional rutting from 10 million ESALs of 2003 Track

PPA/SBS Modified Sections
Non-PPA/SBS Modified Sections
Permanent Deformation
2003 Test Track

*PG 70-22
** Fatigue Failure ~ 2,000,000 ESALs
Gray bar sections = SBS Modified PG 76-22 in upper layer
Fatigue
2003 Test Track

- Fatigue Cracking Observed in Three Test Sections
- All Sections Within the Eight Structural Sections
- None of the Fatigue Cracked Sections Contained PPA/SBS Modified Binder
- Two Sections Contained SBS Modified Binder
Moisture Damage

- Average Annual Rainfall in Excess of 40 inches
- Some Aggregates in Construction of Both Research Cycles Susceptible to Moisture Damage
- Moisture Damage was not a Mode of Failure Identified in Either Research Cycle
- In Top Down Cracked Sections Moisture Damage was not Apparent
Test Cell Designs

- PPA Only
- PPA + SBS
- SBS Only
- PPA + Elvaloy
- Level 3 Superpave
- PG 58-34 Binder
- No RAP
- Limited Limestone
- Hydrated Lime
- Liquid Antistrip
Rutting Data (PPA Sections)

- Fall 2007
- Spring 2008
- June 2008
- July 2008

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<th>Outside</th>
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Jnr @ 58°C, 3.2 kPa

- 58-34 SBS
- 58-34 SBS + PPA
- 58-34 PPA
- 58-34 Elvaloy + PPA
% Recovery @ 58°C, 3.2 kPa
Summary

- All 4 PPA mixes performing well since 2007
- Field samples showed excellent rutting and stripping performance in lab tests
  - Low Temperature Cracking test results coming soon.
- PPA + Polymer generally performed better than either modifier alone
- Test sections will continue to be monitored for 5 years
Conclusions

- The Effects of Asphalt Modification with Polyphosphoric Acid is Asphalt and Crude Source Dependent.
- Polyphosphoric Acid works with SBS polymer to improve cross-linking and improve elastomeric response.
- The Effect of PPA on moisture damage is asphalt and aggregate dependant and is treatable with both lime and liquid anti-strips.
Conclusions

- Polyphosphoric Acid is a valuable tool to binder suppliers necessary to provide binders that meet current specifications and provide performance desired.
- PPA use should be limited to one grade bump.
- PPA has been used successfully on actual pavements using a wide variety of aggregate sources even limestone.
Thank You!