XIII Congreso Mexicano del Asfalto. 20, 21y 22 de agosto de 2025, Cancún, Quintana ROO, México

Restoring Aged Asphalt in RAP
Is it Softer, Younger, or Just a Little Better?

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Outline

- Background
- RAP, what is it and what is it good for?
- Restore the properties in RAP: can it be done?
- Softening vs. rejuvenating: the fountain of youth & eternal life?
- Did we make it better?
- Summary & Conclusions

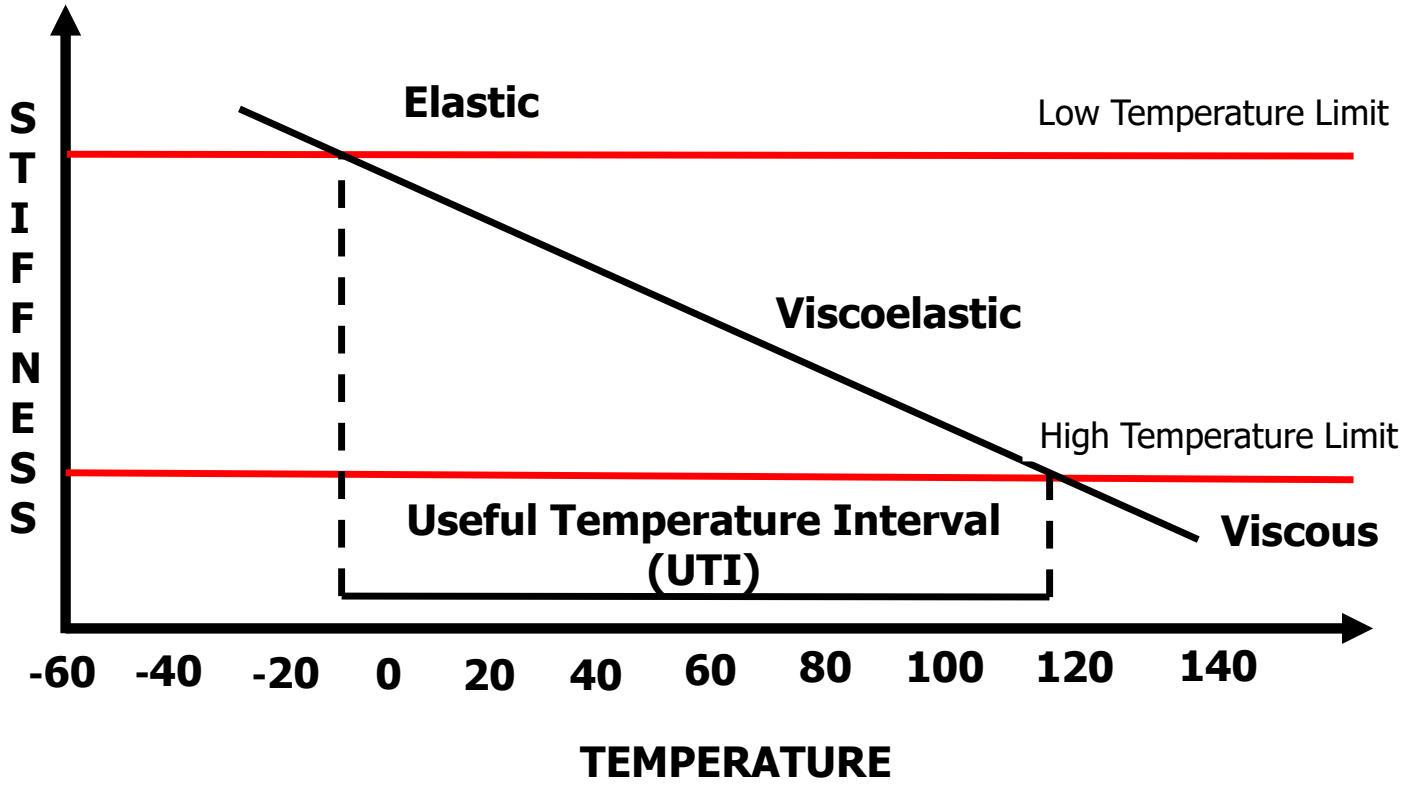
Background

Useful Temperature Interval (UTI)
“Asphalt Made Simple”

It’s Real Logical

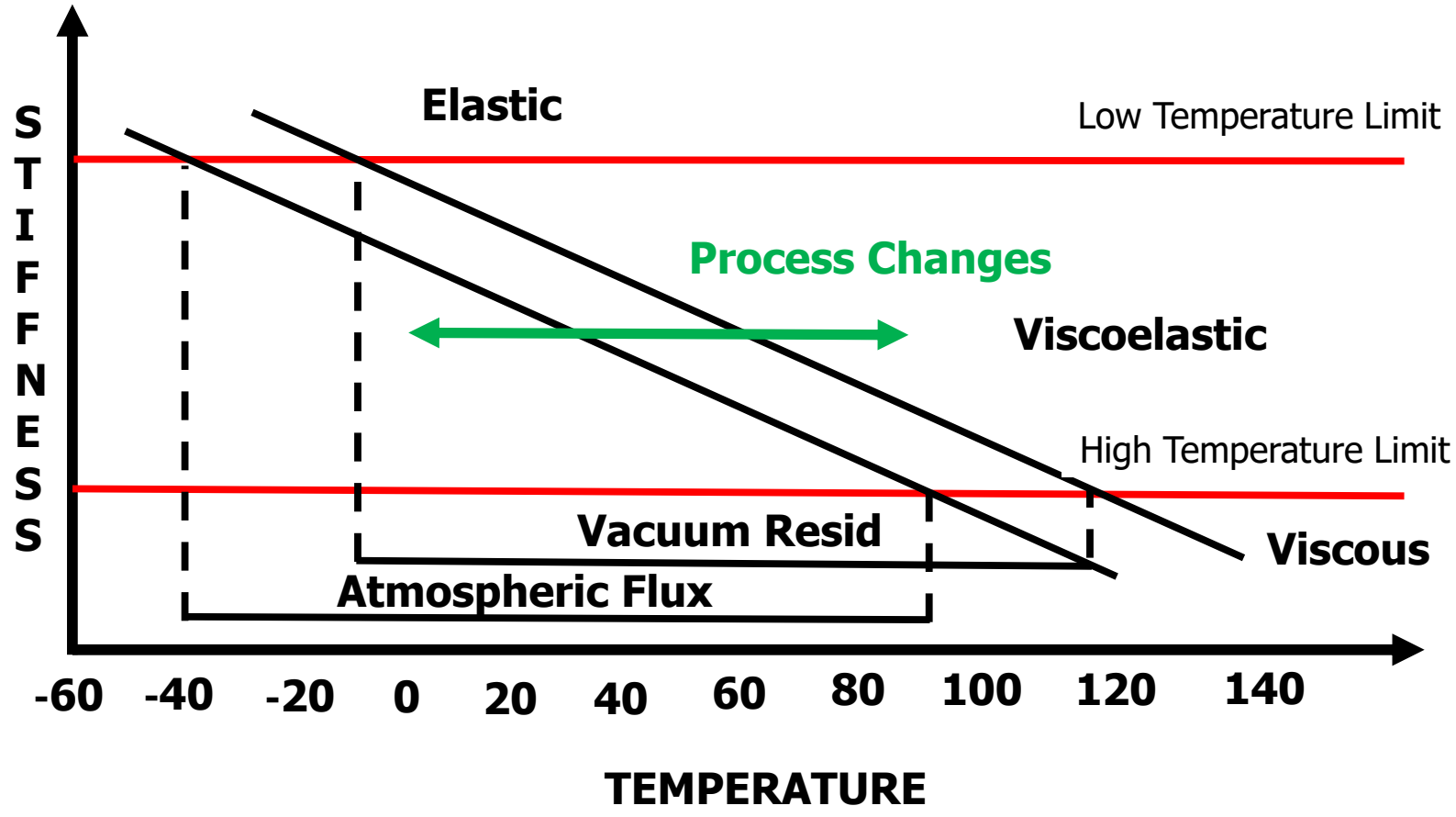
Useful Temperature Interval (UTI)

Source: Meynard, Jean-Yves and Nicolas, Yves (1981) "Les Melanges Elastomere Bitume et Leur Emploi dans L'etancheite des Overages de Genie Civil," *Revue General des Routes et des Aerodromes,* No. 574.



Useful Temperature Interval (UTI)

(Crude Signature)



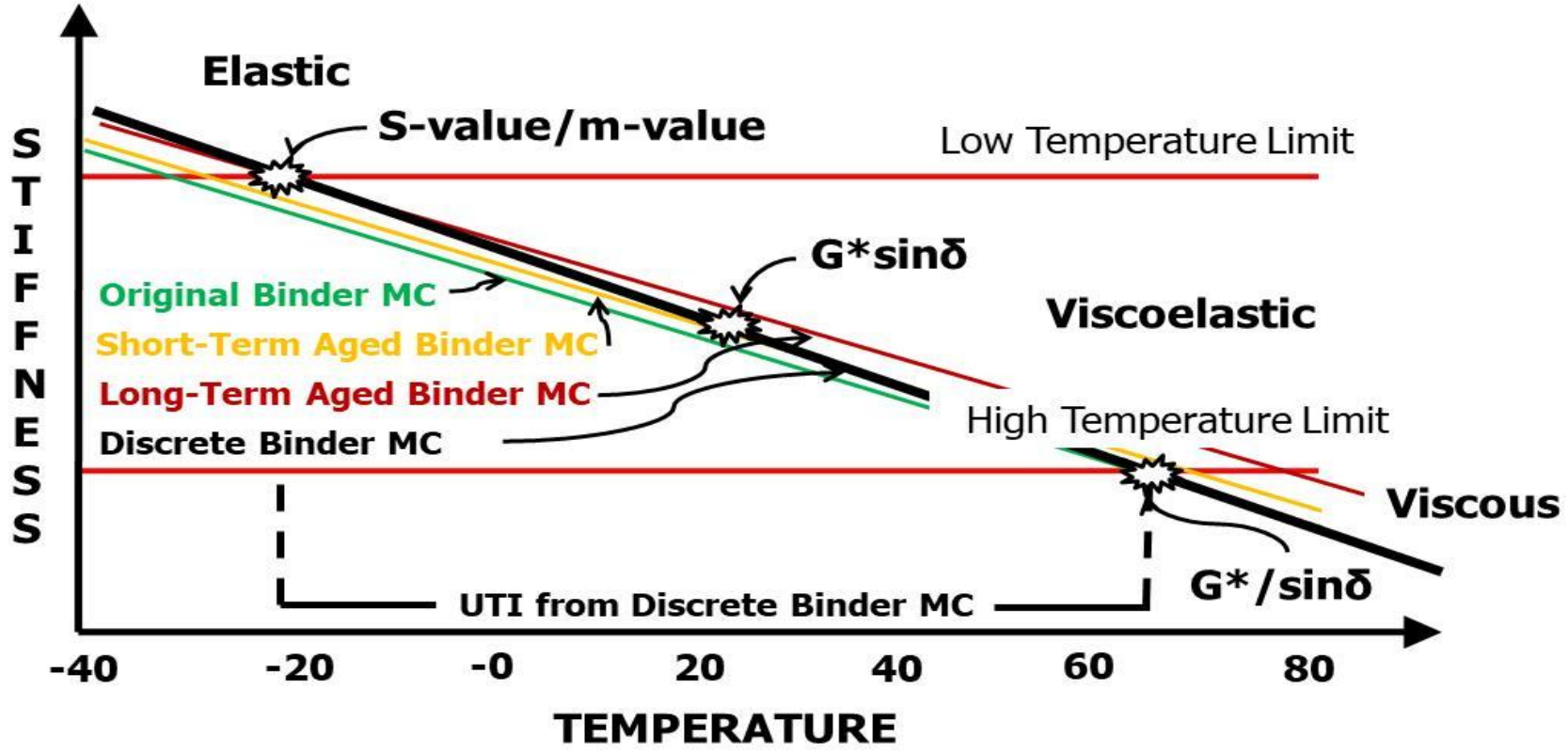
Asphalt Binder Aging

- Aging is mainly attributed to asphalt binder in the asphalt mixture.
- For asphalt binder aging simulation, rolling thin film oven (RTFO) according to AASHTO T 240 is used to simulate short term aging (STA),
- Pressure aging vessel (PAV) according to AASHTO R 28 is used to simulate long term aging (LTA), providing insights into aging resistance.
- The main reason behind aging considerations is its direct influence on asphalt brittleness, which severely impacts long-term performance.

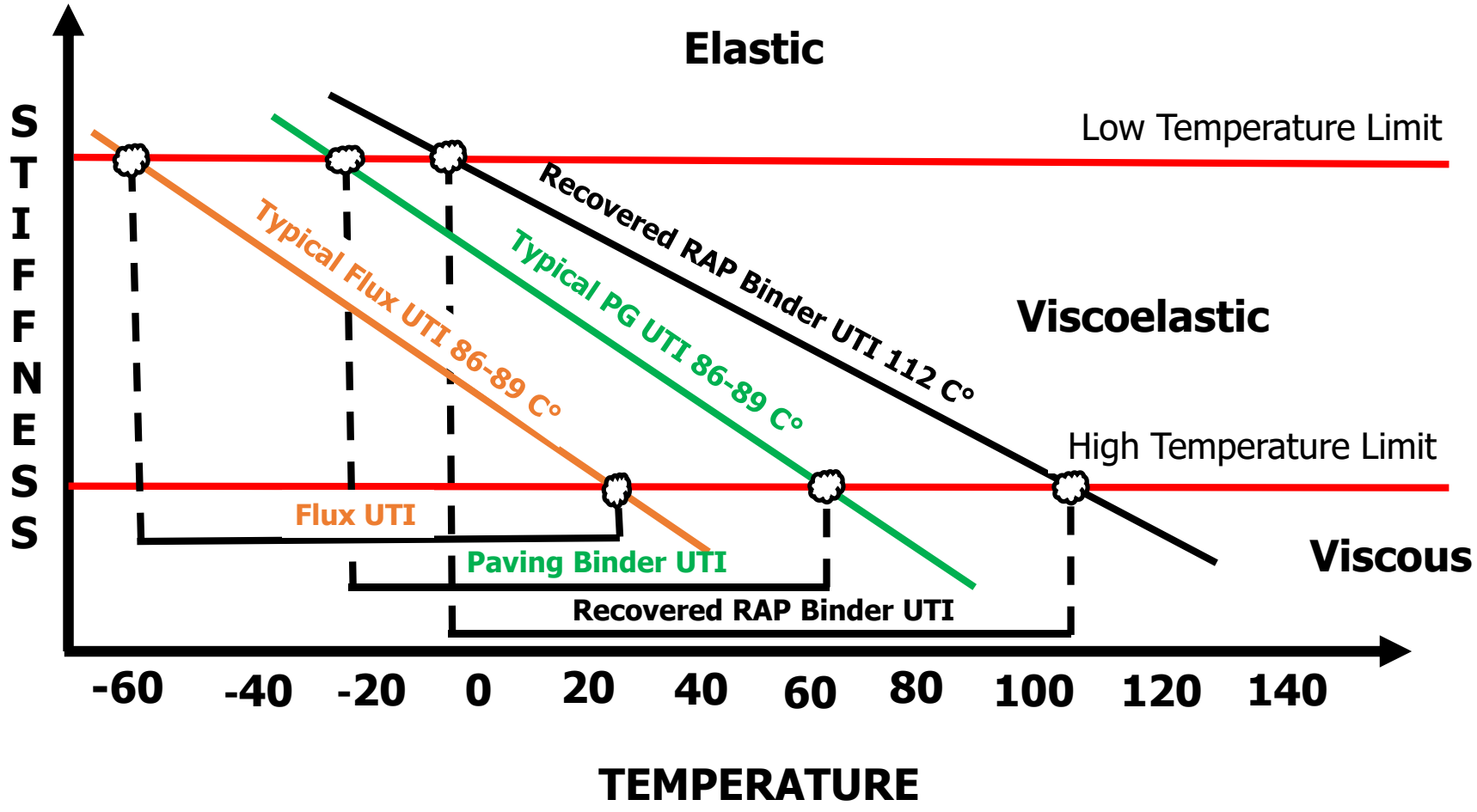
SuperPave PG Grade Specification

Testing Parameter	Criteria (Specifcation)
DSR - Original Binder	G*/sinδ, Min 1.0 kPa
DSR - RTFO Binder	G*/sinδ, Min 2.2 kPa
MSCR - RTFO Binder	J_{nr}, (S< 4.5, H<2.0, V<1.0, E<0.5)
DSR - PAV Binder	G*(sinδ), Max 6000 kPa, δ > 42°
BBR - PAV Binder	S < 300 Mpa (G* = 111MPa)
	m > 0.300 (δ = 26.8°)

Useful Temperature Interval (UTI)



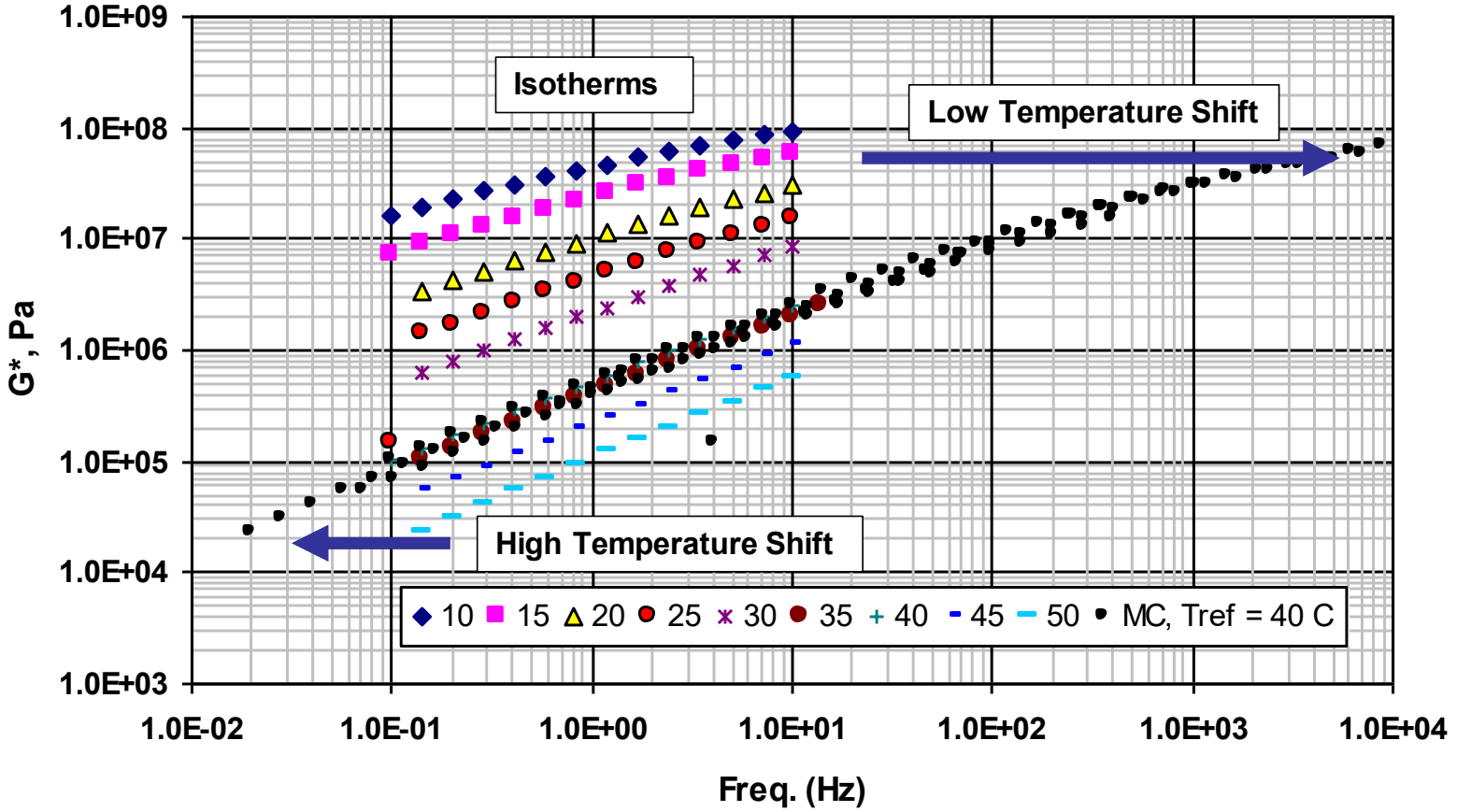
Useful Temperature Interval (UTI)



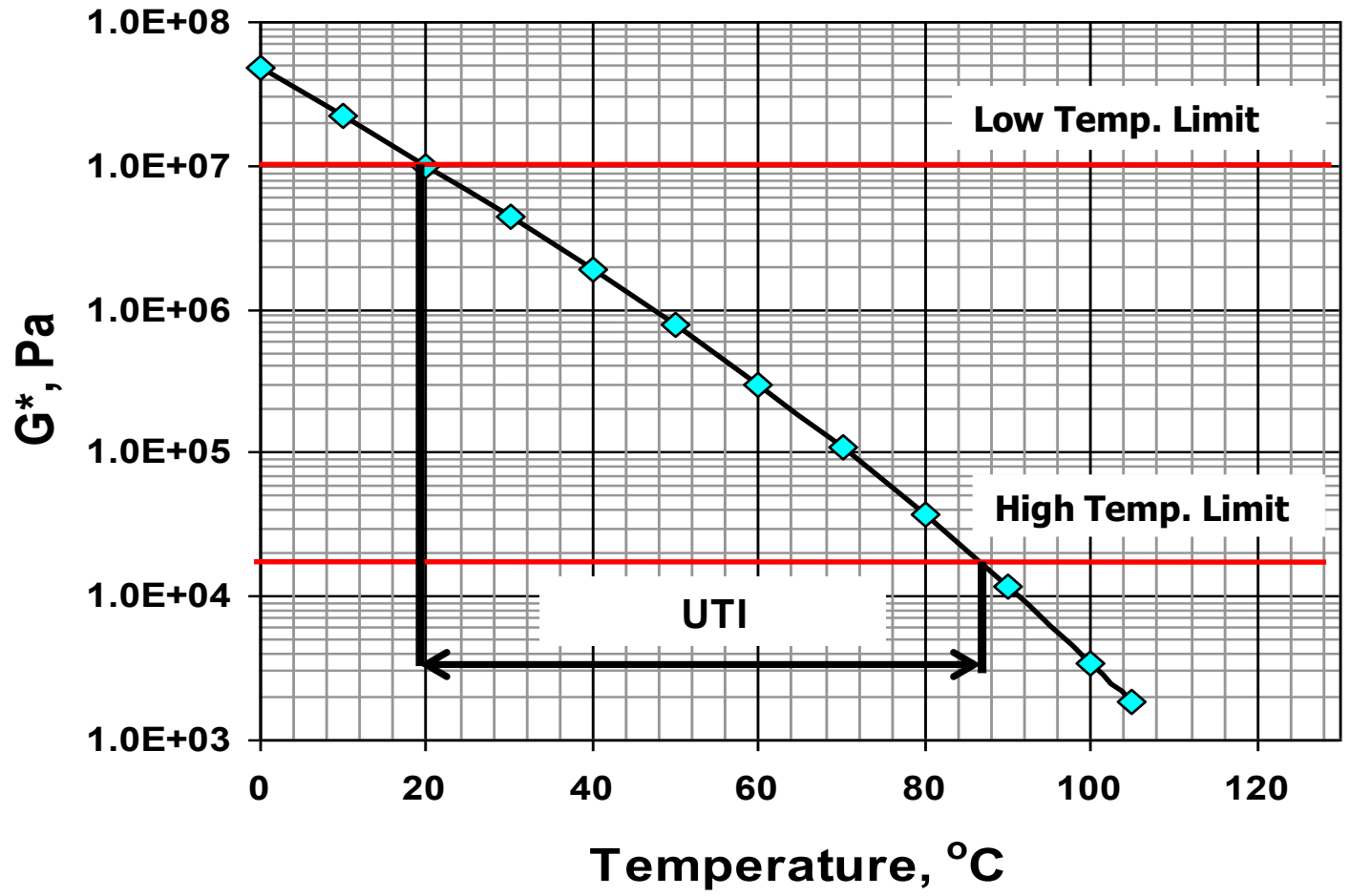
Chemical and Rheological Characteristics, Protocols

Asphalt Binder Test	Test protocol	Test parameter (response)
GPC	ASTM D6579	Molecular Weight
FTIR	--	CL, SI
SARA	ASTM D3279	Binder Fractions
DSR	AASHTO M320	HTG, G-R, Aging index, R-Value
BBR	AASHTO T 313	Delta Tc
LAS	AASHTO TP 101	
ABCD	AASHTO T 387	

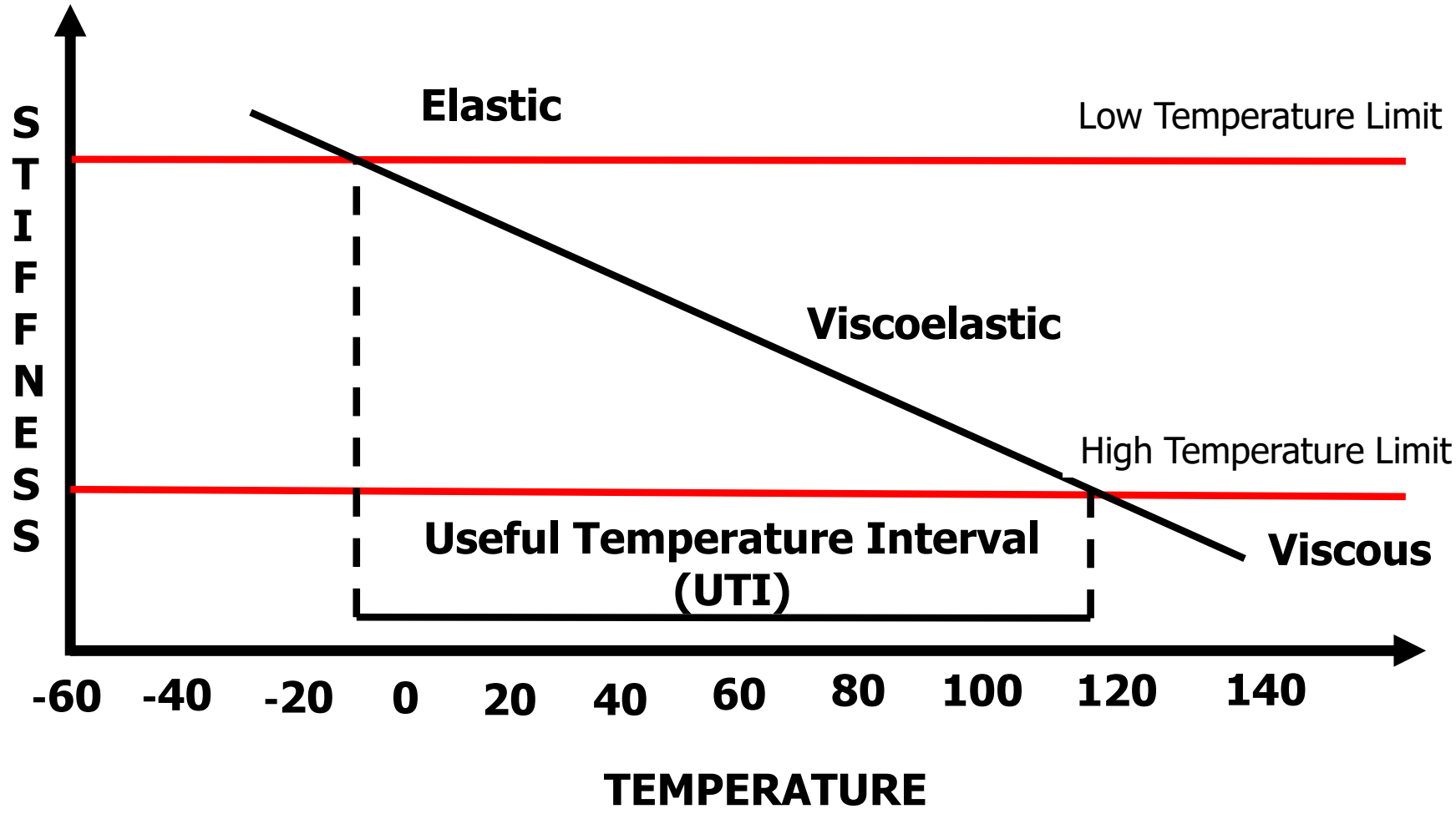
Dynamic Modulus Master Curve



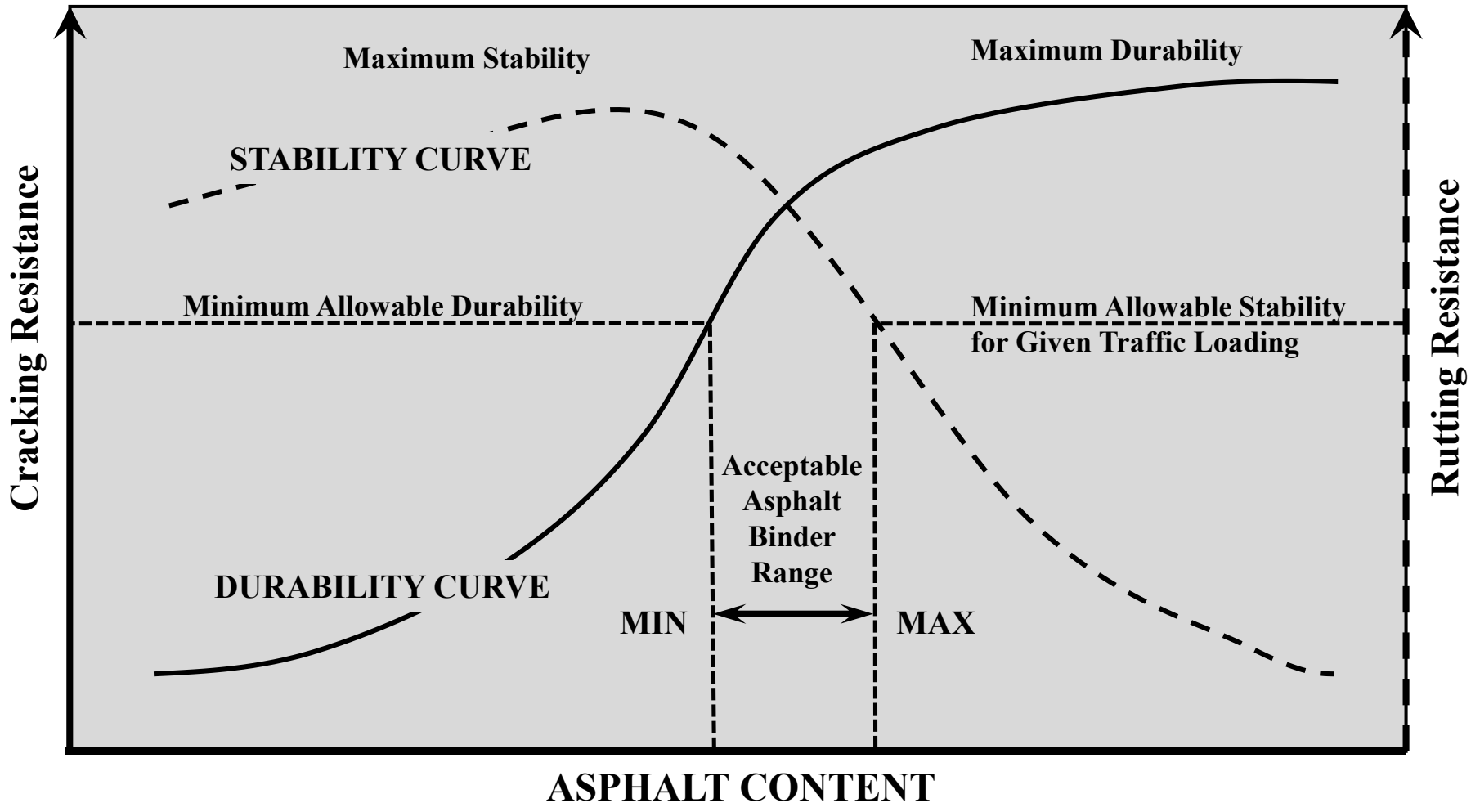
G* Master Curve Defining UTI



Useful Temperature Interval Applies



Balanced Mixture Design



RAP: what is it and what is it good for?

RAP, what is it?

- Definition*
- Reclaimed Asphalt Pavement (RAP) is the term used for materials generated when asphalt pavements are removed for reconstruction, resurfacing, or other construction activities. RAP consists of high-quality, graded aggregates that are coated with a durable asphalt binder. It is widely used in new asphalt mixtures to reduce the consumption of virgin materials, improve sustainability, and lower construction costs.

*According to Hey NAPA!

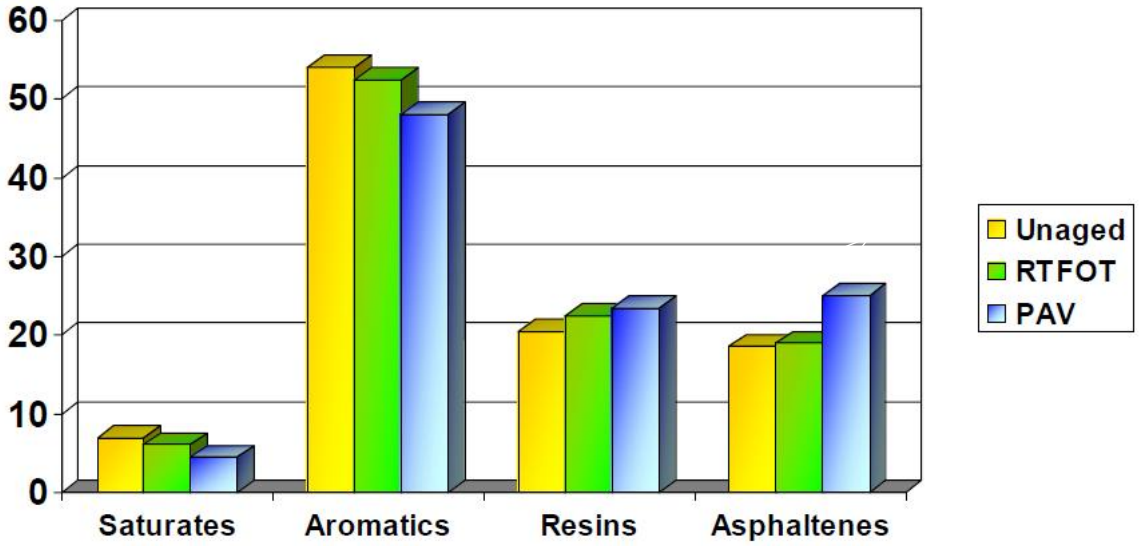
RAP, what is it?

Components:

- Aggregate
- Asphalt Binder; what grade is it?

Effects of Aging on Asphalt Composition

- Short- and long-term aging effects simulated using RTFO and PAV



What is RAP good for?

- Reduce cost of pavements
- Reduce climate impact of pavements and paving operations
- Reduce waste
- Reduce need for virgin aggregate and virgin binder (extend available sources of binders and aggregates)

Restore the properties in RAP; Can it be done?

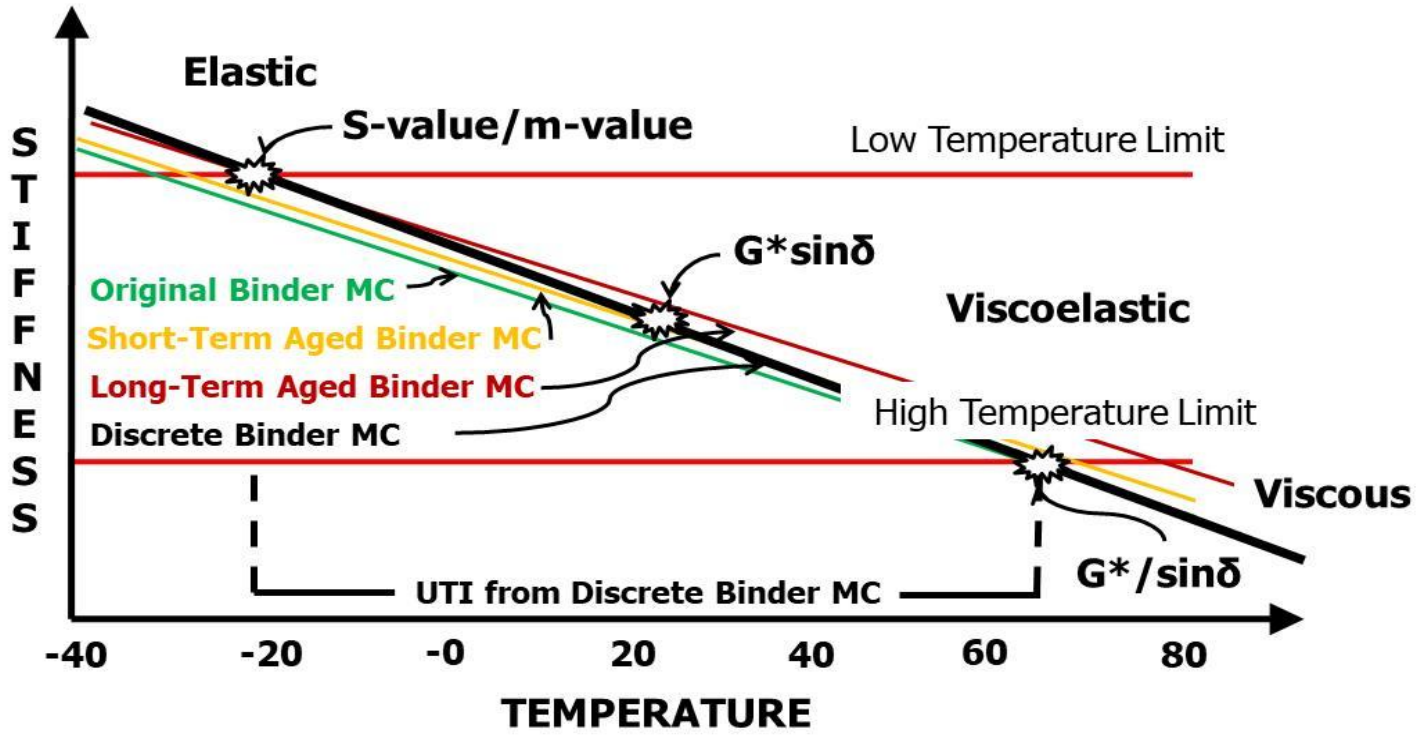
Reclaimed Asphalt Pavement (RAP) and Asphalt Rejuvenators

A. The need for effective rejuvenating additives for asphalt binder has become more important in the past 10 years
    a) Desire to use higher levels of RAP binder replacement, e.g., >30%
    b) Potential for effective use of RAS
B. Bio derived rejuvenators have proliferated
    a) Typically function well as softening additives for aged asphalt binder
    b) Some studies have shown asphalt binder blends with bio derived additives age poorly
        i. Ongel, et al, *Construction and Building Materials 94 (2015*); Reinke, et al, *Transportation Research Board, Vol 2633, Issue 1, Asphalts and Mixtures, Vol 3,* 2017, Cavalli, et al *Composites Part B, 2018*
C. Research conducted by MTE and PTSi has shown rejuvenating additives to be effective in mitigating the aging rate of asphalt binder compared to sonme bio-oils.

Functional Difference Between Sterol and Bio Oil

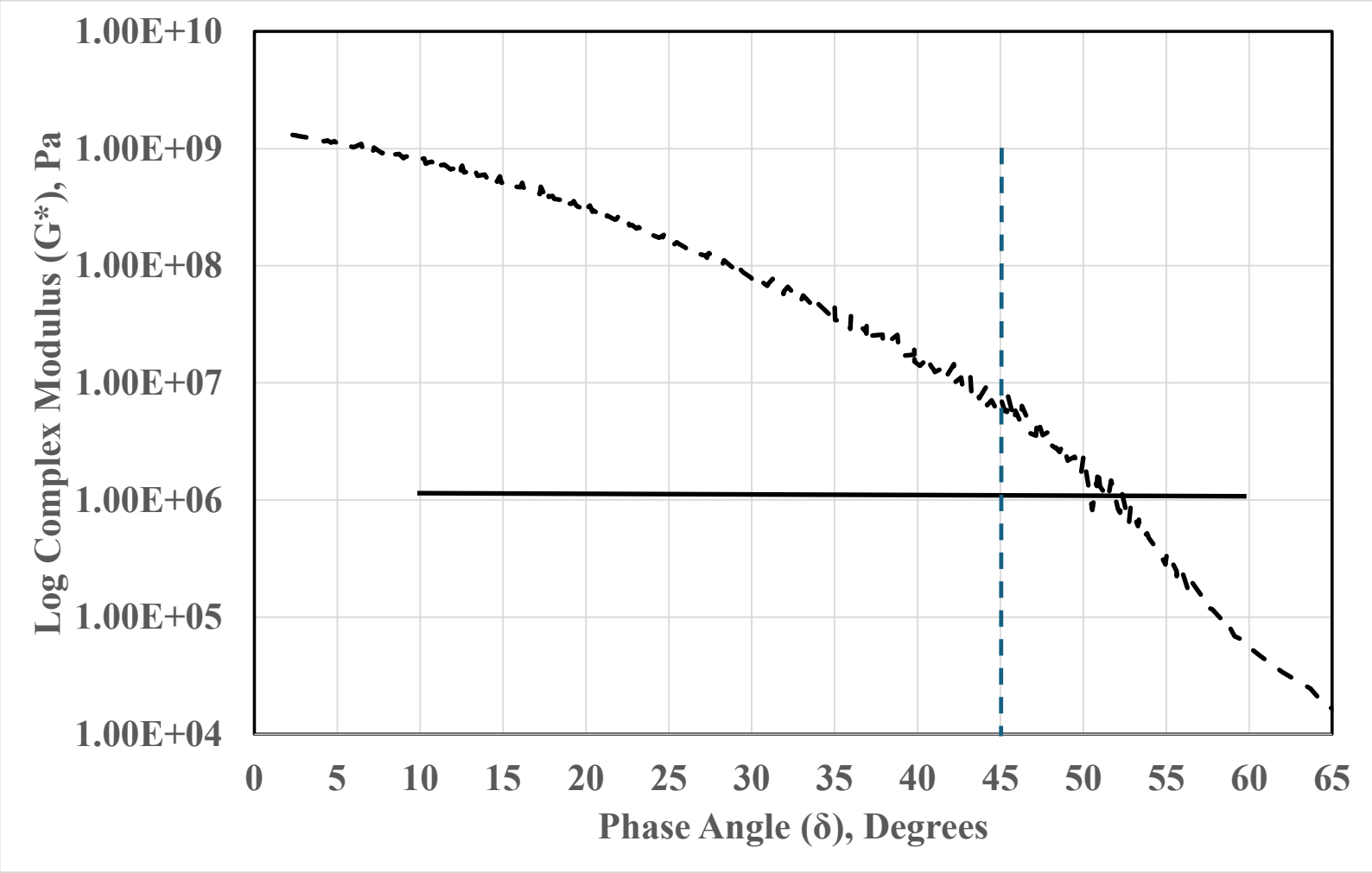
A. Bio oils we have so far evaluated are *translational* in function
   a. Bio oils soften the aged asphalt binder into which they are added,
   b. When viewed on a Black Space plot bio-oils extend the complex shear modulus (G*) to lower values and higher phase angles but along the same path as the original asphalt binder,
   c. As with the translation of a sentence from one language to another, the words are different, but the message is the same. Softening does not change the asphalt binder it is a dilution procedure; R-Values increase compared to control during aging, a negative outcome.
B. Rejuvenating additives we have evaluated are *transformative* in function
   a. Rejuvenators alter the internal asphalt binder structure; asphaltenes & carbonyls decreased; R-Values reduced,
   b. When rejuvenator treated asphalt binder is aged, asphaltenes and carbonyls increase at reduced rate compared to the original binder; R-Values increase-remain lower than control at same aging time,
   c. Black Space plots are altered such that for a given value of G* the phase angle will be higher than for the original binder at the same G* value; higher phase angles imply better binder relaxation.

UTI, Black Space and Cracking

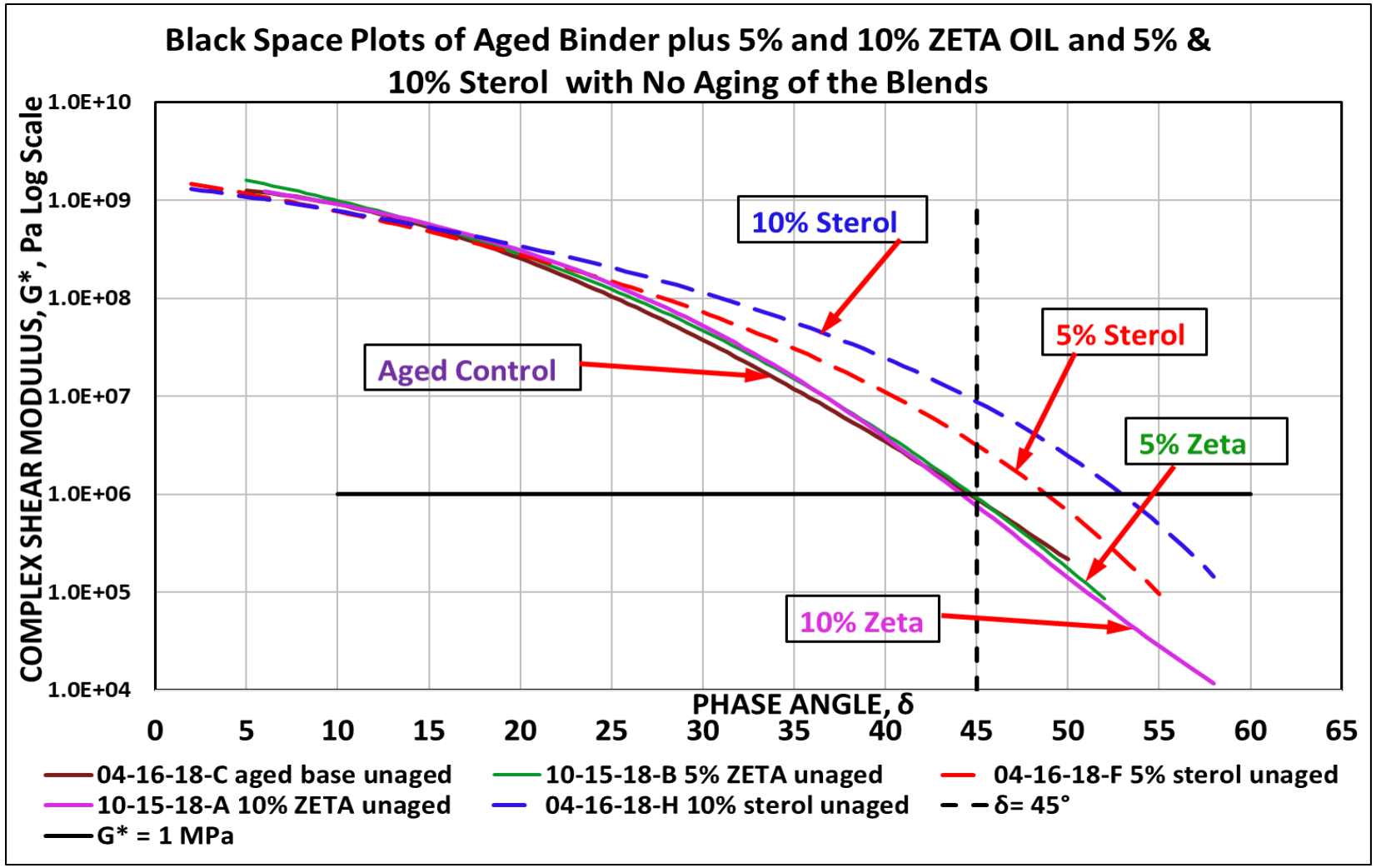


Asphalt Mixture Test	Test protocol	Test parameter (response)
SCB-Jc	ASTM D8044	Jc
I-FIT	AASHTO T 393	FI
IDEAL-CT	ASTM D8225	CT Index
OT	TEX-248-F	Fracture Energy index
DCT	ASTM D7313-13	Fracture Energy

What is Black Space



Black Space – Unaged

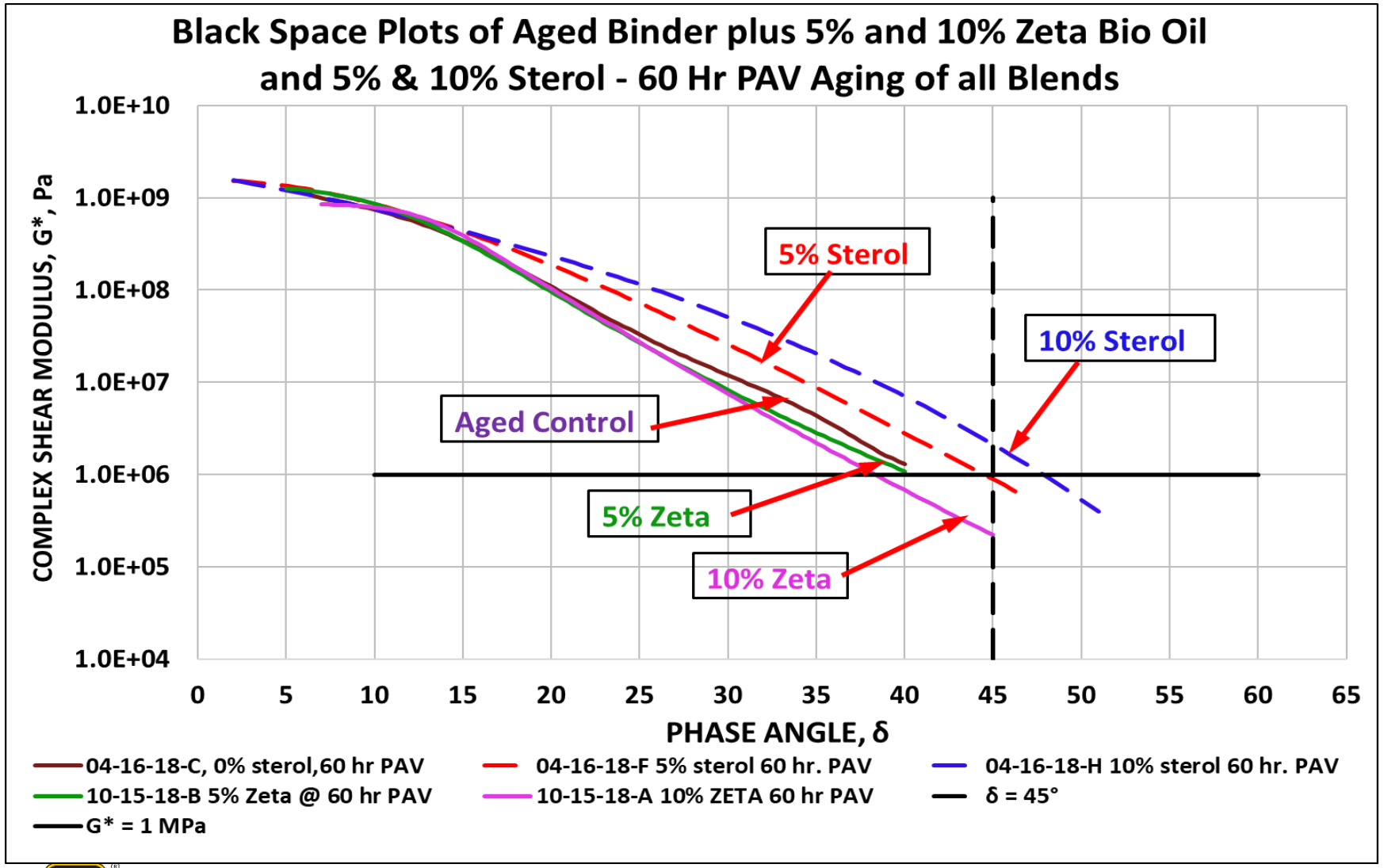


PG 58-28 binder was lab aged to serve as a surrogate RAP used for blends. Result--
High PG Grade =117°C, low PG Grade = -18°C, R-Value =2.683

Bio oil (Zeta) blends soften as shown but don't alter the relationship between modulus and phase angle as established by the base binder.

Sterol alters the relationship between modulus and phase angle; for any given modulus, phase angle increases meaning better relaxation properties of the blend.

Black Space - Aged

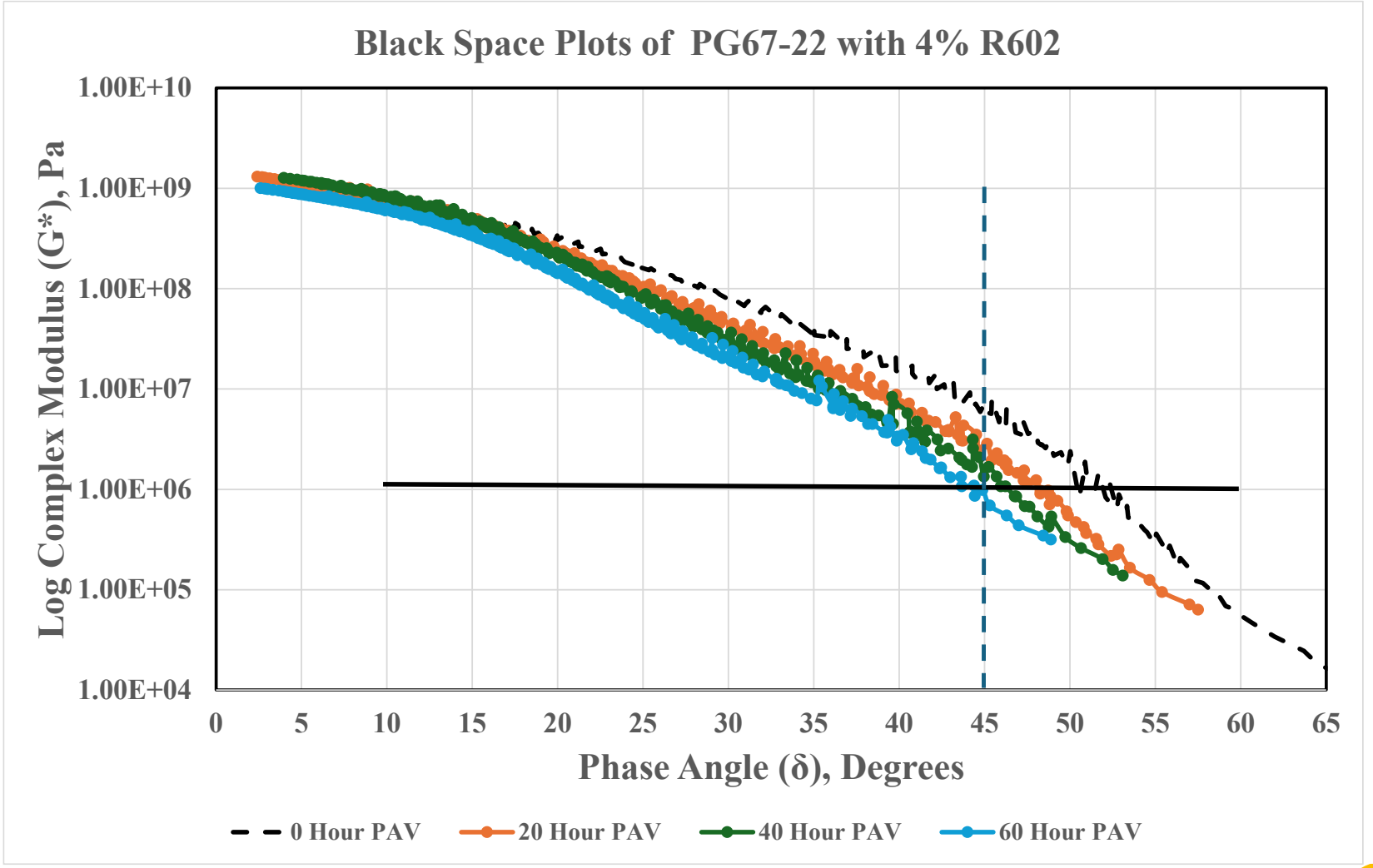


After 60 hours PAV aging all plots have decreased to lower phase angles for a given modulus.

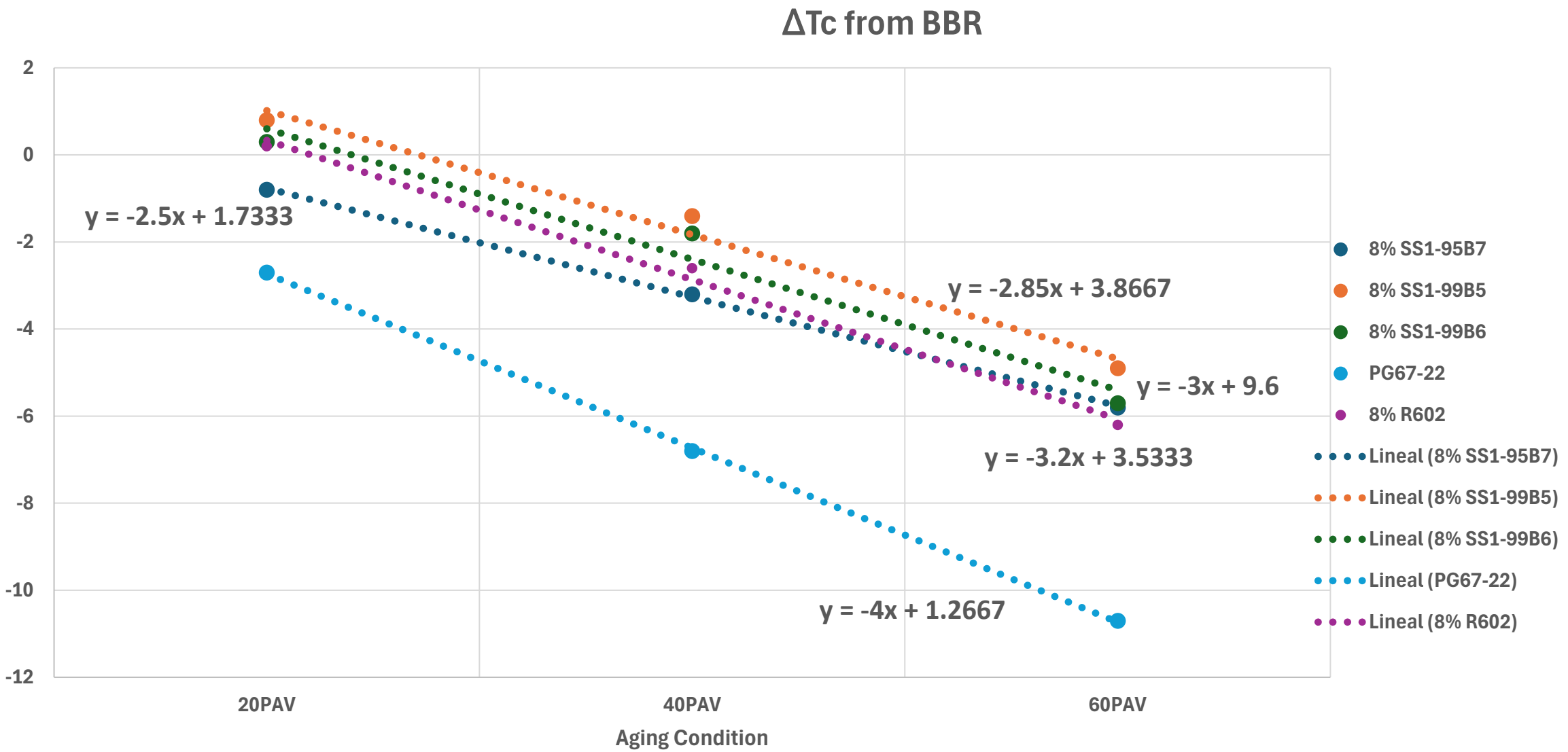
10% bio-oil has lowest plot because it has aged more substantially than 5% bio-oil or the control. 10% Zeta still has lower modulus than 5% Zeta or Control.

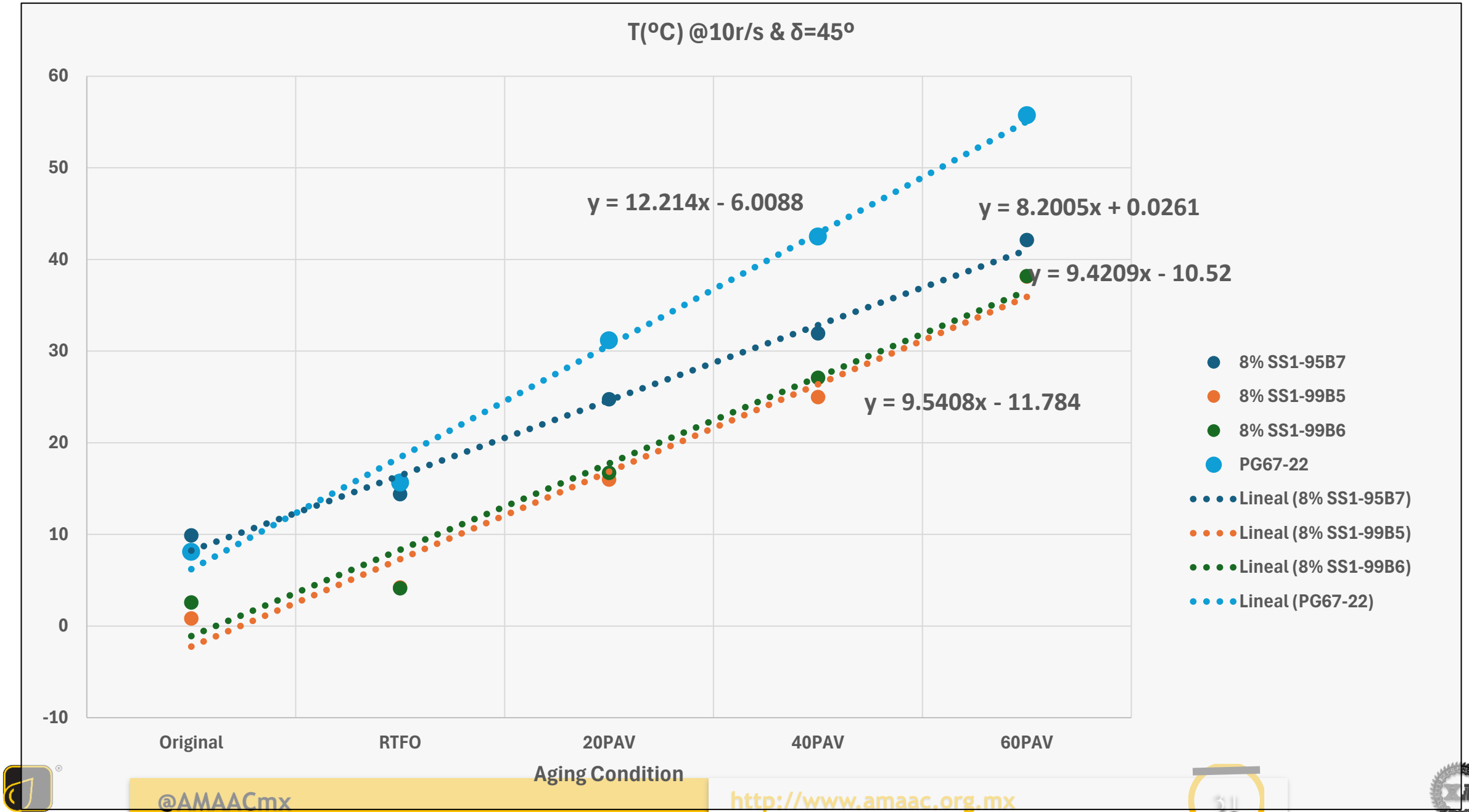
Sterol blends have aged-- 10% sterol maintains better properties than 5% sterol; sterol blends continue to exhibit beneficial transformed properties relative to bio-oil.

Black Space - Unaged and Aged

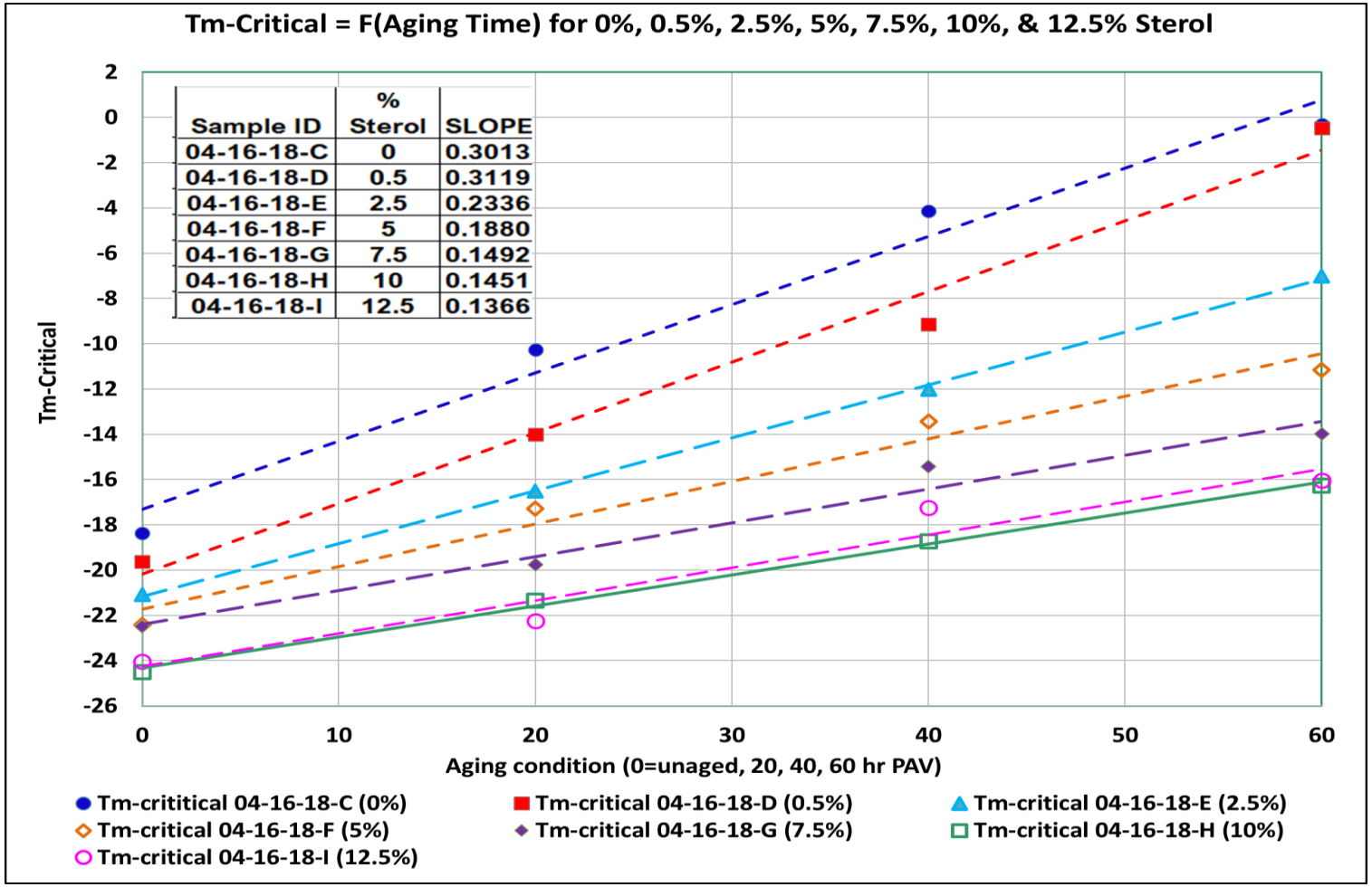


Did we make it better?


ΔTc from BBR
2
0
-2
-4
-6
-8
-10
-12
y = -2.5x + 1.7333
y = -2.85x + 3.8667
y = -3x + 9.6
y = -3.2x + 3.5333
y = -4x + 1.2667
20PAV
40PAV
60PAV
Aging Condition
8% SS1-95B7
8% SS1-99B5
8% SS1-99B6
PG67-22
8% R602
Lineal (8% SS1-95B7)
Lineal (8% SS1-99B5)
Lineal (8% SS1-99B6)
Lineal (PG67-22)
Lineal (8% R602)

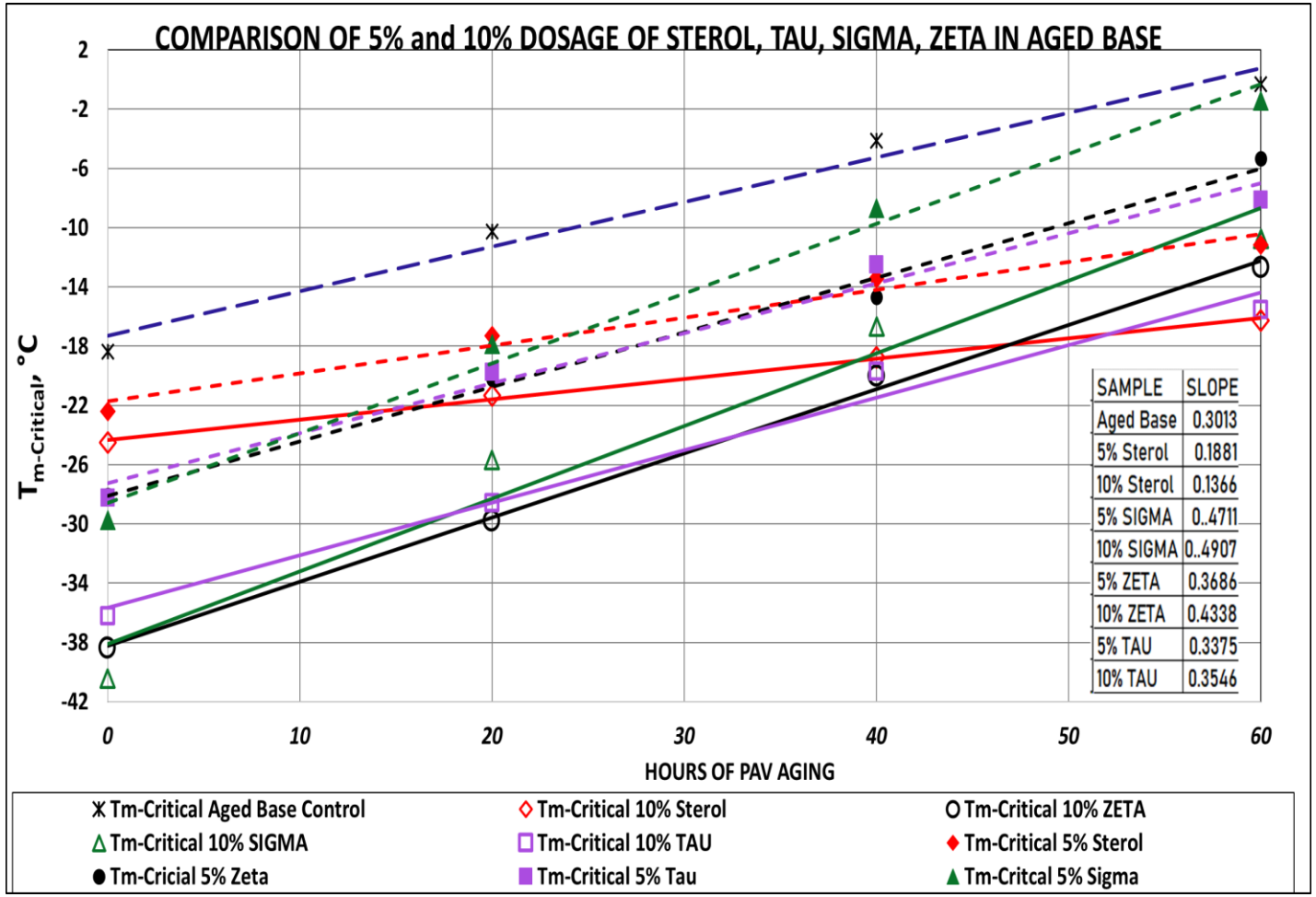

T(ºC) @10r/s & δ=45º
60
50
40
30
20
10
0
-10
y = 12.214x - 6.0088
y = 8.2005x + 0.0261
y = 9.4209x - 10.52
y = 9.5408x - 11.784
8% SS1-95B7
8% SS1-99B5
8% SS1-99B6
PG67-22
Lineal (8% SS1-95B7)
Lineal (8% SS1-99B5)
Lineal (8% SS1-99B6)
Lineal (PG67-22)
Original
RTFO
20PAV
40PAV
60PAV
Aging Condition

$T_{m\text{-}CRITICAL}$ = f(Aging Time)



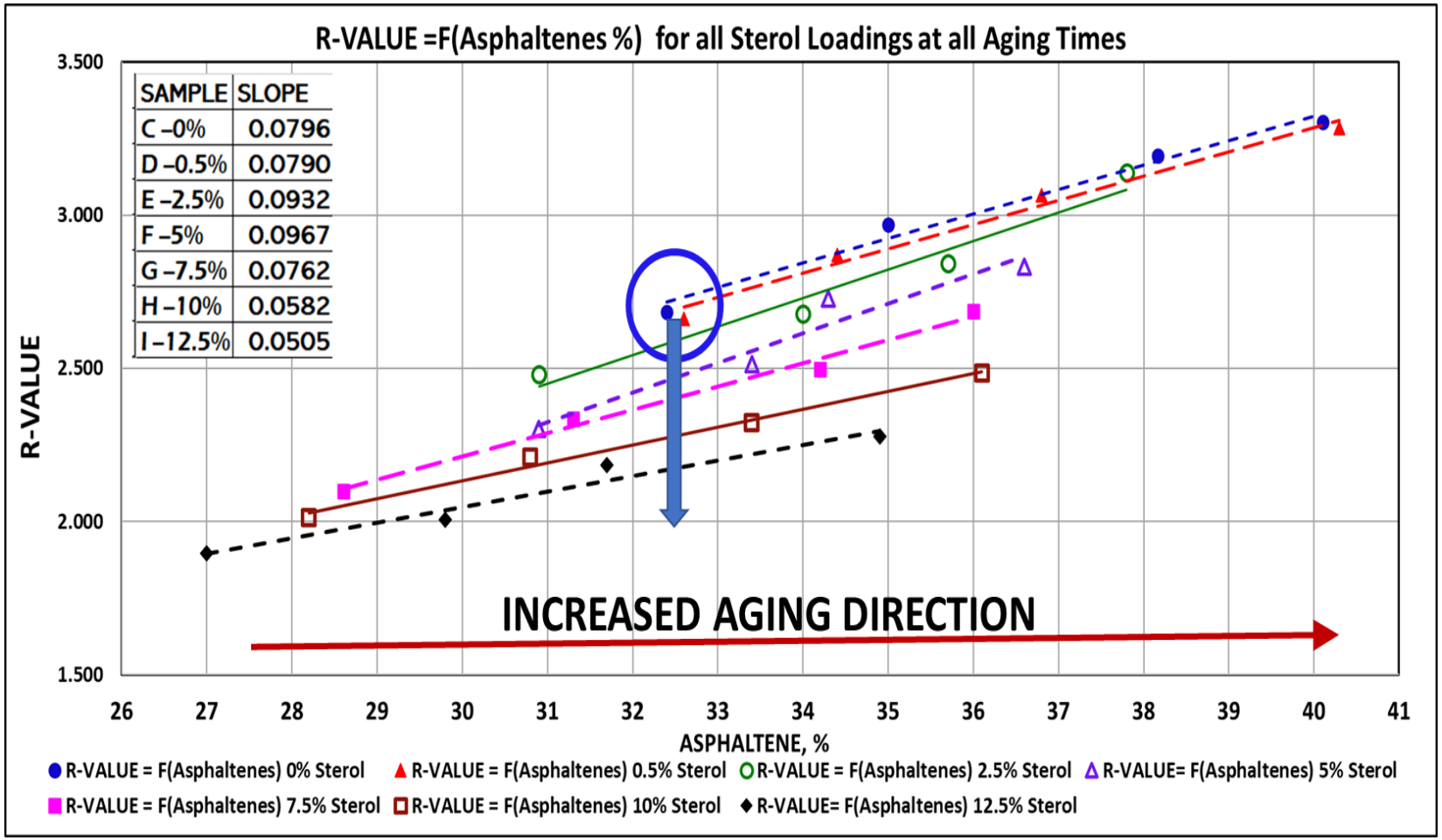
1. Even a low dose of 0.5% sterol improves the low temperature $T_{m\text{-}Critical}$ value.
2. This demonstrates the benefit of using sterol to improve aged bitumen.
3. Increasing levels of sterol show significant improvement in the low temperature value.
4. Beyond 5-7.5% sterol a point is reached where more sterol does not provide added benefit.

COMPARATIVE AGING OF STEROL & SOFTENERS



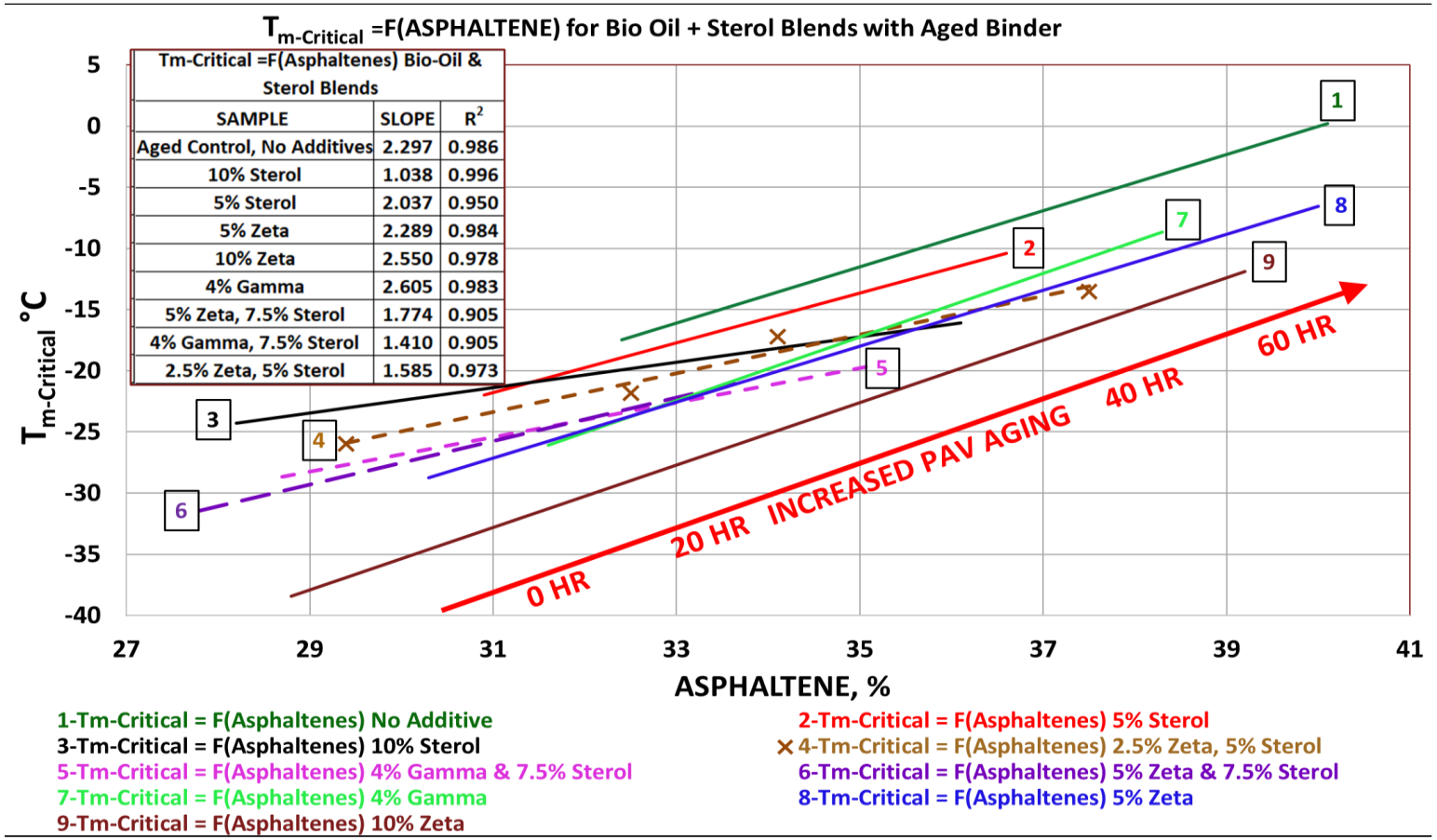
1. All 10% bio-oil blends age at a faster rate than 5% blends (see slopes).
2. 10% sterol blend ages at lower rate than 5% sterol blend.
3. Expectation is that 10% of a beneficial additive would perform superiorly to 5% of the same additive.
4. Equal Bio-oil amounts soften $T_{m\text{-}Critical}$ to nearly same values at zero time.
5. Sigma bio-oil ages more rapidly than Zeta or Tau.

R-Value = f(Asphaltenes)



- Each successively higher sterol dosage level has a unique aging trend line with reduced levels of asphaltenes and R-Values at each aging time.
- Each sterol level represents a unique and improved asphalt binder compared to the aged control.

$T_{m\text{-}Critical}$ = f(Asphaltene)



- Bio-oil blends (7, 8, 9) have asphaltene aging slopes greater than the aged control (1).
- After 60 hours PAV aging bio-oil asphaltenes (7,8,9) are within 2% or less of the control.
- Blends of bio-oil plus sterol produce Tm-Critical values lower than bio-oils alone except for 10% Zeta(9).
- Data shows that sterol can help preserve the softening benefits of bio-oil, reduce the rate of asphaltene increase (lower slopes) and result in lower Tm-Critical values at 60 hours of aging.
- Bio-oils age more rapidly with increasing concentration; a lower amount of bio-oil with sterol is better ☛ 2.5% Zeta + 5% sterol (4) has 8.1% asphaltene increase & 12.5°C Tm-Critical increase from 0 to 60 hr. PAV.
- 10% Zeta(9) has 10.4% asphaltene increase and 25.7°C Tm-Critical increase from zero to 60 hr. PAV.

Summary & Conclusions

¡Muchas gracias!

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paragon technical services, inc.