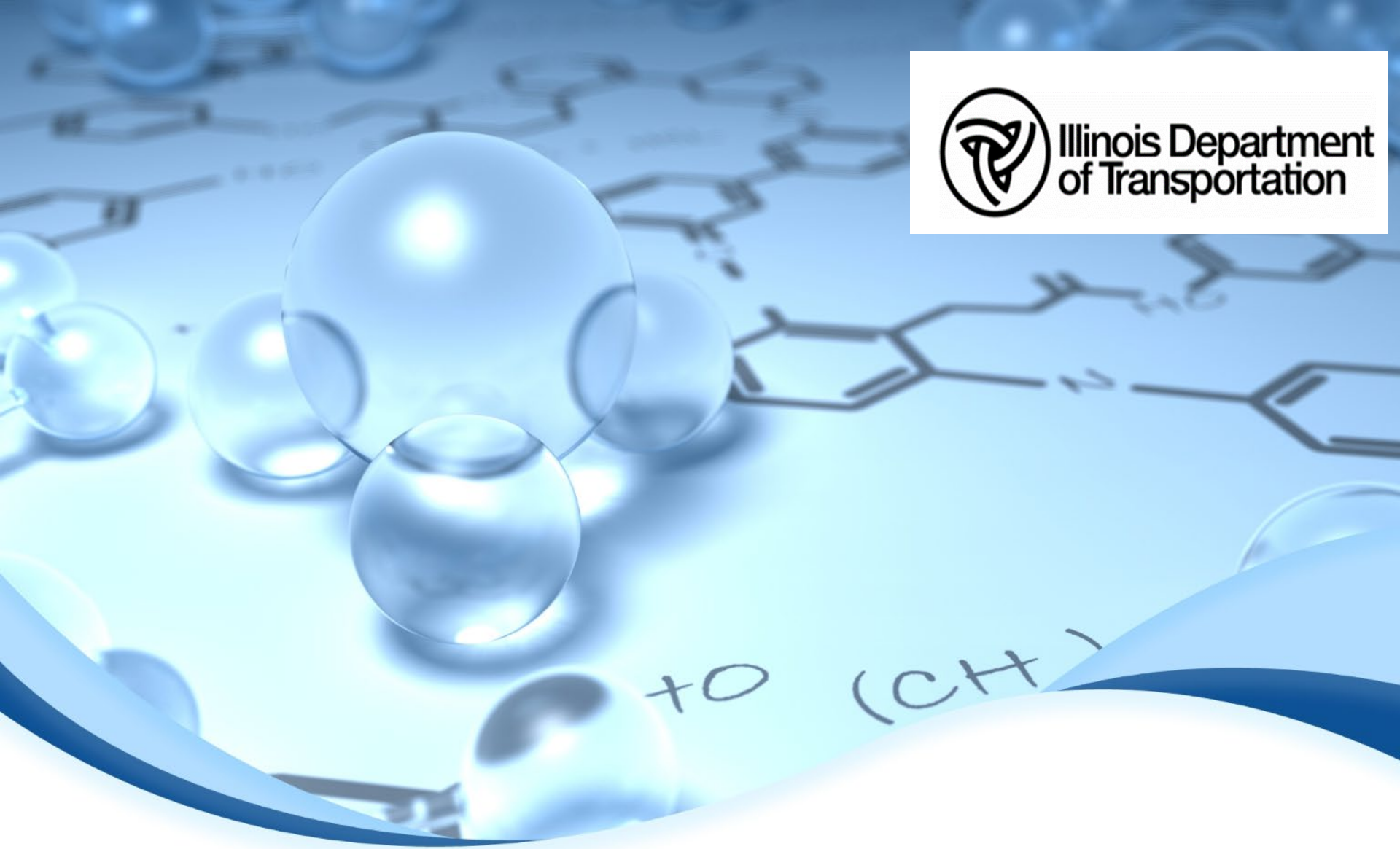


Development and Implementation of a New Modified Binder Protocol

Background

- In 2016, Asphalt binder sources requested that the Department consider the use softeners to achieve softer grades of PG binder, PG 58-28.
- In 2016, IDOT requested assistance from IAPA to develop a protocol to allow the use of softeners
- In 2017, IDOT worked with industry to develop a research need statement and initiated research through the Illinois Center for Transportation

Research

- July 2018, IDOT awarded ICT Project R27-196HS to the University of Illinois Champaign Urbana
- "Rheology-Chemical Based Procedure to Evaluate Additives/Modifiers used in Asphalt Binders for Performance Enhancements"
- Dr. Imad Al-Qadi, Dr. BK Sharma and Dr. Hasan Ozer

IDOT's Objectives:

- Implement an improved protocol for testing and qualifying asphalt binders.
- Test qualified asphalt binders in HMA and perform the long-term aging protocol and test for mixture performance properties.
- Provide Contractors asphalt binders with improved performance that can be used in mixed designs successfully
- Improve the performance and durability of HMA pavements.

R27-196HS Summary

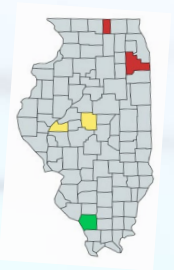
Rheology

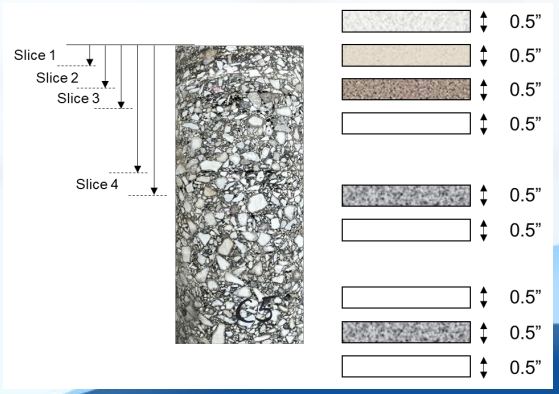
- FS (Gr, w_c, R-value)
- BBR (ΔT_c)
- LAS

Chemistry

- FTIR
- GPC
- TLC FID, SARAD
- Microscopy
- TGA/DSC

- 20-hr PAV
- 40-hr PAV
- 60-hr PAV
- Modified PAV to match real time aging





Long-Term Lab Aging

Modifiers

Modifier ID	Type
A	NA
B	Fatty acid derivatives
C	Fatty acid derivatives
D	Bio Oil Blend
E	Mod. Veg Oil
F	Mod. Veg Oil
G	Glycol Amine
H	Asphalt
I	Soybean Oil, Methyl ester
J	Vegetable oil
K	ReOB
L	NA

ID	Binder	Qty.
S1	PG 64-22	110 gal.
S2	PG 64-22	50 gal.
S3	PG 64-22	50 gal.
S5	PG 58-28	20 gal.
S6	PG 46-34	20 gal.
S7	PG 52-34	20 gal.
S8	PG58-28	4 gal.
S9	PG64-22	4 gal.

RHEOLOGY SUMMARY

- The base binder, S1, could not be modified to a 58-28 with modifier K (ReOB)
- ReOB modifier consistently worst rheological performer
- Modification of S1 improved ΔTc for all modifiers except K
- Glycol amine and fatty acid-based modifiers demonstrate better cracking resistance characteristics compared to vegetable oil-based modifiers.
- Small strain parameters: FS and ΔTc are promising indicators for rheological performance and correlate well.

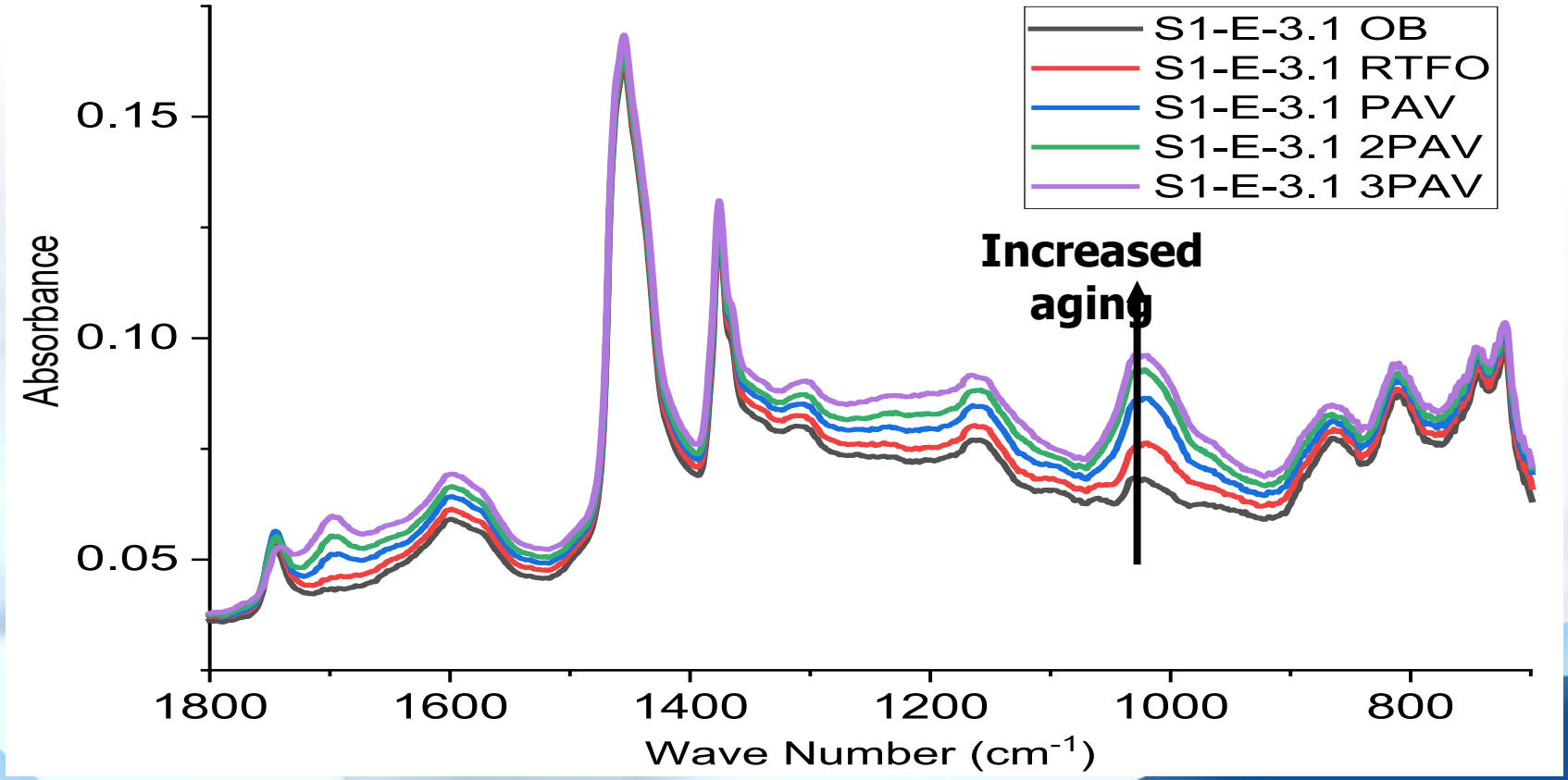
RHEOLOGY SUMMARY

- ΔTc trends for the modified binders are mostly consistent with aging, especially 2-PAV & 3-PAV
- m-value is the governing factor determining grade with long-term aging
- Large strain parameters are indicators of different characteristics than small strain parameters.
- LAS and proposed $\Delta\,|G^*|_{peak\,\tau}$ shows excellent promise as it provides consistent trends with aging and known binder data from small strain tests. This parameter was able to distinguish some performance differences that the small strain parameters did not.

Modifier Chemistry Testing:

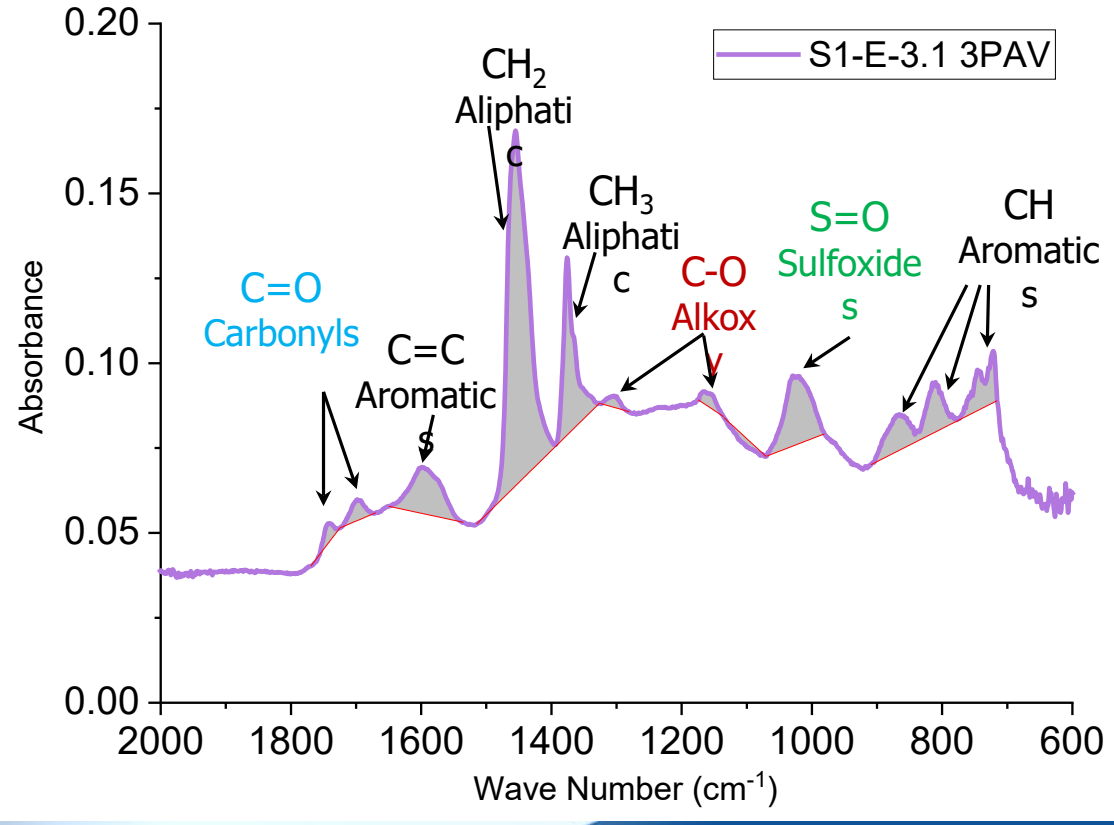
- Six Modifiers Tested
- Chemical Characterization
  - CHNS
  - FTIR
  - TGA
  - TLC-FID
  - GPC
- Develop a Fingerprint

Impact of Aging on Binder Chemistry



Oxidation Indices

- Carbonyl Index (ICO)
  - $ICO = \frac{\sum A_{1770-1650}}{\sum A}$
- Sulfoxide Index (ISO)
  - $ISO = \frac{\sum A_{1070-990}}{\sum A}$
- ICO + ISO
- ICO + ISO + Alkoxy

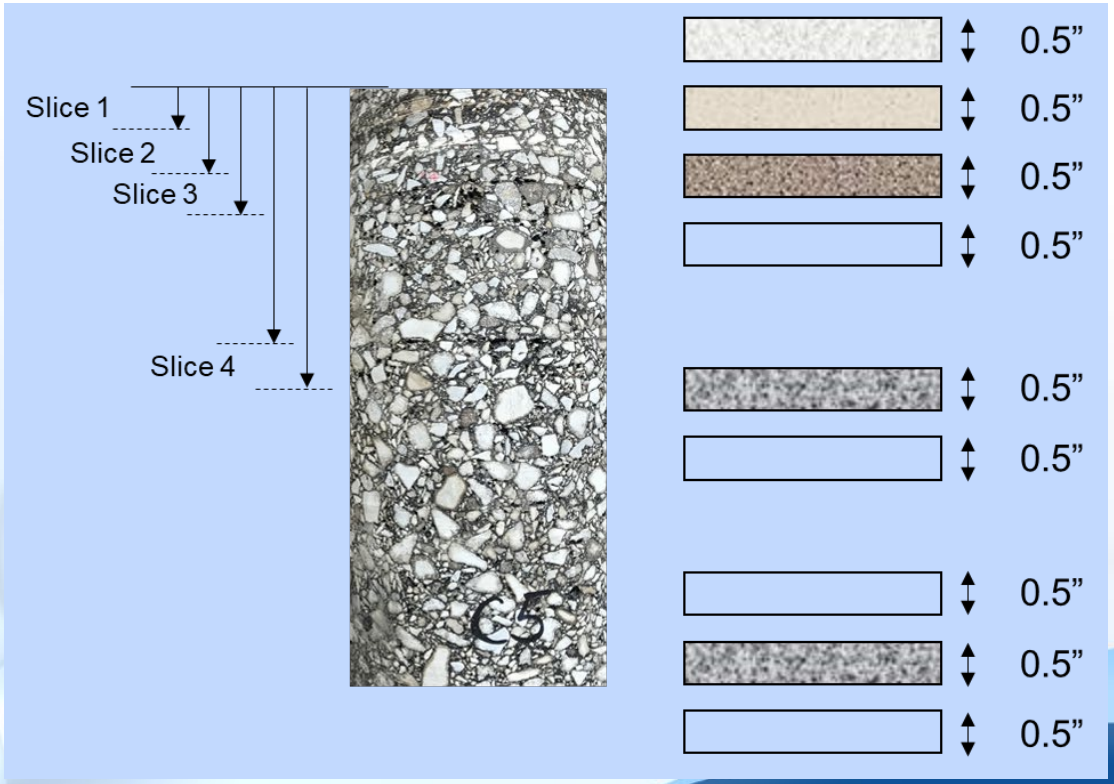


Field Core Inventory

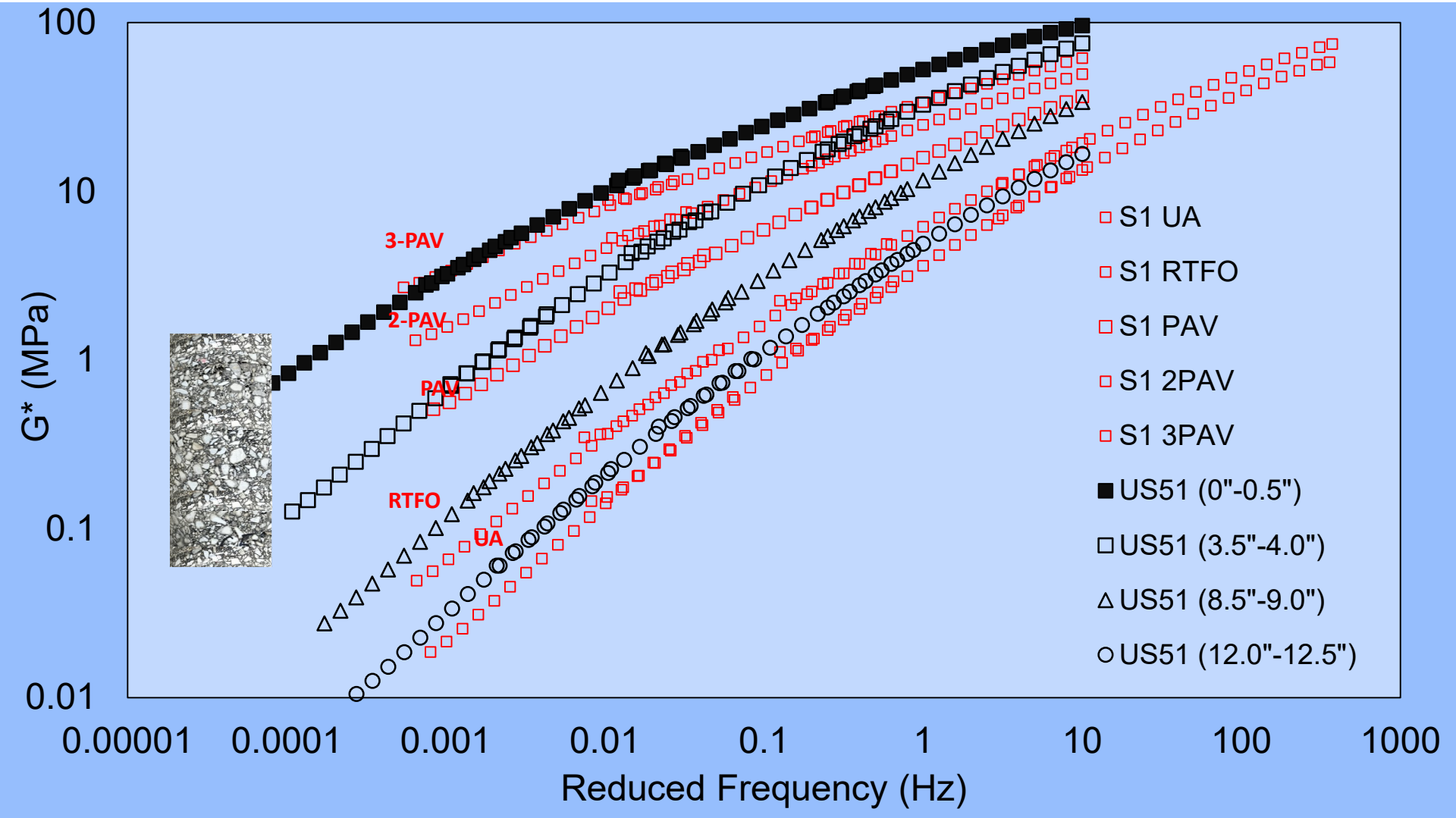
Field Core ID	District	Binder PG	Year of Construction	Year of Coring	Age
I-355	D2	64-22	2007	2018	11 yrs
I-90	D1	64-22	2006	2018	12 yrs
22STR2	D2	58-22	2004	2014	10 yrs
2RT26	D2	**76-28**	2004	2014	10 yrs
ICT L1	D5	64-22	2008	2019	11 yrs
ICT L2	D5	64-22	2009	2019	10 yrs
IL-125	D6	64-22	2009	2018	9 yrs
I-72 1E	D6	64-22	2003	2013	10 yrs
US-51	D8	64-22	2001	2018	17 yrs

Long-Term Field Aging

- Aging extent varies with AC layer depth
- Core sliced @ 0.5-in-depth to extract binder
- Top 0.5-in slices were considered for long-term aging characterization



Aging Gradient with Depth



Field Aging of AC Surface

- Field-aged binder is different than laboratory-aged binder
- Field aging varies with depth
  - Almost equivalent to 3 PAV at top 0.5 inch
  - Minimal aging at bottom of the 12-inch core, less than RTFO but more than unaged binder
- Results suggest that single PAV not representative of realistic field aging.

Research Proposed Protocol

Asphalt Binder Fact Sheet

Superpave™ PG **58-28 (60.3-30.4)**

Rheology

Cracking Parameters

Fatigue Cracking (Load Related)

ΔG*, *LAS @ Int. temp. 2-PAV* — *> 50%*

Thermal Cracking (Non-Load Related)

GR, *@ Int. temp, 10 rad/s, PAV/2-PAV* — *12,0000 kPa*

Low Temperature Cracking (Non-Load related)

ΔT_c, PAV/*2-PAV* — *-2.5/-5.0°C*

Advanced Rheology

Thermal Cracking (Non-Load Related)

VETT

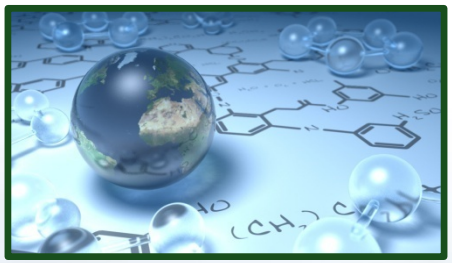
Black Angle, @ G = 8967 kPa* — *min. 45°*

GR, *@ 15C, 0.005 rad/s, PAV/2-PAV* — *max. 800 kPa*

Composition & Chemistry

Oxidation Index

IDOT Test Parameters Chosen



FTIR Fingerprinting

- Collect electronic spectral files to develop an IL asphalt binder library
  - ITP 601

Small Strain Rheological Parameter

- Delta Tc after 40 hours or 2 PAV

Large Strain Rheological Parameter

- Delta G after 40 hours or 2 PAV

Section 1032 Revision Overview

Exclusions:

- Air Blown Asphalt
- Recycled Engine Oil Bottoms (ReOB)
- Polyphosphoric Acid (PPA)

PERFORMANCE GRADED ASPHALT BINDER (BDE)

Effective: January 1, 2022

Revise Article 1032.05 of the Standard Specifications to read:

"**1032.05 Performance Graded Asphalt Binder.** These materials will be accepted according to the Bureau of Materials Policy Memorandum, "Performance Graded Asphalt Binder Qualification Procedure." The Department will maintain a qualified producer list. These materials shall be free from water and shall not foam when heated to any temperature below the actual flash point. Air blown asphalt, recycle engine oil bottoms (ReOB), and polyphosphoric acid (PPA) modification shall not be used.

When requested, producers shall provide the Engineer with viscosity/temperature relationships for the performance graded asphalt binders delivered and incorporated in the work.

(a) Performance Graded (PG) Asphalt Binder. The asphalt binder shall meet the requirements of AASHTO M 320, Table 1 "Standard Specification for Performance Graded Asphalt Binder" for the grade shown on the plans and the following.

Test	Parameter
Small Strain Parameter (AASHTO PP 113) BBR, ΔTc, 40 hrs PAV (40 hrs continuous or 2 PAV at 20 hrs)	-5 °C min.

Note:

- Lab testing indicates some binders that are currently qualified will not meet this new criteria.
- Anticipate the use of a softener to address binders that do not meet the ΔTc -5°C minimum.

Revised 1032.05(b) Modified Performance Graded (PG) Binder. AASHTO M320 Table 1 and the following:

- No longer just polymer modification.
- Asphalt binder modification shall be done at the **SOURCE**.
- Modified binder shall be safe to handle under normal temperatures for construction, production and storage.

(b) Modified Performance Graded (PG) Asphalt Binder. The asphalt binder shall meet the requirements of AASHTO M 320, Table 1 "Standard Specification for Performance Graded Asphalt Binder" for the grade shown on the plans.

Asphalt binder modification shall be performed at the source, as defined in the Bureau of Materials Policy Memorandum, "Performance Graded Asphalt Binder Qualification Procedure."

Modified asphalt binder shall be safe to handle at asphalt binder production and storage temperatures or HMA construction temperatures. Safety Data Sheets (SDS) shall be provided for all asphalt modifiers.

Revised 1032.05(b) Modified Performance Graded (PG) Binder. AASHTO M320 Table 1 and the following:

Subheadings for various modifiers now allowed.

1. Polymer Modification – Added SB/SBS/SBR PG 64-34 and moved SB/SBS/SBR PG 70-28 to the right column, per industry request.
2. Removed Forced Ratio requirement due to redundancy with Elastic Recovery and efforts to streamline testing in cooperation with binder sources
3. Removed IL-4.75 ER of 80 min statement. No longer relevant.

Revised 1032.05(b)(2)

Ground Tire Rubber (GTR) Modification. Revised D1 GTR Special to create a Central Bureau of Materials (CBM) Statewide specification in 2019 (Added more PG testing).

That CBM was modified slightly for Standard Specification format and added to the BDE.

Revised 1032.05(b)(3)

Softener Modification (SM) added to the BDE.

- Specification and Protocol resulted from ICT R27-196.
- BDE allows the addition of organic compounds to the base binder to achieve the specified PG.

(3) Softener Modification (SM). Softener modification is the addition of organic compounds, such as engineered flux, bio-oil blends, modified vegetable oils, glycol amines, and fatty acid derivatives, to the base asphalt binder to achieve the specified performance grade. Softeners shall be dissolved, dispersed, or reacted in the asphalt binder to enhance its performance and shall remain compatible with the asphalt binder with no separation. Softeners shall not be added to modified PG asphalt binder as defined in Articles 1032.05(b)(1) or 1032.05(b)(2).

Softener Modification (SM) Cont.

SM Modification Protocol:

ATR-FTIR spectra collected on unaged, 20 hr PAV and 40 hr PAV.

- Electronic spectral files will be sent to CBM
- Spectra will be used to establish a baseline fingerprint of the SM binders
- Oxidation Indices or Rates will be analyzed by the Instrument Lab at CBM.

-

3. Softener Modification (SM) added to the BDE.

- New grades added to the section include:
- SM PG 46-28
- SM PG 52-28
- SM PG 58-22
- SM PG 64-22
- SM PG 46-34
- SM PG 52-34
- SM PG 58-28

SM Modification Protocol:

- Small Strain Parameter, ΔTc, added
- Large Strain Parameter, Δ|G*|peak τ

Softener modified asphalt binders shall meet the requirements in Table 4.

Table 4 - Requirements for Softener Modified Asphalt Binders	
Test	Asphalt Grade SM PG 46-28 SM PG 46-34 SM PG 52-28 SM PG 52-34 SM PG 58-22 SM PG 58-28 SM PG 64-22
Small Strain Parameter (AASHTO PP 113) BBR, ΔTc, 40 hrs PAV (40 hrs continuous or 2 PAV at 20 hrs) 1/	-5°C min.
Large Strain Parameter (Illinois Modified AASHTO T 391) DSR/LAS Fatigue Property, Δ|G*|peak τ, 40 hrs PAV (40 hrs continuous or 2 PAV at 20 hrs) 1/	Results (%) shall be reported to the Central Bureau of Materials

1/ Frequency of the testing will be determined by the Bureau of Materials Policy Memorandum, "Performance Graded Asphalt Binder Qualification Procedure."

Implementation Steps

- ✓ 1. BDE Finalized.
- ✓ 2. Ongoing work with DSR manufacturers to get instrument software updated to run modified LAS procedure to derive Δ|G*|peak τ without operator interpretation.

3. Finalize IL Modified AASHTO T391. Drafted and internally reviewed.

- ✓ 4. Revisions finalized for IL Test Method 601 for collection of ATR-FTIR.

5. Send CBM collected and aged softener modified binder samples out for round robin testing of Δ|G*|peak τ.

Recent work with Asphalt Institute to perform a round robin on the ΔT_c parameter. IDOT CBM participated as well as many other IL binder sources. Will closely review that report.

Implementation Steps

- ✓ 6. PG Policy will not change. QC plans may change if Source plans to use softeners.

7. Amend certification forms to include new test parameters.

8. Revise material codes in MISTIC to new naming indicated in BDE 1032. i.e. SB/SBS/SBR, GTR, SM.

9. Update QPL with new naming and qualification procedures

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