



Providing solutions to highway building materials problems

Asphalt Aging - Actual versus Predicted

Mike Farrar, Mike
Harnsberger, Ken Thomas,
William Wiser, Janet Wolf

Western Research Institute

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Asphalt field aging compared to predicted aging based on:

■ Global Aging System

- Published 1995 (AAPT, Vol. 64)
- Integral part of NCHRP 1-37A Mechanistic-Empirical Design Guide

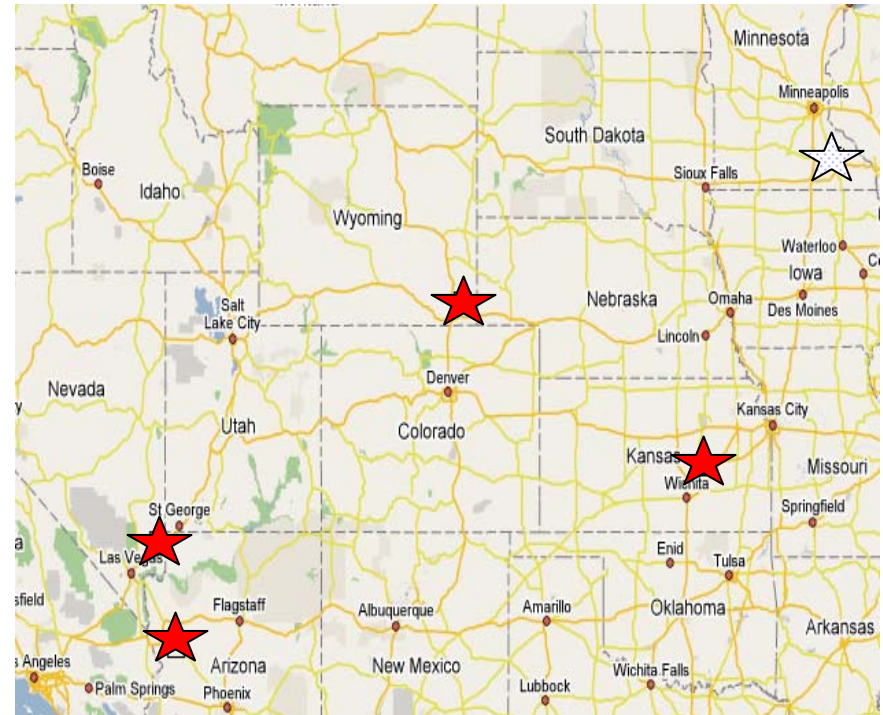
■ PAV Model

- NCHRP 9-23
- Suggested as an addendum to AASHTO R-28

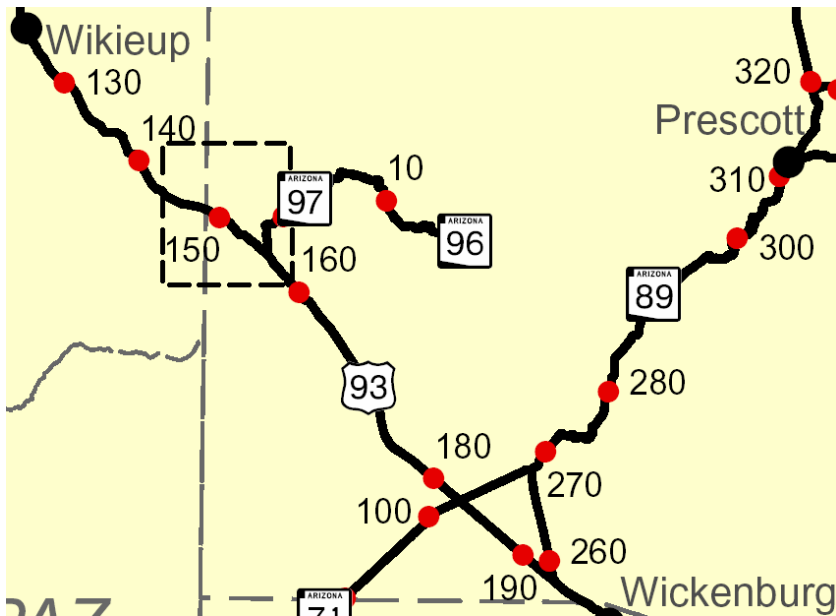
“Accelerated Aging of Asphalt Binder Using a Pressurized Aging Vessel (PAV)”

WRI Field Validation Sites

- Crude oil source the only variable
- State DOT projects
- Mix design approved by state DOT
- Mix design checked using alternate asphalt sources



Arizona Site



- New construction, Nov. 2001
- 2 - 2 ½" lifts HMA
- ¾" rubberized OGFC (travel lanes only)
- MAAT = 61°F
- 4 asphalt sources

Crude sources

- AZ1-1 West Texas intermediate sour blend
- AZ1-2 Venezuelan
- AZ1-3 Rocky Mountain blend
- AZ1-4 Canadian

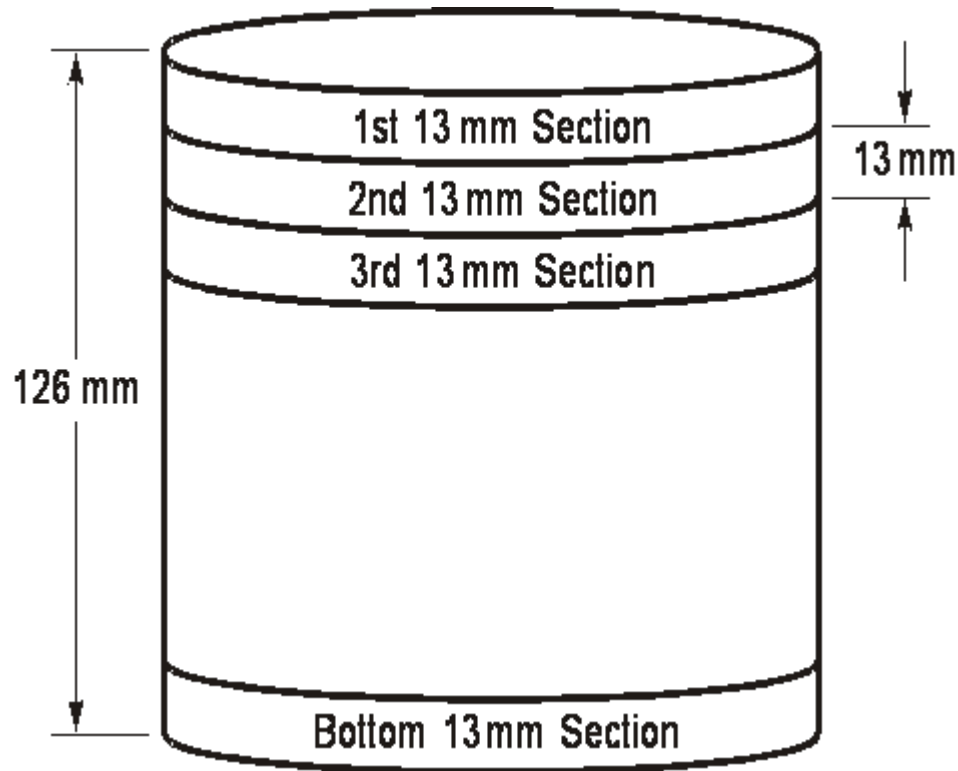
Arizona site – mix details

- ¾" nominal maximum size dense-graded aggregate
- Total asphalt content is 4.7%
- 1% hydrated lime
- PG 76-16 (AZ1-1, AZ1-3, & AZ1-4)
- PG 76 -22 (AZ1-2)

NMR Analysis

- Phosphorus NMR measurements
 - Polyphosphoric acid not detected (0.1 wt% detection limit)
- Proton NMR measurements
 - SBS type polymers not detected (0.5 wt% detection limit)

Shoulder coring (Nov. 2005)



Core extraction and rheology

■ Extraction

- Solvent - 85/15 (v/v) mixture toluene and 95% ethanol
- Centrifuged and filtered
- Rotovap with argon purge
- FTIR - confirmed removal of solvent

■ DSR

- Temperature range 0 to 80°C, 10°C increments
- Frequency sweep 0.1 to 100 radians/second

Global Aging System

■ Short-term aging model

- Predicts mix/laydown viscosity
 - $f(\text{original viscosity, hardening code})$

■ Long-term aging model

- Predicts aged viscosity at assumed depth of 0.25"
 - $f(\text{mix/laydown viscosity, time, MAAT, and temperature})$
 - Optional adjustments for air void effects and change in air voids with time

■ Depth model

- Predicts aged viscosity with depth
 - $f(\text{aged viscosity, MAAT, and depth})$

PAV Model

- Predicts field aging time
 - f(PAV temperature, original air voids, MAAT and RTFO viscosity @ 60°C)
 - **No adjustment for depth**

$$t_{aging} = \exp \left(\frac{\left(\frac{T_{PAV}}{0.445445 \times VA_{orig}^{0.378370}} \right) - 109.9632 + 78.2945 \times (\log \log \eta_{RTFO,60^\circ C})^2}{2.132432 + 0.193560 \times (\log \log \eta_{RTFO,60^\circ C})^2 \times MAAT} \right)$$

Houston, W. N., et al. NCHRP 9-23 Preliminary Draft
Final Report, Part 1, September 2005.

Conversion of DSR data (G^* and δ) to viscosity

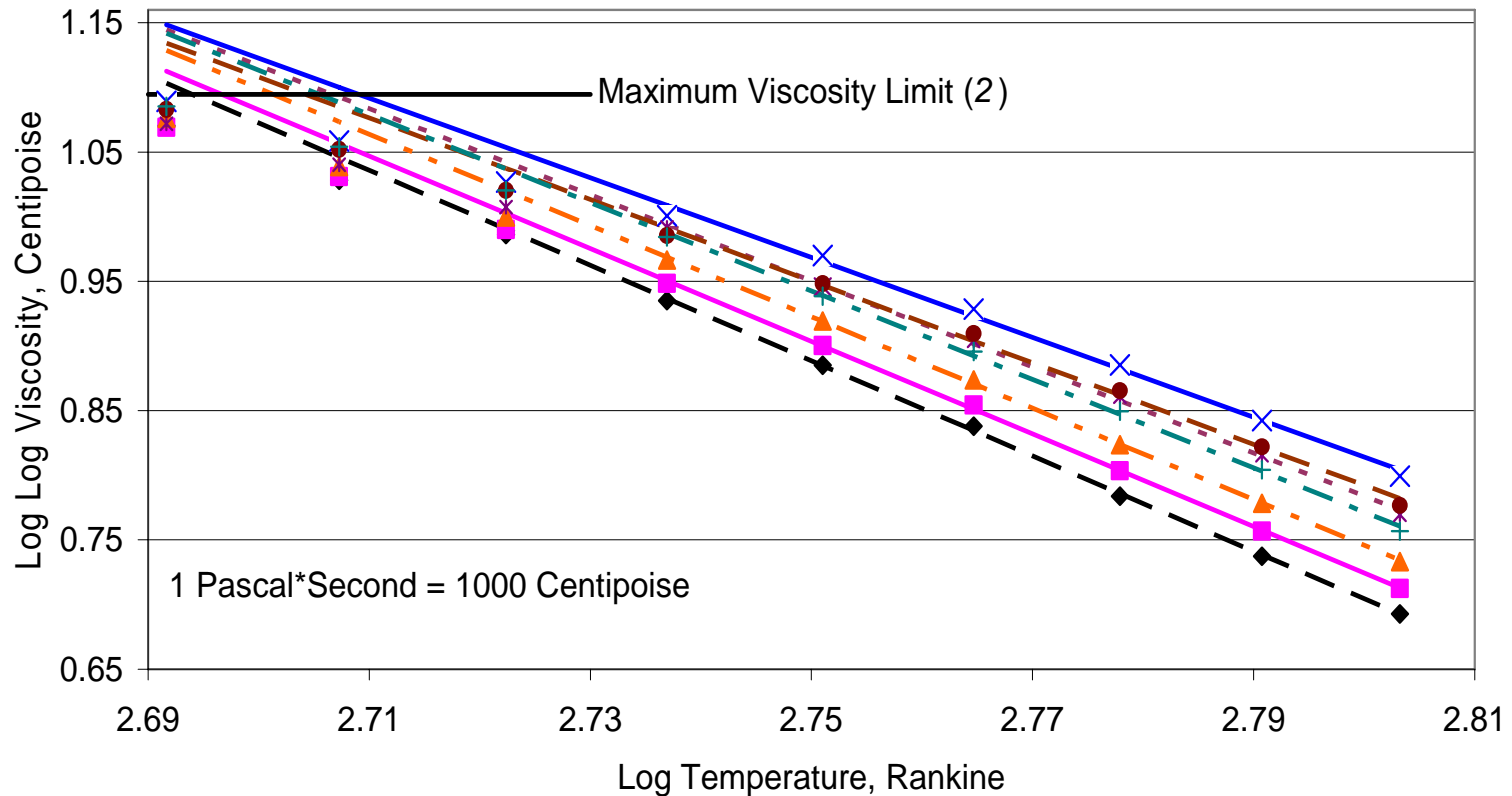
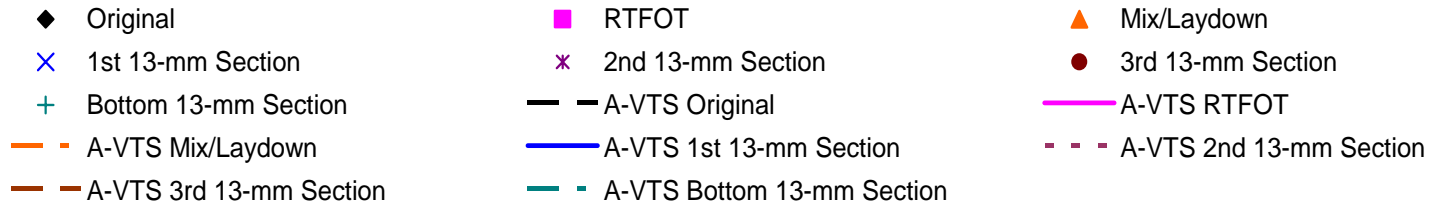
Newtonian behavior

Correction factor for Non-Newtonian behavior at low temperatures

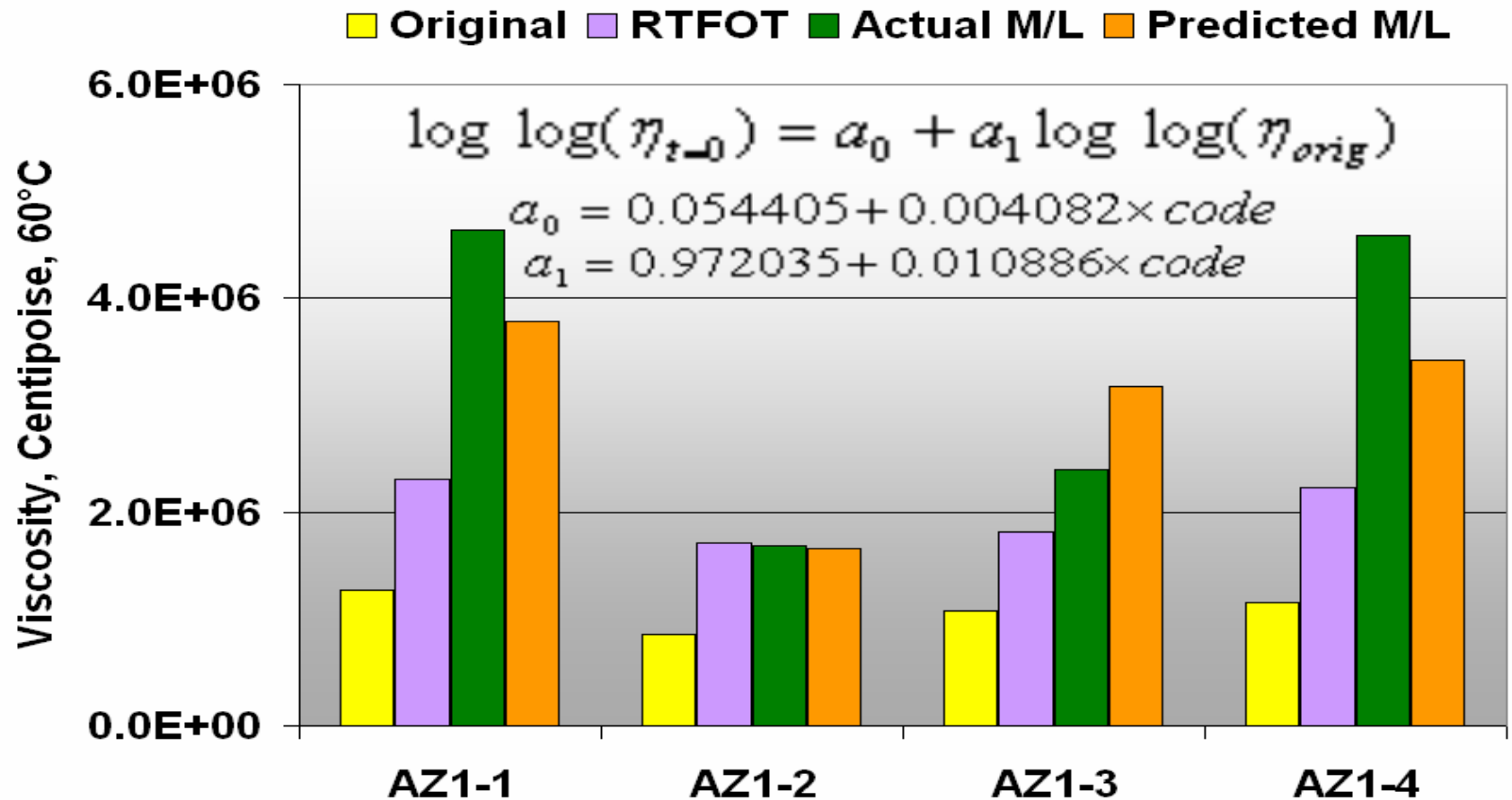
$$\eta = \frac{|G^*|}{10} \left(\frac{1}{\sin \delta} \right)^{4.8628}$$

Superpave Support and Performance Models Management, FHWA No. DTFH 61-94-R-00045,
Team Technical Report, Civil Engineering Department, University of Maryland, College Park, MD,
May 15, 1998.

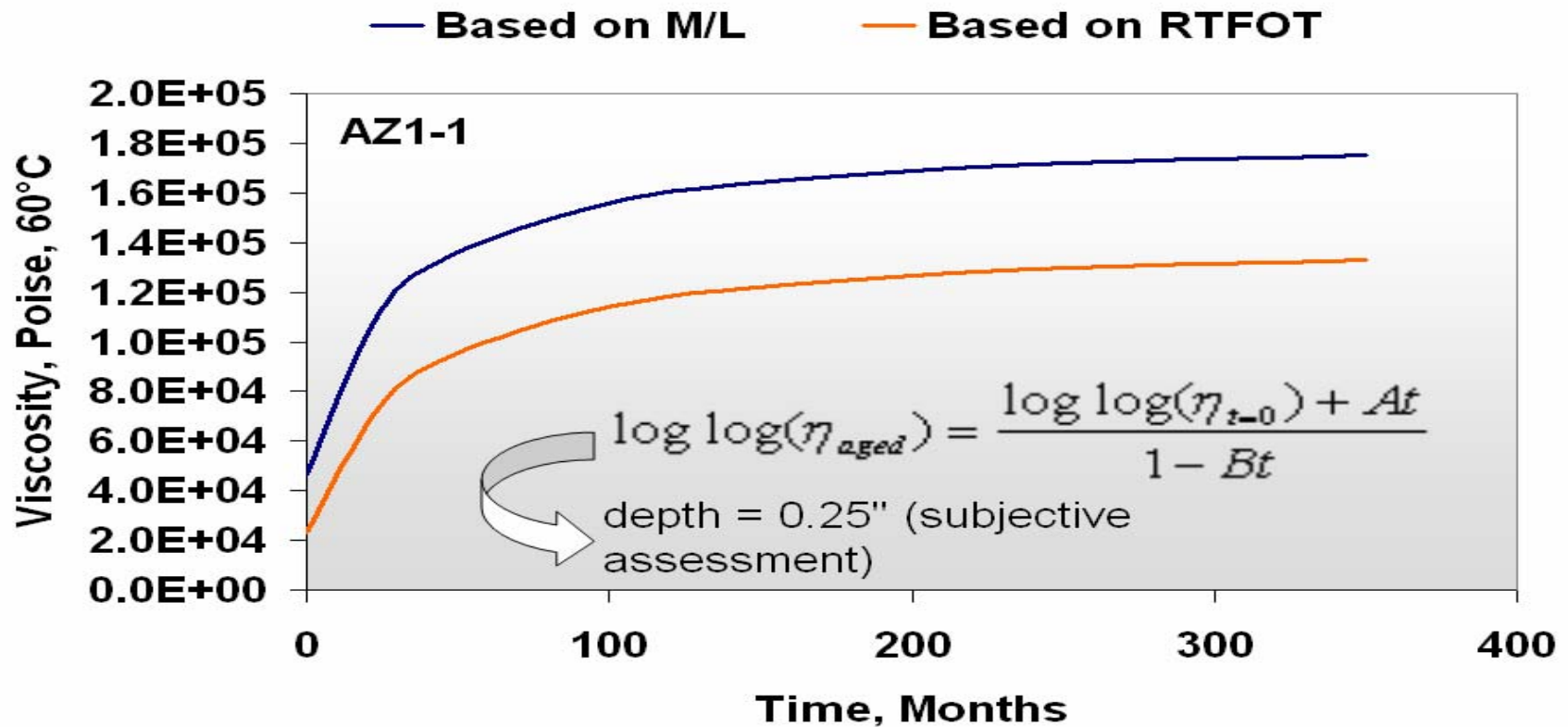
Viscosity temperature relationships AZ1-1



GAS Short-Term Aging Model

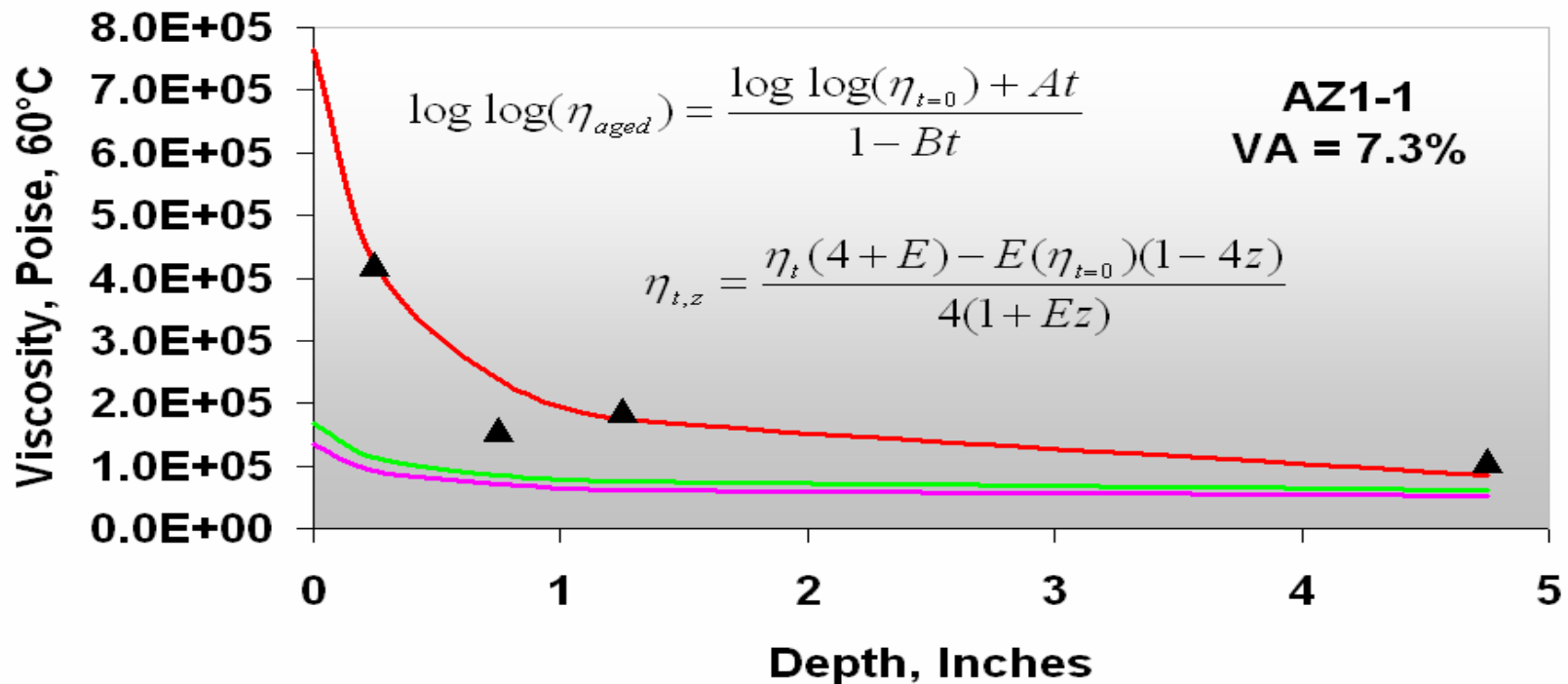


Differences between GAS predicted aged viscosity



Actual vs. GAS predicted viscosity as a function of depth

- 48 month w/o VA correction
- 48 month w VA correction
- ▲ 13-mm sections
- Fit to 13-mm sections

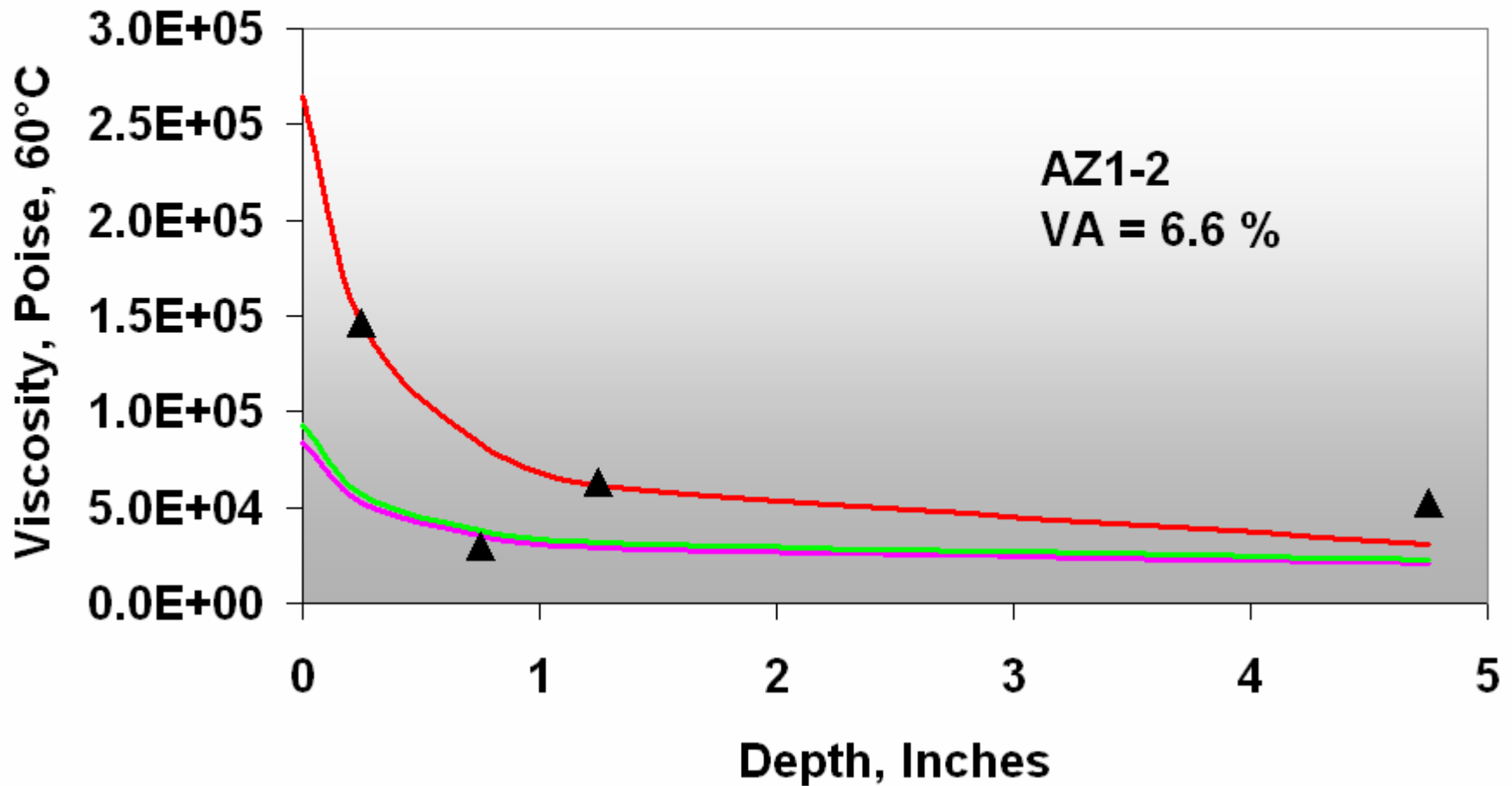


— 48 month w/o VA correction

— 48 month w VA correction

▲ 13-mm sections

— Fit to 13-mm sections

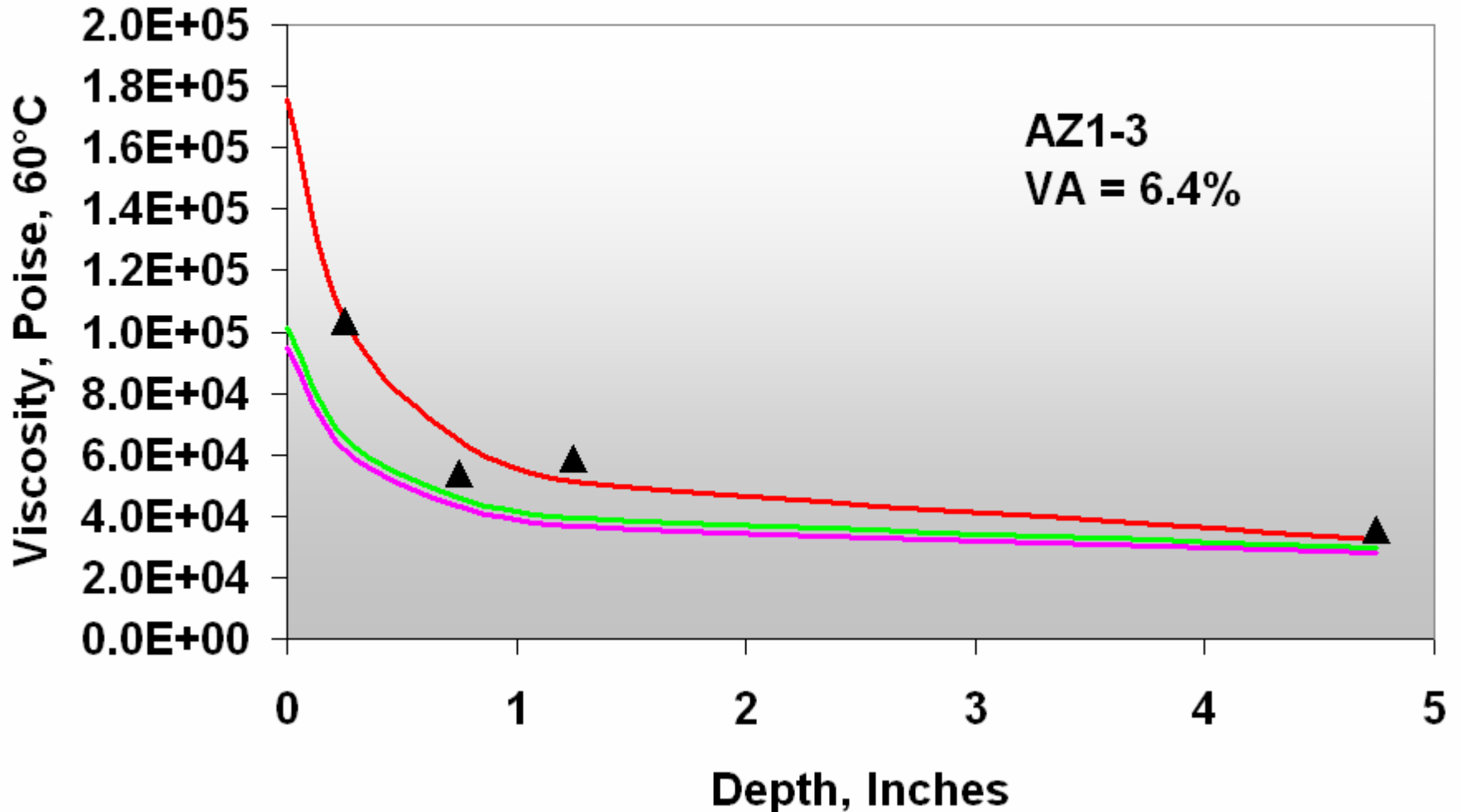


— 48 month w/o VA correction

— 48 month w VA correction

▲ 13-mm sections

— Fit to 13-mm sections

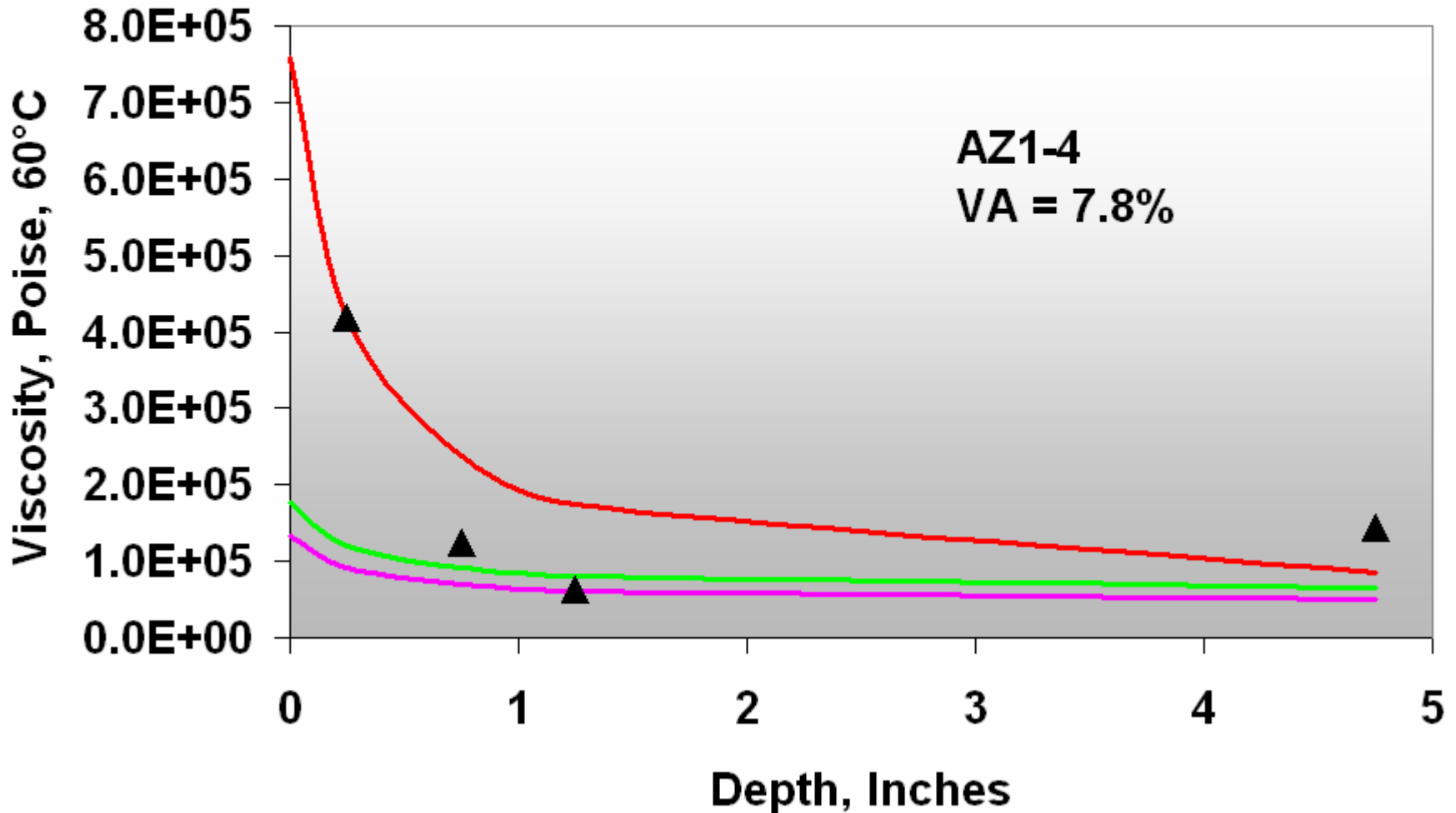


— 48 month w/o VA correction

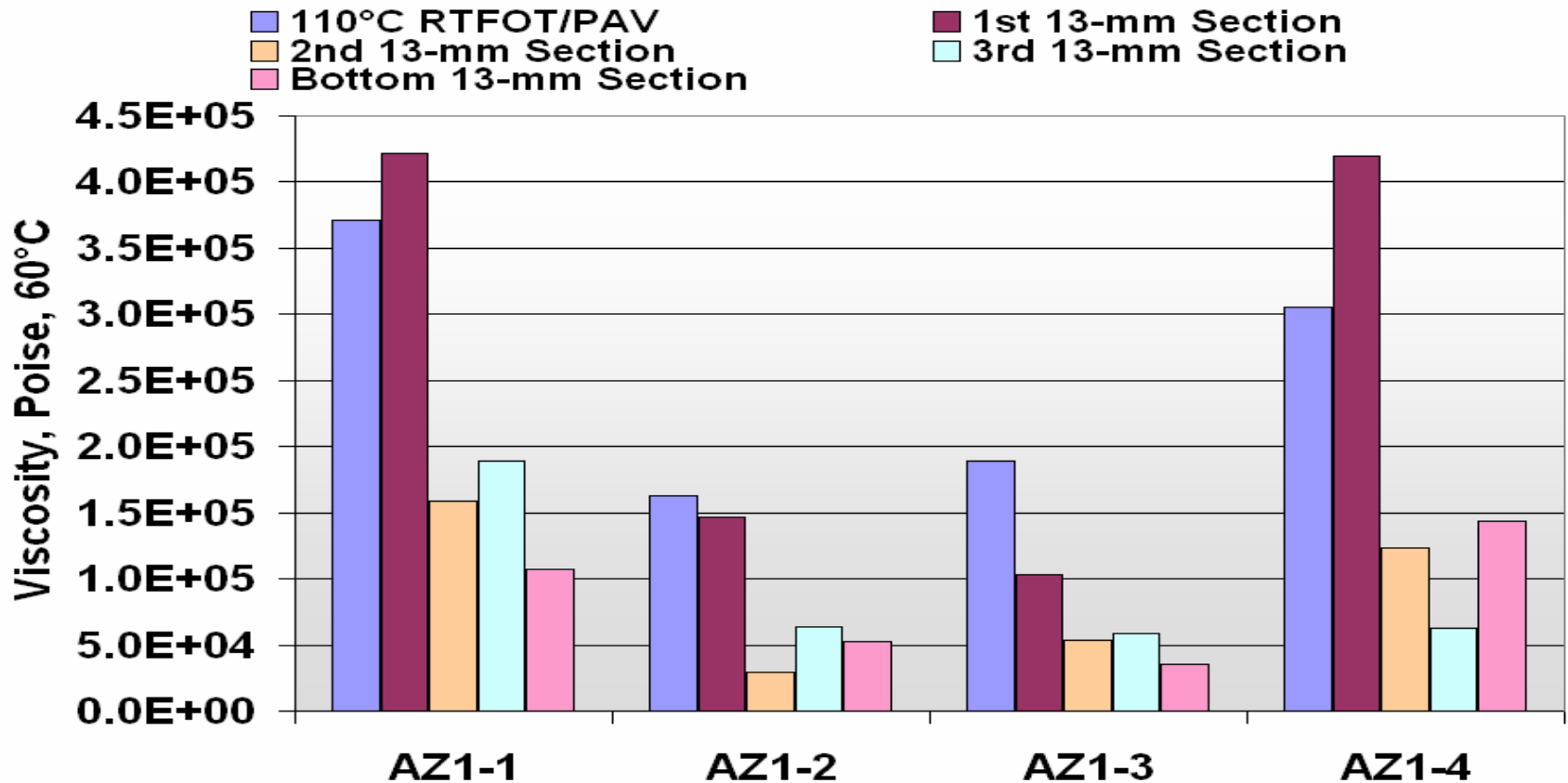
— 48 month w VA correction

▲ 13-mm sections

— Fit to 13-mm sections



RTFO/PAV vs. 13-mm section viscosities



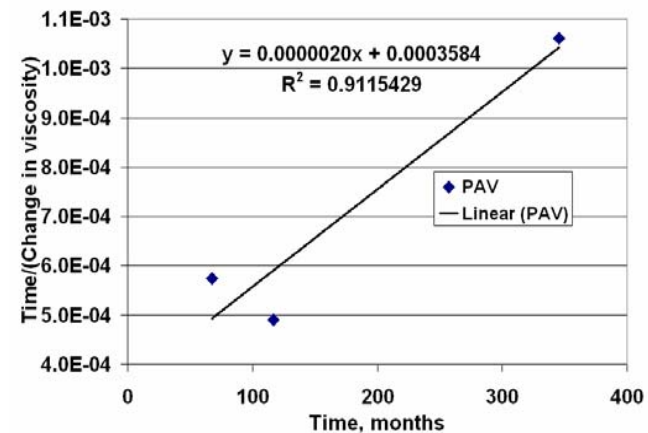
PAV Model

AZ1-1

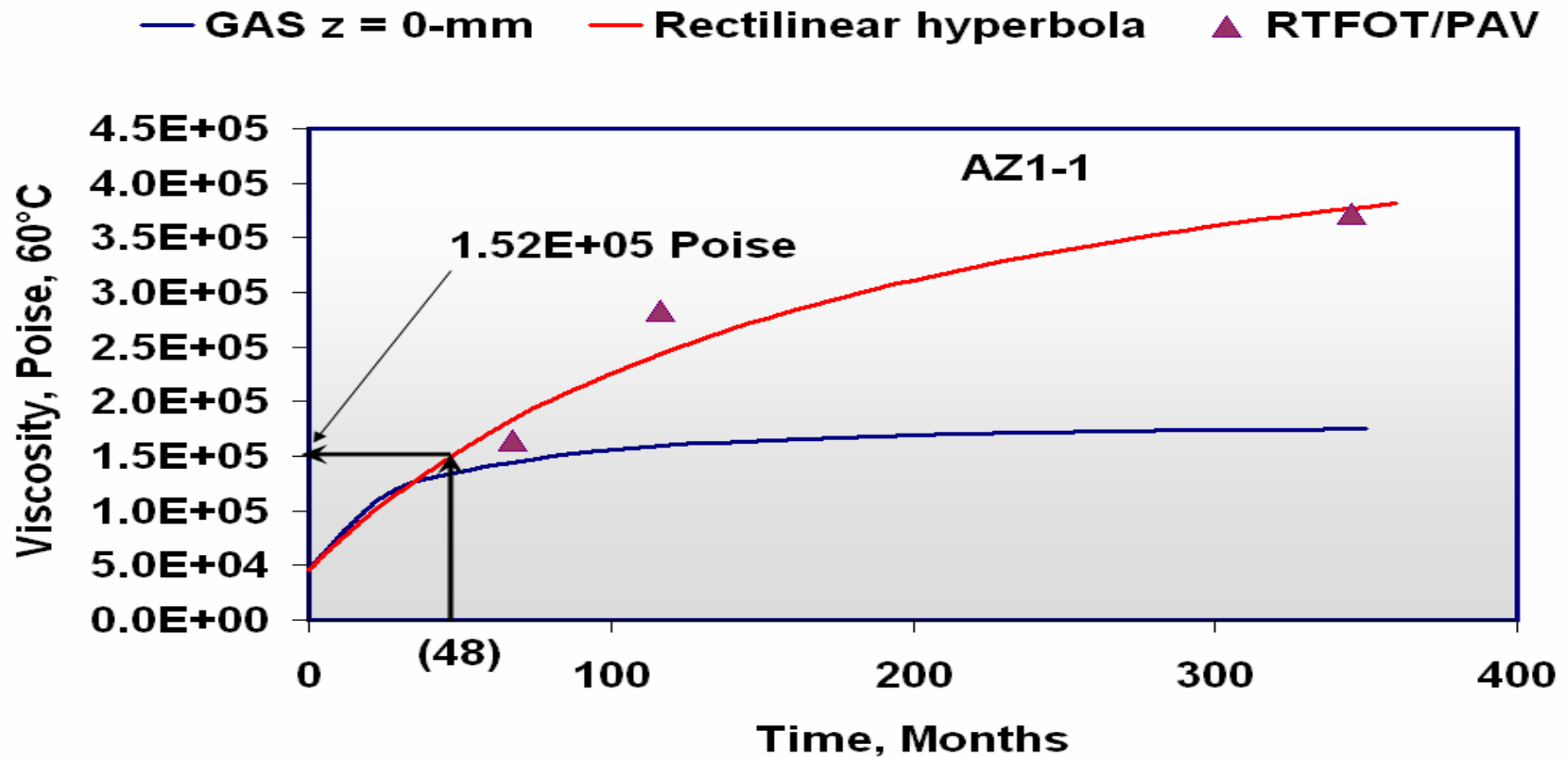
T_{PAV} °C	RTFOT/PAV Poise, 60°C	Predicted aging time, Months
95	1.64E+05	68
100	2.84E+05	117
110	3.72E+05	345

$$\frac{t}{\Delta y} = a + bt \longrightarrow$$

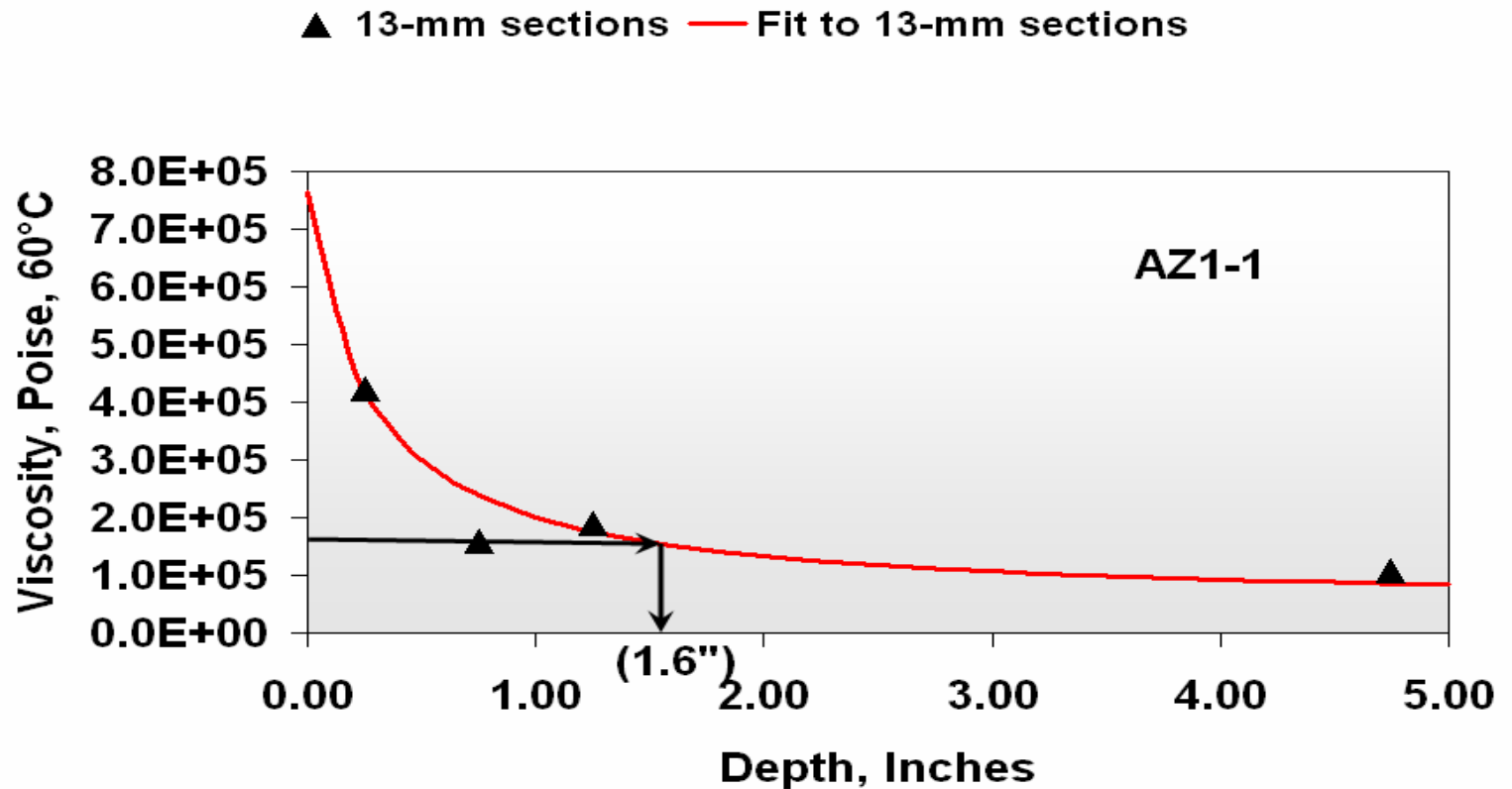
Brown, A. B., et al., AAPT, Vol. 26, 1957



GAS predicted aged and hyperbolic fit of RTFOT/PAV viscosity vs. time



PAV model estimated depth



Conclusions

- ❑ Reduction of extracted viscosity from the top 13-mm to the next 13-mm ranged from 48% to 70% (average 65%)
- ❑ Minor differences between the 13-mm sections below the top 13-mm section
- ❑ Extracted four-year viscosity is substantially greater than the GAS predicted viscosity, particularly in the top 13-mm of pavement
- ❑ In this limited analysis of the PAV aging model confined to just AZ1-1, the depth of the RTFO/PAV viscosity corresponding to 48 months was estimated at 40 mm

Thank You!



North Platte is just over the ridge