Asphalt Expert Task Group Update, AASHTO, and Emerging Topics

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U.S. DOT | Federal Highway Administration
Asset Management, Pavement, and Construction
May 10-11, 2016
Asphalt Expert Task Groups

- Forum for Government, Industry, and Academia
- Discussion of ongoing asphalt binder and mixture technology
- Provide technical input for current and future research, development, and specifications.
Asphalt Expert Task Groups

• Asphalt Mixture & Construction ETG
  • Last meeting in Salt Lake City on April 25-27, 2016
  • POC – John Bukowski

• Asphalt Binder ETG
  • Last meeting in Salt Lake City on April 27-28, 2016
  • POC – Matthew Corrigan

• Sustainable Pavements TWG
  • POC – Gina Ahlstrom

Open Meetings
All are Welcome!
Upcoming ETG Meetings
To Be Announced (Next meeting plan - week of Sept 12, 2016)

Past ETG Meetings
September 2015 — Asphalt Mix ETG, Oklahoma City, OK
September 2015 — Binder ETG, Oklahoma City, OK
April 2015 — Asphalt Mix ETG, Fall River, MA
April 2015 — Binder ETG, Fall River, MA
September 2014 — Asphalt Mix ETG, Baton Rouge, LA
September 2014 — Binder ETG, Baton Rouge, LA
Current Asphalt ETG - Activities

- Asphalt Mixture Performance Tester (AMPT)
- Performance Tests for Cracking/Fatigue
- RAP & RAS Asphalt Binder Replacement
- Re-refined Engine Oil Bottoms (REOB)
- MSCR Binder Grading
- Ground Tire Rubber
- Provide technical input to AASHTO Subcommittee on Materials (SOM) & assist the revision and update standards
In reality, a pavement experiences multiple:
- Loading cycles
- Load magnitudes
- Strains
- Temperatures

- **Low-temperature extremely high strain**
- **Reflection High strain**
- **Bottom-up/top-down Lower strain**

**Cracking Modes versus Tests**

One (1) load cycle (monotonic) vs. No. of cycles
# Cracking Laboratory Tests

Ten (10) protocols - highlighted as part of NCHRP Proj. 09-57

<table>
<thead>
<tr>
<th>Low Temperature</th>
<th>Reflection</th>
<th>Bottom-Up</th>
<th>Top-Down</th>
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<tbody>
<tr>
<td>DCT (ASTM D7313-13)</td>
<td>Texas OT (TxDOT-Tex 248-F)</td>
<td>Beam fatigue (AASHTO T321)</td>
<td>IDT (Univ. of Florida)</td>
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<tr>
<td>SCB (AASHTO TP105)</td>
<td>DCT (ASTM D7313-13)</td>
<td>AMPT Cyclic Fatigue (AASHTO TP107)</td>
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<tr>
<td>IDT (AASHTO T322)</td>
<td>SCB (Louisiana State Univ. - LTRC)</td>
<td>RDT (Texas A&amp;M Univ.)</td>
<td>RDT (Texas A&amp;M Univ.)</td>
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<tr>
<td>TSRST/UTSST (Univ. of Nevada, Reno)</td>
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</table>
Asphalt Mix Performance Tester (AMPT)

www.fhwa.dot.gov/pavement/asphalt/tester.cfm

- Results used for PavementME Design inputs
- AASHTO Standards:
  - PP 60 for preparation of AMPT test specimens
  - TP 79 for Dynamic Modulus $E^*$ & Flow Number ($F_n$)
  - PP 61 for developing $E^*$ master curves
  - TP 107 for Cyclic Fatigue protocols

Already invested in AMPT equipment for Pavement ME ... the AMPT can do much more than just $E^*$ testing!!
Why AMPT Cyclic Fatigue Test?

1. Heritage and “pedigree” of the theory – aerospace industry application for solid rocket propellant

2. Vetting and peer review; “winning” candidate in NCHRP Project 09-19 (Tasks F&G)

3. Wanted a performance test that could be defensible, not empirical correlations

4. AASHTO TP 107-14 *Determining the Damage Characteristic Curve of Asphalt Mixtures from Direct Tension Cyclic Fatigue Tests*
1.1 Description of the Problem

Solid propellants are the prime component of solid rocket motors and the performance of such motors is influenced largely by the mechanical properties of propellant grains. The structural integrity of solid rocket motors is determined by performing stress analysis for loading and environmental conditions under which the motor is likely to operate. Consequently, the accuracy of the representation of the mechanical behavior is essential for the usefulness of stress analysis results.

All modern solid propellants use an elastomeric binder which is filled with quite high levels of solid particles. The mechanical behavior of solid propellants is mainly determined by the polymeric nature of the binder and the binder-filler interaction. The application of a load causes irreversible microstructural changes referred to as damage. They mainly consist of broken molecular chains and interfacial debonding, also called dewetting, that result in the formation of microvoids at or near the interface of the particles and surrounding matrix. Under these influences solid propellants exhibit very complicated behavior including features associated with time and rate effects, temperature and superimposed pressure dependence, large deformations and large strains, stress softening during cyclic loading, called Mullins' effect, and transition from incompressible to compressible behavior...
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...sounds a lot like asphalt?...
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CONSTITUTIVE EQUATIONS FOR SOLID PROPELLANTS
Sebnem Ozupek - PhD Dissertation UT-Austin 1997
Some more on solid rocket propellant

Castable composite solid rocket motors were invented by John Whiteside "Jack" Parsons at Caltech in 1942 when he replaced double base propellant with **roofing asphalt and potassium perchlorate**. [...] Charles Bartley, employed at JPL (Caltech), **substituted curable synthetic rubber for the gooey asphalt**, creating a flexible but geometrically stable load-bearing propellant grain that bonded securely to the motor casing. This made possible much larger solid rocket motors. Atlantic Research Corporation significantly boosted composite propellant in 1954 by increasing the amount of **powdered aluminum in the propellant to as much as 20%**.


http://www.wired.com/2011/12/to-build-a-diy-spacecraft-is-a-daunting-task/
Some more on solid rocket propellant

Common modes of failure in solid rocket motors include fracture of the grain, failure of case bonding, and air pockets in the grain. All of these produce an instantaneous increase in burn surface area and a corresponding increase in exhaust gas and pressure, which may rupture the casing.

http://www.braeunig.us/space/propuls.htm

https://youtu.be/lNyDnruVpTw

time stamp 8:47 – 12:02

The Rocket: Solid and Liquid Propellant Motors
Richard Schapery’s theories provided the foundation for asphalt viscoelastic continuum damage (VECD) using AMPT cyclic fatigue; all beginning with:

This is not a “Johnny-come-lately” methodology!

“Asphalt” AND “Continuum Damage”
4. Unified/common AMPT equipment & spec
   - Custom MTS or UTM machines which can differ greatly from institution to institution (laboratory to laboratory)

5. Unified/common compaction control with SGC
   - Density uncertainty with slab compactors
   - Other compactors vary greatly by design
     - slab, vibratory, plate-kneading, tamping, and shear box
   - Less material, less waste, easier handling
   - Less Testing!
Why AMPT Cyclic Fatigue Test?

6. **Extended time-temperature superposition !!!!!**
   - Discovered during NCHRP 9-19 Tasks F&G
   - Shift factors for $|E^*|$ vs. Temperature are the same
     for explaining fatigue damage vs. Temperature

7. **Certainty in the stress–strain state within the test specimen**
   - Uniaxial stress state is uniform not like a
     bending/flexural stress which is different everywhere
   - Strains are measured on the specimen rather than a
     beam deflection, avoiding end effects and other artifacts
8. **The test tells you a lot about your mix!!!**
   - Response under multiple strains: STRUCTURE/TRAFFIC
   - Response under multiple load rates: TRAFFIC
   - Response under multiple temperatures: SEASONAL
   - More information gained from this test protocol and analysis than from other single tests at a single rate/temperature

9. **Connect mix design and construction by means of distress and performance prediction**
   - not just a pass/fail test
Recent ETG efforts - AMPT Draft AASHTO Specifications

- Draft Documents
  - MP XX Equipment Specification
  - Equipment Spec Commentary
  - TP 79 Dynamic Modulus
  - TP XX Flow Number
- Distribute for Review & Comment
- Address Comments & Revise Drafts
- Submit to SOM Tech Section 2d
Specification Updates

• Equipment Spec based on NCHRP 9-29
• Revisions to address:
  • TP 107 Direct Tension Cyclic Fatigue
  • TP 116 iRLPD
• Tension Loading
• TP 79 split into E* and FN standards
• Calibration moved to Equipment Spec
• Computations moved to test standards
Comments were received ...

Next Steps: Address Comments & Revise Draft Documents to forward to AASHTO

Contacts:
  – Ray Bonaquist (aatt@erols.net)
  – Jeff Withee (jeff.withee@dot.gov)
New RAP/RAS Task Force within ETG

- Current main issue to be addressed:
  - How much of the RAS binder becomes effective asphalt binder? “Quantity”
  - How to address the stiffness/brittleness of the RAS binder? “Quality”
  - Binder grade adjustment guidelines
Recycled/Reclaimed Asphalt Shingles (RAS)

Existing Guidance

- **M 323: Superpave Volumetric Mix Design**
  - Modifications; Binder replacement revisions for RAS
    (RAS needs inclusion)

- **PP 78-14: Standard Practice for Design Considerations When Using RAS in Asphalt Mixtures**

- **MP 23-14: RAS for Use in Asphalt Mixtures**
  - Modifications regarding RAS
**Existing Approach (AASHTO PP 78)**

- **Binder Quantity**
  - uses RAS binder availability factor 0.70-0.85

- **Binder Quality**
  - uses binder grade adjustment guidelines

<table>
<thead>
<tr>
<th>Recommended Virgin Asphalt Binder Grade</th>
<th>RAS or RAS + RAP Binder Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>No change</td>
<td>&lt;15</td>
</tr>
<tr>
<td>One grade softer</td>
<td>15 to 25</td>
</tr>
<tr>
<td>Use blending charts</td>
<td>&gt;25</td>
</tr>
</tbody>
</table>
ETG TF Recommendations - Quantity

- Raise minimum VMA by 0.1% for every 1% RAS (by weight of total aggregate).
  - Based on assumption of 70% binder availability
  - Will increase effective binder in the mix to offset for the potential for non-effective binder on the RAS

- Simple way of addressing binder availability
  - More binder → Improved durability
  - Angular aggregate and stiffer binder in RAS → Minimal risk of rutting
• Focus on the critical low temperature difference of the binder $\Delta T_c$ using BBR:

$$
\Delta T_c = \text{BBR Stiffness critical temp (S)} - \text{the BBR Relaxation critical temp (m-value)}
$$

$$
= T_c(S) - T_c(m-value)
$$

• Criteria: $\Delta T_c$ for the blended binder should be greater than (warmer) or equal to -5.0°C – Binder is PAV aged for 40 hours
The grading system is based on climate via a project specific location’s in-service pavement temperatures.

**Binder Selection**

- **PG Asphalt Binder Designation**
- **Performance Grade**
- **Damage weighted high pavement temperature**
- **Min pavement temperature**

**PG XX - YY**
Pressure Ageing Vessel
Bending Beam Rheometer

Thermal Cracking
Bending Beam Rheometer

Determines low temperature specification parameters standardized in AASHTO M320

![Graph showing Creep Stiffness (S(t)) and Creep slope (m-value).]

- Creep Stiffness (S(t))
- Creep slope (m-value)
## Example 1

<table>
<thead>
<tr>
<th>Test</th>
<th>Temperature</th>
<th>Result</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RTFO and PAV Residue – Aged Binder</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic Shear Rheometer G*sin(δ)</td>
<td>19°C</td>
<td>NR</td>
<td>≤ 5000 kPa</td>
</tr>
<tr>
<td></td>
<td>25°C</td>
<td>4100 kPa</td>
<td></td>
</tr>
<tr>
<td></td>
<td>28°C</td>
<td>NR</td>
<td></td>
</tr>
<tr>
<td>Bending Beam Rheometer, Stiffness, S</td>
<td>-24°C</td>
<td>NR</td>
<td>≤ 300 MPa</td>
</tr>
<tr>
<td></td>
<td>-18°C</td>
<td>368 MPa</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-12°C</td>
<td>187 MPa</td>
<td></td>
</tr>
<tr>
<td>Bending Beam Rheometer, m-value</td>
<td>-24°C</td>
<td>NR</td>
<td>≥ 0.3</td>
</tr>
<tr>
<td></td>
<td>-18°C</td>
<td>0.270</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-12°C</td>
<td>0.330</td>
<td></td>
</tr>
</tbody>
</table>

\[ \Delta T_c = -25.7 - (-25.0) = -0.7 \degree C \]
### Example 2

<table>
<thead>
<tr>
<th>Test</th>
<th>Temperature</th>
<th>Result</th>
<th>Criteria</th>
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</thead>
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</tr>
<tr>
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<td>19°C</td>
<td>NR</td>
<td>≤ 5000 kPa</td>
</tr>
<tr>
<td></td>
<td>25°C</td>
<td>NR</td>
<td></td>
</tr>
<tr>
<td></td>
<td>28°C</td>
<td>1870 kPa</td>
<td></td>
</tr>
<tr>
<td>Bending Beam, Rheometer, Stiffness, S</td>
<td>-24°C</td>
<td>313 MPa</td>
<td>≤ 300 MPa</td>
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<tr>
<td></td>
<td>-18°C</td>
<td>110 MPa</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-12°C</td>
<td>60 MPa</td>
<td></td>
</tr>
<tr>
<td>Bending Beam, Rheometer, m-value</td>
<td>-24°C</td>
<td>NR</td>
<td>≥ 0.3</td>
</tr>
<tr>
<td></td>
<td>-18°C</td>
<td>0.266</td>
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</tr>
<tr>
<td></td>
<td>-12°C</td>
<td>0.309</td>
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</table>

\[ \Delta T_c = -33.6 - (-23.3) = -10.3 \degree C \]
Critical Temperature Difference ($\Delta T_c$)

$\Delta T_c = \text{BBR Stiffness critical temp (S)} - \text{the BBR Relaxation critical temp (m-value)}$

$= T_{c(S)} - T_{c(m-value)}$

$= -25.7°C - (-25.0°C) = -0.7°C > -5°C$

$= -33.6°C - (-23.3°C) = -10.3°C < -5°C$

Critical temperature ($T_c$)
also know as “continuous grade”
Two Approaches

1. Binder Blending Procedure

• Agency sets allowable RAS tiers;
• Extract, recover, blend typical materials (RAS, RAP, base binder, etc.) at varying percentages
• RASBR = 0.00, 0.15, 0.30
• PAV age the blended binder for 40 hours
• Test the blended binders to determine $\Delta T_c$
• Set the allowable tiers based on the criteria that $\Delta T_c$ must be greater than or equal to -5.0°C, and the appropriate PG grade is met.
Two Approaches

1. Binder Blending Procedure

\[ \Delta T_C = T_{C,s} - T_{C,m} \]

-35 -30 -25 -20 -15 -10 -5 0

0 1 02 03 04 05 06 0

% Binder Replacement by RAS

Post Consumer Shingles
Post Manufacturer Shingles
Two Approaches

2. Mixture Extraction Procedure

- Individual mixes are fabricated, extracted, the binder recovered and then PAV aged for 40 hours
- The recovered binder is tested to determine $\Delta T_c$
- $\Delta T_c$ must be greater than or equal to -5.0°C, and the appropriate PG grade is met
• A mixture performance test for cracking implemented by the State may be acceptable in lieu of the binder testing for $\Delta T_c$
  – Cracking test development and deployment in its infancy
• Default value option – a maximum RASBR can be used in lieu of testing
  – for example $\text{RASBR} \leq 0.10$
Alternate Loose Mix Aging Procedure

- Mixture Extraction Procedure
  - Individual mixes are fabricated
  - Loose mix is conditioned at 135°C for 24 hours
    - Uncovered pan at a depth of 25 to 50 mm placed in a forced-draft oven with no stirring
  - Mix is then extracted, the binder recovered
  - The recovered binder is tested to determine $\Delta T_c$
  - $\Delta T_c$ must be greater than or equal to -5.0°C, and the appropriate PG grade must be met
Assumptions

• Assumes “worse case” scenario (from a binder perspective)
  – If blending is less than complete, the impact of the aged binder on stiffening and relaxation is less than the laboratory would predict
  – If blending is completely homogeneous, the impact on stiffening and relaxation would be accounted for.
Advantages

• Simple approach ... easy for states to make an informed decision on setting RAS limits based on available virgin binders and existing RAS materials.
• Quantified relationship to actual field cracking performance

Drawbacks

• Doesn’t address all mixture or binder design issues if the RAS binder does not become fully blended
  – Binder volume would be less than calculated
  – Could have a mix with better quality binder but not enough of it
• Standard PAV conditioning not effective to identify poor ageing characteristics
Summary

- Revised Draft PP 78 *Standard Practice for Design Considerations When Using RAS in Asphalt Mixtures*
- Increased minimum VMA to address issue of binder quantity to help prevent low asphalt content and durability issues
- Used $\Delta T_c$ to address binder quality
  - Recovered binder is PAV aged for 40 hours
  - Criteria: $\Delta T_c \geq -5.0^\circ C$
- Added loose mix aging (135°C for 24 hours) as an alternate in the appendix
  - Criteria: $\Delta T_c \geq -5.0^\circ C$
Multiple Stress Creep Recovery (MSCR)

FHWA is working with the Asphalt Institute to assist States to effectively understand and implement MSCR.

• Technical Brief FHWA-HIF-11-038

• Resources posted on AI’s website
  – www.asphaltinstitute.org/public/engineering/mscr-information.dot
Multi Stress Creep & Recovery (MSCR)

• Targeted interaction by FHWA and Institute engineers to gather information and document issues identified as hurdles to MSCR understanding, use, and implementation nationwide.
• Understand issues and provide solutions.
• Need your feedback!!
“In some cases when the $J_{nr}$ value is close to 4.5 a negative percent recovery may occur. With some rheometers when the load is cut off at the end of the creep cycle inertia of the movable plate causes it to continue to rotate and load the specimen. When the binder is Newtonian and has little to no recovery this can appear as a negative percent recovery. In these cases the strain at the end of the 1 second creep load shall be used to calculate the $J_{nr}$ compliance value. The percent recovery shall be recorded as zero.”
MSCR – $J_{nr\text{diff}}$ for “E” traffic

Remove the $J_{nr\text{diff}}$ max 75% for Extremely Heavy Traffic “E” grades with $J_{nr3.2} \leq 0.5$ kPa$^{-1}$ due to very low non-recoverable creep compliance values for both $J_{nr3.2}$ and $J_{nr0.1}$ when “E” binders are evaluated at the specified environmental PG temperature (i.e. not the grade bumped temperature).
MSCR – Draft Stand Alone Recovery Standard Practice

- FHWA Binder ETG developed draft “Practice for Evaluating the Elastic Behavior of Asphalt Binders Using the MSCR Test”
- MSCR Recovery Practice submitted to AASHTO Subcommittee on Materials
- Technical Section 2b Task Force reviewing draft standard for action.
Performance Grading

- Extensive development work conducted by Anton Paar on GTR modified binder with CC geometry
  - Reveal the practical and rheological challenges
  - Suggestion of a suitable measuring geometry for PG measurements of GTR modified Asphalt Binder
  - Finalized tool dimensions and requirements
- DSR Concentric Cylinder (CC) geometry ... also known as Cup & Bob geometry
  - “required to enable good rheology!” ... “Gap size matters!”
Small cylinder inside a big cylinder enables the use of large gaps

Absolute and Relative CC17SP
Gap ≈ 6.2 mm
Suitable for neat and RTFO asphalt binder (high PG temperatures)

CC10SP
Gap ≈ 9.5 mm
Suitable for PAV asphalt binder (intermediate PG temperatures)

Courtesy of Anton Paar
Advantages

▸ Large gaps possible!
▸ Sample cannot flow off the shear gap
▸ No sagging / leak of binder issues
▸ No specimen trimming/sample geometry issues
▸ Representative sample volume
▸ No edge effects
▸ Disposable cups can be used

Drawbacks

▸ Increased sample volume
  - Slower heating and cooling rates
  - Higher temperature equilibrium time required
▸ Relative measuring geometry
  - Calibration with Cannon N2700000 viscosity standard
Ongoing work:

- Need to address RTFO and PAV conditioning challenges with increasing GTR %.
- Need to address BBR and DTT specimen fabrication and testing challenges with increasing GTR %
Ongoing work:

• **increasing emphasis on use of hybrid asphalt rubber systems**
  – use of smaller/finer GTR grind size
  – use of lower percentage of GTR in combination with lower percentage of traditional polymers

• **Triple Bottom Line Approach to Hybrid Binders and Dense Graded Asphalt Mixtures**
  – three Ps: profit, people, and planet
New REOB Task Force within ETG

Discussions:

• Which rheological parameter
  – critical temperature change ($\Delta T_c$)
  – Glover-Rowe (GR)
  – rheological index (R value)
  – cross over frequency ($\omega_c$)

All of these parameters can be interrelated from understanding the relationship between loading time (or frequency) and temperature.
What is REOB?

- The **re-refined** residual distillation product from a **vacuum tower** in a re-refinery dedicated to processing recovered waste drain lubricating oil

Both “re-refined” and “vacuum tower” are important features for this product
Example: used engine drain oil from
- automobile and truck dealerships
- instant oil change establishments
- automotive parts stores
- local and regional oil recycling centers
the used oil is picked up by collection companies (collectors) and shipped to the waste oil refinery and re-refined into lubricant base oil for use again in automobiles and trucks.
Re-refined Engine Oil Bottoms (REOB)
aka: Re-refiners use the term
Vacuum Tower Asphalt Extender (VTAE)
What is not REOB?

- NOT: residual from a crude oil refinery vacuum tower – it is NOT asphalt
- NOT: from only atmospheric distillation
- NOT: recovered waste oil
- NOT: cleaned/de-watered waste oil
- NOT: recycled waste oil
- NOT: recycled fuel oil

Both “re-refined” and “vacuum tower” are important features for this product
Base Credit: Asphalt Institute, and Kleen Performance Products

Waste or Recovered Lubricating Oil from Collectors

Re-refined Engine Oil Bottoms (REOB) aka: Re-refiners use the term Vacuum Tower Asphalt Extender (VTAE)

*Process flow for hydrotreating lube oil re-refining facility
What is REOB?

- The re-refined residual distillation product from a vacuum tower in a re-refinery dedicated to processing recovered waste drain lubricating oil.
- It is not a “manufactured” product – i.e. REOB’s properties are variable depending on the lube oil source(s) and the process(es) used to re-refine and control it’s production.
Why REOB?

- Used to soften base binder PG grade
- Increased use of RAP/RAS has led to a need for softer grades, which has led to increased demand for REOB or other “soft” fluxes
- Limited crude sources and refineries to produce “softer” grades w/o back blending
- Economic and market share pressures
- Recycling and “Green” initiatives

“Used since mid 1980’s” ... as reported by REOB re-refiners/suppliers
“If used, re-refined engine oil bottoms are typically present at 5% to 10% by weight of the binder. ... In the past the main use for waste lubricating oils was as an industrial fuel. However, more recently economic incentives to re-refine waste drain oil to produce base oils have led to an increase in the volumes being re-refined. As a result there have been increased incentives to utilise these materials in bitumen. Little systematic research into the performance of pavements produced with REOB containing binders has been conducted.”
“These materials have been added to BITUMEN to change the low temperature properties and to enhance the oxidation of some bitumen roofing products. Numerous other terms have been employed by the producers and users of this type of additive. When used in paving the materials is added up to 10% to soften the BITUMEN for use with RAP or RAS or meet cold weather requirements. When used in OXIDISED ASPHALT it is added up to 6% as a paraffinic oil to increase penetration.”

“see OIL (PETROLEUM) VACUUM DISTILLATION BOTTOMS, USED “
<table>
<thead>
<tr>
<th></th>
<th>ETG meeting presentations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Asphalt Binder Modification with Re-refined Heavy Vacuum Distillate Oil - D’Angelo</td>
</tr>
<tr>
<td>2.</td>
<td>Safety-Kleen Eco Addz (VDB’s) – D’Angelo</td>
</tr>
<tr>
<td>3.</td>
<td>REOB Background/Issues - M. Anderson</td>
</tr>
<tr>
<td>4.</td>
<td>REOB FHWA Research on Mixture Effects - Gibson</td>
</tr>
<tr>
<td>5.</td>
<td>REOB and other Additives Impact on Binder Aging and Mixture Low and Intermediate Properties – Reinke</td>
</tr>
</tbody>
</table>
ETG meeting presentations

6. REOB: RAS/RAP & Recycling Agent Considerations - Mohammad
7. REOB: AASHTO Task Force - Ahearn
8. REOB: Asphalt Institute Task Force - Buncher
9. REOB: Update on Olmsted County, MN comparative test sections & pavement distress survey - Reinke
10. REOB: University of Massachusetts Dartmouth - Mogawer
ETG meeting presentations

11. REOB: TFHRC Research - Gibson
12. REOB: Rutgers University - Bennert
13. REOB: Blended REOB Binder Advanced Chemical & Physical Characterization – Planche
14. REOB: AI’s Task Force Update - Buncher
15. REOB: Evaluation and Performance - Reinke
16. REOB: TFHRC Research Update - Gibson
ETG meeting presentations

17. Asphalt Binder $\Delta T_c$ and S Value – Youtcheff
18. RAP/RAS Task Force Summary & $\Delta T_c$ recommendations - Musselman
19. REOB: Effect of REOB on the Performance of Asphalt Mixtures Containing RAS – Mohammad
20. Binder ETG - REOB Task Force – Rowe
22. Evolution and Use of the $\Delta T_c$ Parameter - Rowe
How do I know if it's REOB?

- There is not an asphalt test that can definitively differentiate re-refined versus non re-refined products
- Supplier or producer certification of vacuum tower distillation may be the best way to ensure the material is vacuum tower derived
• Typically encountered to designate REOB with description: *Lubricating oils, used, residues*.

• REOB is only one of many products that may fall under this CAS# designation.

• Re-refined vacuum tower distillation products are also typically designated with this same CAS#
• Other products which are not re-refined using vacuum tower distillation may be designated with this same CAS#.
• The CAS# designation does not assure the product is re-refined using vacuum tower distillation processes.
• Supplier or producer certification may be the best way to ensure the product is re-refined using vacuum tower distillation.
Detection of trace elements by X-Ray Fluorescence (XRF) Spectroscopy
- Phosphorous
- Sulfur
- Calcium
- Iron
- Copper
- Zinc
- Molybdenum
FHWA has tested 2,600 XRF samples
   – Select ~3% of the data set for further study...
REOB Detection – other approaches

• Proton Nuclear Magnetic Resonance ($^1$H NMR) spectroscopy
  – REOB/VTAE contains much less aromatic protons and is mostly saturate alkanes (aliphatics); some of which are very different from those found in asphalt.

• Inductively Coupled Plasma (ICP) techniques

No standard guidance on how to perform these tests to quantify REOB
• Various REOB products may behave differently
  – properties can vary
• Impact on final properties is dependent on
  *both* the REOB and the base binder
  – interaction with base asphalt binder
• Irresponsible use and increasingly higher
dosage rates have detrimental impact
• Limited field project data linked to accelerated
  pavement ageing and cracking distress
ETG Consensus Items

- Concerns exist from the agency/DOT perspective on the durability of asphalt pavements
- $\Delta T_c$ could be used to track performance and is readily available in the existing data
- The amount of REOB generally affects the $\Delta T_c$ but not all materials are created equal
- High RAS and RAP/RAS binder replacement can result in more negative values of $\Delta T_c$
- PAV conditioning requirements
Critical Temperature Difference ($\Delta T_c$)
Critical Temperature Difference ($\Delta T_c$)

Credit: Tom Bennert, Rutgers University
Field Studies

- FHWA/Asphalt Research Consortium/WRI Validation Sites
  - Rochester, MN - Olmsted County 112

- MnROAD Test Track Low Volume Road Test Section Sites
FHWA/Asphalt Research Consortium/WRI Validation Sites

Credit: Western Research Institute (WRI) via Asphalt Research Consortium
### Sample Designation

<table>
<thead>
<tr>
<th>Sample Designation</th>
<th>Performance Grade</th>
<th>Project specifications</th>
<th>Source Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MN1-2</td>
<td>PG 58-34</td>
<td></td>
<td>Canadian blend, Elvaloy modified</td>
</tr>
<tr>
<td>MN1-3</td>
<td>PG 58-28</td>
<td></td>
<td>Canadian blend</td>
</tr>
<tr>
<td>MN1-4</td>
<td>PG 58-28</td>
<td></td>
<td>Middle East Blend</td>
</tr>
<tr>
<td>MN1-5</td>
<td>PG 58-28</td>
<td></td>
<td>Venezuelan blend</td>
</tr>
</tbody>
</table>

**Credit:** Western Research Institute (WRI) via Asphalt Research Consortium
• XRF analysis & REOB estimate
  • MN1-4 tank asphalt binder metal content (ppm)
    • Ca 618.1, Cu 36.6, Fe 88, Zn 359.4, Mo 50.5 (V 350, Ni 72)
  • MN1-1, 1-2, 1-3, 1-5 average metal content (ppm)
    • Ca 0, Cu 0, Fe 27, Zn 6.6, Mo 2 (V 390, Ni 83)

➤ REOB found in MN1-4 ... estimated at about 8% content
Rochester, MN – 2012 Distress Data

Transverse Cracking

Length transverse cracking (m)

- Low Severity
- Moderate Severity

MN1-2  MN1-3  MN1-4  MN1-5

8% REOB

Longitudinal Cracking

Length longitudinal cracking (m)

- Low Severity
- Non-Wheel Path

MN1-2  MN1-3  MN1-4  MN1-5

8% REOB

Low Severity Fatigue Cracking

Area fatigue cracking (m²)

MN1-2  MN1-3  MN1-4  MN1-5

8% REOB

Rutting

Average Rut Depth (mm)

MN1-2  MN1-3  MN1-4  MN1-5

8% REOB
Rochester, MN – BBR vs cracking

- BBR limited T grading did not predict the cracking issue on the MN1-4 section
- But the BBR $T_c$ is significantly m-value controlled $\Delta T_c < -5^\circ C$
- Agreement with others
• Field performance – **limited data**
  – Potential cracking issue in cold climate (MN), both thermal and fatigue, in comparison with other similar PG asphalt w/o REOB
  – Could be captured through binder evaluation after **appropriate aging**
• REOB identification techniques:
  – XRF are promising possibilities
Follow-up work on Olmsted County

- New distress survey conducted in October 2014
- Samples of original project binders were laboratory conditioned for both 20 hour and 40 hour pressure ageing vessel (PAV) to simulate long term field ageing
Follow-up work on Olmsted County

- Retained original project construction mixtures from WRI were oven conditioned loose for both 12 and 24 hours
- Binders were recovered from aged mix and tested
Recall the (MN1-4) Kirkuk PG 58-28 is the one that contain the REOB additive

The (MN1-2) 58-34 PMA binder was produced using Elvaloy and PPA from a PG 52-34 which came from a blend of Canadian crudes, similar to the (MN1-3) PG 58-28
Olmsted Co. updated distress data – 2014

Total distress is correlated to $\Delta T_c$

Total Distress = $F(\Delta G(t)-m)$

Binders recovered from top 0.5 inch of field cores

- $\Delta T_c (\Delta G(t)-m)$
- Linear ($\Delta T_c (\Delta G(t)-m)$)

$y = -54.788x + 151.08$
$R^2 = 0.9638$
$\Delta T_c$ of the 20 hr PAV residue under predicts the field binder recovered from cores.
ΔT_c of the 40 hr PAV residue more closely predicts the binder recovered from cores.
1999 SuperPave Cells
Cell 33 – PG 58-28
Cell 34 – PG 58-34
Cell 35 – PG 58-40
MnROAD Test Track Sections

- Constructed in Sept 1999
- same mixtures with three (3) different binders
  - PG 58-28
  - PG 58-34
  - PG 58-40 (created with REOB) [Cell 35]
- Traffic until April 2007
- Annual distress surveys conducted
Cell 35 Crack Maps [.pdf]

Credit: MnROAD
### Data from 20 hr. PAV tests performed in 2000

<table>
<thead>
<tr>
<th>Binder grade</th>
<th>S critical from BBR (°C)</th>
<th>m critical from BBR (°C)</th>
<th>ΔTc (S grade - m grade)</th>
<th>S_critical from 4 mm DSR (°C)</th>
<th>m_critical_temp from 4 mm DSR (°C)</th>
<th>ΔTc (S grade - m grade)</th>
</tr>
</thead>
<tbody>
<tr>
<td>58-28</td>
<td>-30.9</td>
<td>-30.3</td>
<td>-0.6</td>
<td>-31.3</td>
<td>-30.5</td>
<td>-0.8</td>
</tr>
<tr>
<td>58-34</td>
<td>-34.8</td>
<td>-35.98</td>
<td>1.2</td>
<td>-35.6</td>
<td>-35.4</td>
<td>-0.2</td>
</tr>
<tr>
<td>58-40</td>
<td>-44.3</td>
<td>-42.9</td>
<td>-1.4</td>
<td>-44.4</td>
<td>-42.0</td>
<td>-2.4</td>
</tr>
</tbody>
</table>

### Binder grade 40 hr. PAV

<table>
<thead>
<tr>
<th>Binder grade</th>
<th>40 hr. PAV S critical from 4 mm DSR (°C)</th>
<th>40 hr. PAV m_critical_temp from 4 mm DSR (°C)</th>
<th>ΔTc (S grade - m grade)</th>
<th>60 hr. PAV S_critical from 4 mm DSR (°C)</th>
<th>60 hr. PAV m_critical_temp from 4 mm DSR (°C)</th>
<th>ΔTc (S grade - m grade)</th>
</tr>
</thead>
<tbody>
<tr>
<td>58-28</td>
<td>-29.5</td>
<td>-26.7</td>
<td>-2.8</td>
<td>-28.5</td>
<td>-22.7</td>
<td>-5.8</td>
</tr>
<tr>
<td>58-34</td>
<td>-34.9</td>
<td>-32.4</td>
<td>-2.5</td>
<td>-33.1</td>
<td>-27.6</td>
<td>-5.5</td>
</tr>
<tr>
<td>58-40</td>
<td>-42.9</td>
<td>-34.6</td>
<td>-8.3</td>
<td>-42.9</td>
<td>-30.5</td>
<td>-12.4</td>
</tr>
</tbody>
</table>

### Binder grade sulfur, %, phosphorus, %, molybdenum, ppm, zinc, ppm

<table>
<thead>
<tr>
<th>Binder grade</th>
<th>sulfur, %</th>
<th>phosphorus, %</th>
<th>molybdenum, ppm</th>
<th>zinc, ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>58-28</td>
<td>4.896</td>
<td>0.001</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>58-34</td>
<td>4.374</td>
<td>0.001</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>58-40</td>
<td>3.969</td>
<td>0.059</td>
<td>18</td>
<td>925</td>
</tr>
</tbody>
</table>
Asphalt Institute REOB Task Group

- Included AI Staff, Member’s, and FHWA
- Most current State of REOB Knowledge thru end of December 2015
- Will become AI’s official guidance and position on REOB
- Publishing Goal: May/June 2016
  - Electronic Format with free download
  - ~ 100 pages & literature review
1. Introduction
2. Production of REOB/VTAE
3. Literature Review of REOB Performance
4. H.S. & E. Considerations
5. Discussion of Alternative Tests, Parameters and Aging Protocols and Their Applicability to Performance
6. Frequently Asked Questions (FAQ)
Takeaways

- **low dosage rates may be innocuous**
  - up to approximately 3%
- **high dosage rates appear detrimental**
  - approximately 10% and greater
- **middle dosage rates ???**
  - dependent on REOB and base binder
  - need to evaluate properties
  - need to evaluate with longer laboratory conditioning (ageing) and use 40 hour PAV
Takeaways

- Asphalts w/ similar performance grades from different crude sources are impacted differently by a given amount & source of REOB
- When compared to neat asphalt binders of equivalent PG grade, asphalt binders modified w/ REOB typically exhibit higher rates of ageing, w/ small changes observed after RTFO & larger changes observed after 40 hours of PAV ageing.
Takeaways

- Test data correlated to field performance is based on long term aged (5+ years) field mixtures
- The binder recovered from field mixtures was better correlated to 40 hour PAV residue properties
- The rate of decrease in the value of $\Delta T_c$ as the binders are aged from 20 to 40 hours is informative
- A higher rate of decreasing $\Delta T_c$ values between 20 to 40 hours PAV ageing indicates potentially problematic materials
Takeaways

- Pavements built with binder $\Delta T_c$ values approaching -5°C & less (colder) have shown to exhibit increased pavement cracking distress in the field.
- The m-value control & $\Delta T_c$ progress with ageing should be investigated to observe the REOB impact on binder properties and determine its susceptibility to accelerated ageing.
Additional Resources

**Expert Task Groups**
**Asphalt Mix & Asphalt Binder**

- www.AsphaltETGs.org
- www.asphaltinstitute.org/re-refined-engine-oil-bottom/
- NCHRP Projects 09-59 and 09-60
  - www.trb.org/NCHRP/NCHRPProjects.aspx
Hamburg Wheel Track Test – AASHTO T 324

- NCHRP Project 20-07/Task 361 Hamburg Wheel-Track Test Equipment Requirements & Improvements to T 324
  - Wheel position waveform, frequency, & maximum speed;
  - Impression measurement system;
  - Temperature measurement and control system;
  - Wheel dimensions and loads;
  - Specimen and track length;
  - Free Circulating Water on Mounting System; and
  - Data collection and reporting.
Hamburg Wheel Track Test – AASHTO T 324

NCHRP Project 20-07 Task 361

- Report available as NCHRP Web Only Document 219
Hamburg Wheel Track Test – AASHTO T 324
NCHRP Project’s Proposed Modifications

- **Section 5.1**: Define a tolerance for wheel dimensions
- **Section 5.1**: Define a tolerance for “*wheel be required to reciprocate over the specimen such that its position varies sinusoidally over time*”
- **Section 5.1**: Define a tolerance for maximum speed
- **Section 5.2**: AASHTO T 324 specifies the use of a water bath capable of controlling the temperature within ±1.0°C over a range of 25 to 70°C. Results of temperature experiment revealed shortcomings in this part of the spec
Hamburg Wheel Track Test – AASHTO T 324
NCHRP Project’s Proposed Modifications

• **Section 5.3:** AASHTO T 324 does not currently specify the locations of the deformation readings or number of deformation readings
  
  – Recommend deformation readings at 11 locations along the length of the track.
  
  – -114, -91, -69, -46, -23, 0, +23, +46, +69, +91, +114 mm with zero being the midpoint of the track.
  
  – Midpoint of the track should be marked by the different manufacturers to assist the user. (cont.)
Hamburg Wheel Track Test – AASHTO T 324
NCHRP Project’s Proposed Modifications

• **Section 9.2**: Report average rut depth based on five middle deformation sensors
  – Recommend sensors located at -46, -23, 0, + 23, and + 46 mm

• **Section 9.3**: Recommended method to calculate the stripping inflection point (SIP) and other reporting parameters not clearly defined in the current specification
• Report recommendations are currently being reviewed for action by AASHTO Subcommittee on Materials, Hamburg Task Force within the Tech Section 2c.
• Other T 324 improvements made by Hamburg Task Force will be published 2016
• Additional T 324 improvements forthcoming based on NCHRP report findings.
• Alpha Release: January 10, 2016 at TRB
• Beta Release: April 2016
• Go-Live: July 2016 with the release of LTPP Standard Data Release 30
MERRA: MODERN-ERA RETROSPECTIVE ANALYSIS FOR RESEARCH AND APPLICATIONS

• MERRA is a NASA reanalysis for the satellite era using a major new version of the Goddard Earth Observing System Data Assimilation System.

• Reanalysis is a scientific method for developing a comprehensive record of how weather and climate are changing over time.
MERRA Data

• Long-term (1979-present) synthesis of climate data from a suite of research satellite observations

• Continually updated with 4.2 million global observations every 6 hours (with 2 week delay)

• A native 1/2° latitude by 2/3° longitude data grid

• Conducted at the NASA Center for Climate Simulations (NCCS)
• Alpha and Beta testers are needed!!
  Please contact Larry Wiser at larry.wiser@dot.gov for information on alpha
  and beta testing.

• Feedback and Comments.
  Larry Wiser: larry.wiser@dot.gov and
  Riaz Ahmad: rahmad@iengineering.com
Enhanced Durability through Increased In-Place Pavement Density

• Assumption – Pavement density can be increased with a minimum of additional cost.

• Long-Term Objective – States will increase their in-place asphalt pavement density requirements resulting in increased pavement life.
Enhanced Durability through Increased In-Place Pavement Density

• A 1% increase in field density (1% less air voids) is claimed to increase asphalt pavement service-life 10+%! (conservatively)
• Today’s compaction target is typically 92% of maximum \(G_{mm}\) (8% air voids), with varying requirements for the area near the longitudinal joint

**Increased Density Pavements** target a 1-2% increase across the entire pavement!
  – Just 1% more... makes a huge difference!
Thank You!!

Discussion / Comments / Questions

FHWA’s Mobile Asphalt Testing Trailer
Office of Asset Management, Pavement, and Construction

www.fhwa.dot.gov/pavement/asphalt