Forthcoming
Draft AASHTO Standard Practice
Characterization of Asphalt Mixtures with High Recycled Materials Contents and Recycling Agents

October 2018

MOTIVATION & CONCERN for High Recycled Binder Ratio (RBR)

- Reclaimed Asphalt Pavement (RAP)

- Recycled Asphalt Shingles (RAS)

- Workability
- Compaction

- Performance **w/Aging**

NCHRP 9-58 Objectives

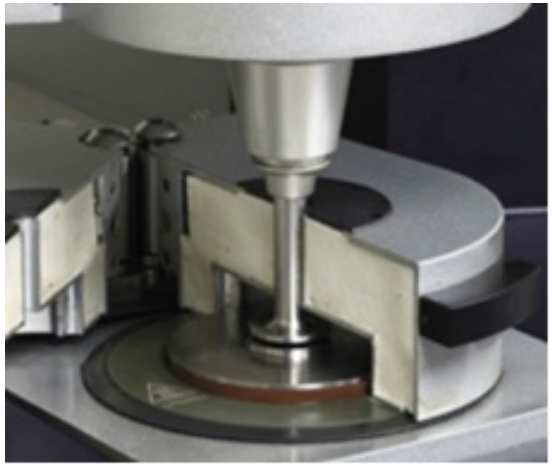
- **High RBR** = 0.3 – 0.5
- Assess effectiveness of recycling agents at selected dose to
  - **partially restore binder rheology**
  - **improve mixture cracking performance** without adversely affecting rutting resistance
- Evaluate the **evolution of recycling agent effectiveness** with aging
- Recommend **evaluation tools**

NCHRP 9-58 Binder Blend Evaluation Tools

- **DSR** for PGH, G-R, $T_{\delta=45}$

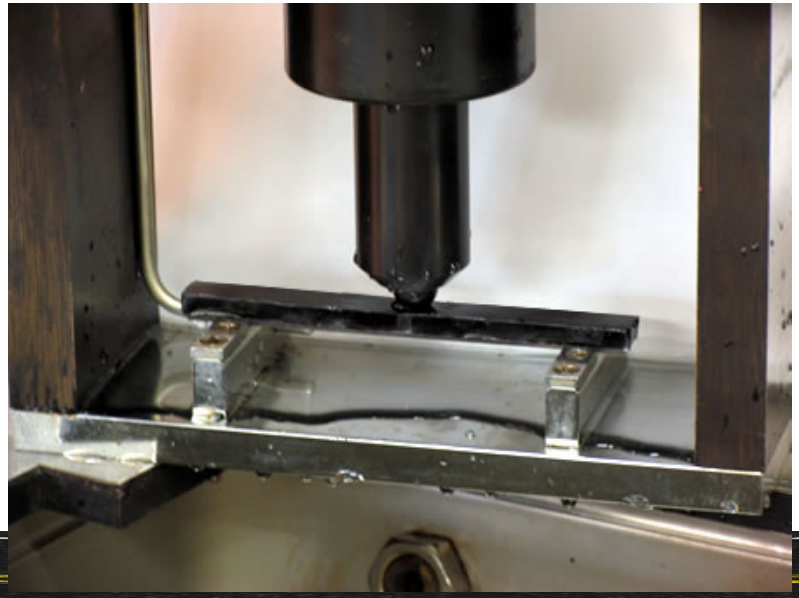
$$G\text{-}R = \frac{G^*(\cos\delta)^2}{\sin\delta}$$ @ 15°C, 0.005 rad/sec

$T_{\delta=45°}$ for G'=G"@ 10 rad/sec



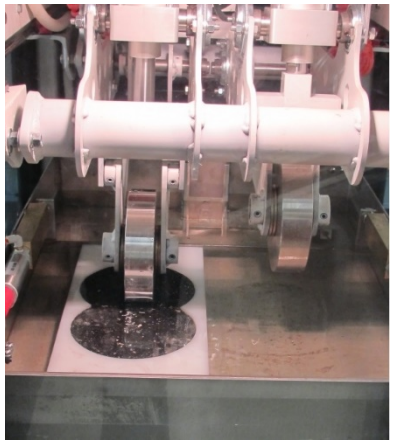
- **BBR** for ΔT_c

ΔT_c @ PAV20 = $T_S - T_m$

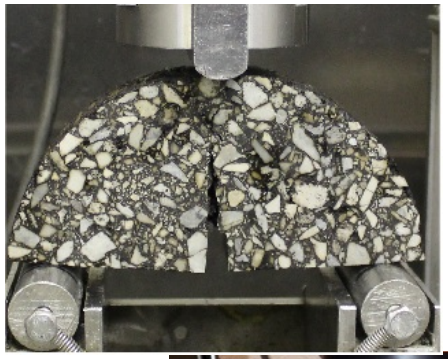


NCHRP 9-58 Mixture Evaluation Tools

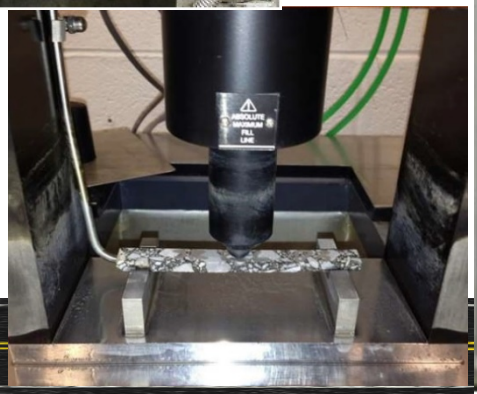
- HWTT/APA for $N_{12.5}$



- E* for G-R_m @ 20C, 5Hz
- I-FIT for FI



- BBR_m for S_m and m-$value_m$
- UTSST for CRI_{Env}



NCHRP 9-58 Materials

TX
NH
NV
IN
WI
DE

TX MWAS,
TOAS
CA TOAS
IN MWAS
DE MWAS

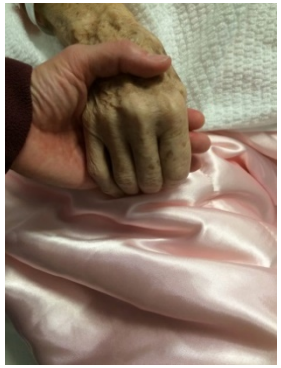
(ΔT_c)
TX PG 64-22 (-4.6), PG 70-22P (-4.9)
NH PG 64-28 (+1.4)
NV PG 64-28P (-3.6)
IN PG 64-22 (-1.2), PG 58-28 (-8.0)
MN PG 58-28 (0.0)
WI PG 58-28 (-3.4), PG 52-34 (+0.4)
DE PG 64-28 (+0.1)

A1, A2
P
T1, T2
V1, V2, V3
B1, B2

TX
NV
IN
WI
DE

Draft AASHTO Standard Practice for 0.3-0.5 RBR + Recycling Agent

- Recycling Agent Dose Selection & Incorporation Methods
- Component Materials Selection & Proportioning Guidelines
- Binder Blend Rheological Evaluation Tools
- Mixture Performance Evaluation Tools
- RAP Binder Availability Factor



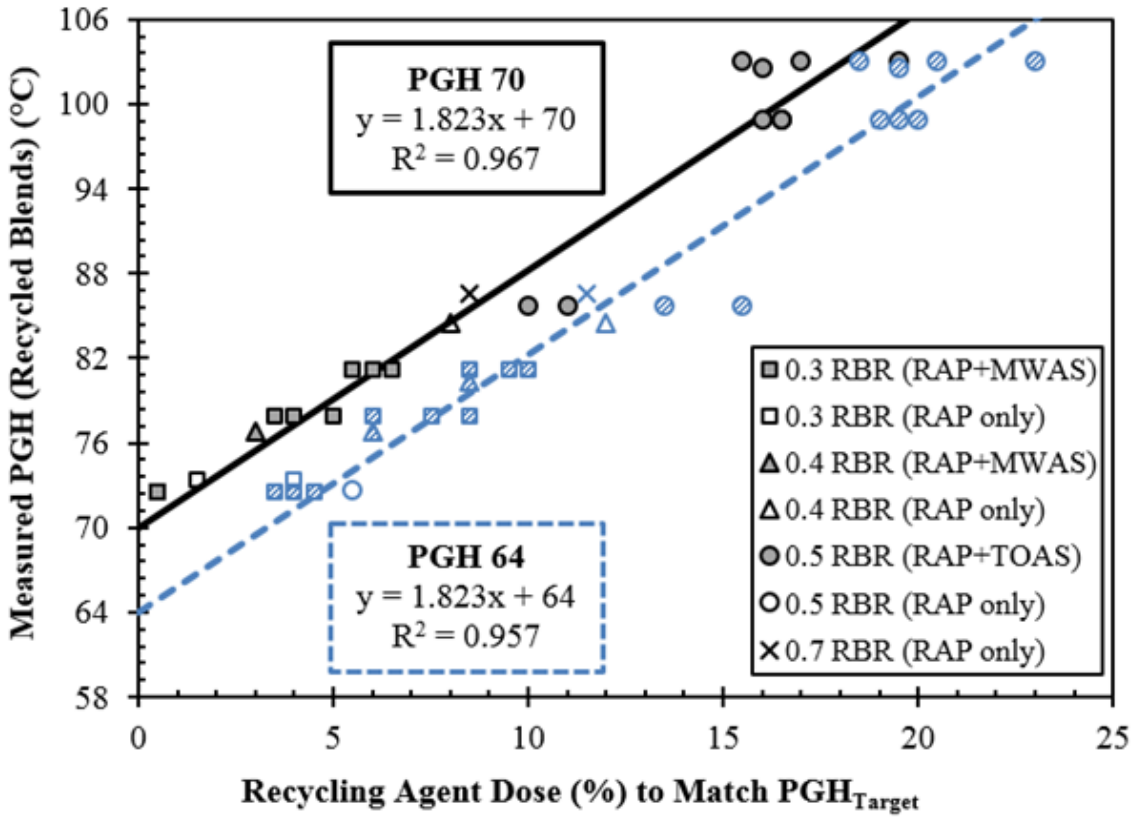
Recycling Agent Dose Selection & Incorporation

- Match *Continuous* PGH = BALANCED

- Dose as % of total binder (virgin + recycled)
  - RAP only: 100% *Replacement* of virgin binder
  - w/RAS & > 5% dose: 50% *Addition*/ 50% *Replacement*

Recycling Agent Dose Selection

$$PGH_{Blend} = (RAP_{BR} \times PGH_{RAP}) + (RAS_{BR} \times PGH_{RAS}) + (B_{BR} \times PGH_{Base})$$



$$\%RA = (PGH_{Blend} - PGH_{Target}) / 1.82$$

Component Materials Selection & Proportioning

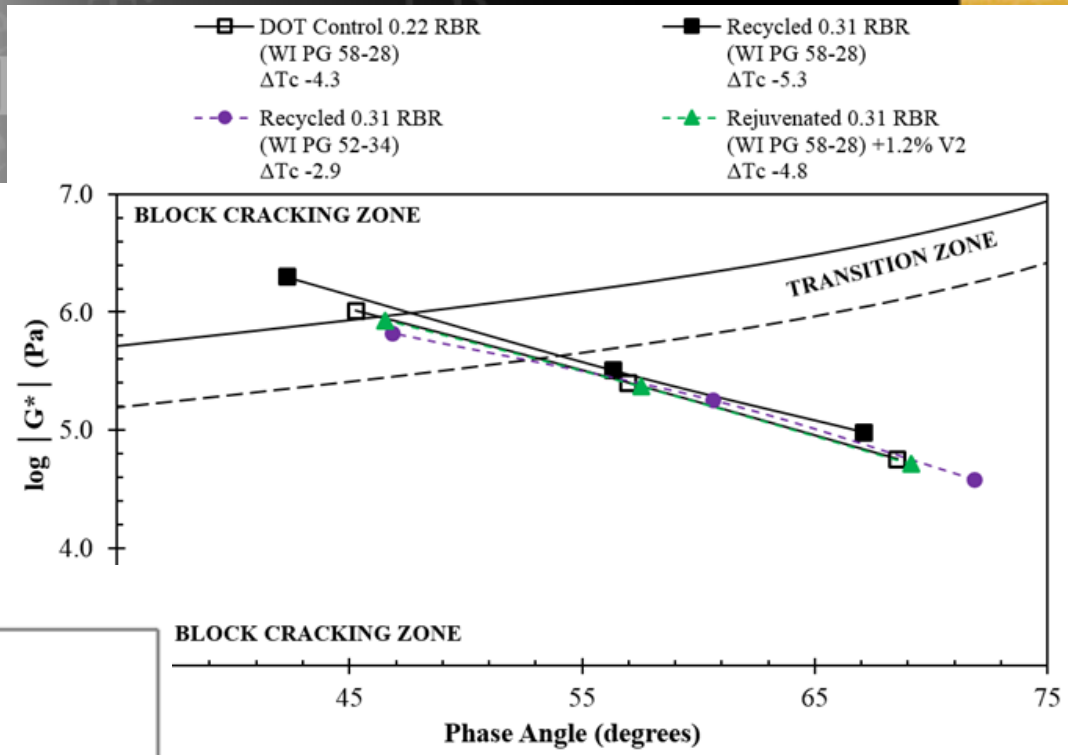
- Base Binder
  - PGH $\leq$ 64°C
  - ΔT_c @ PAV20 $\geq$ -3.5°C

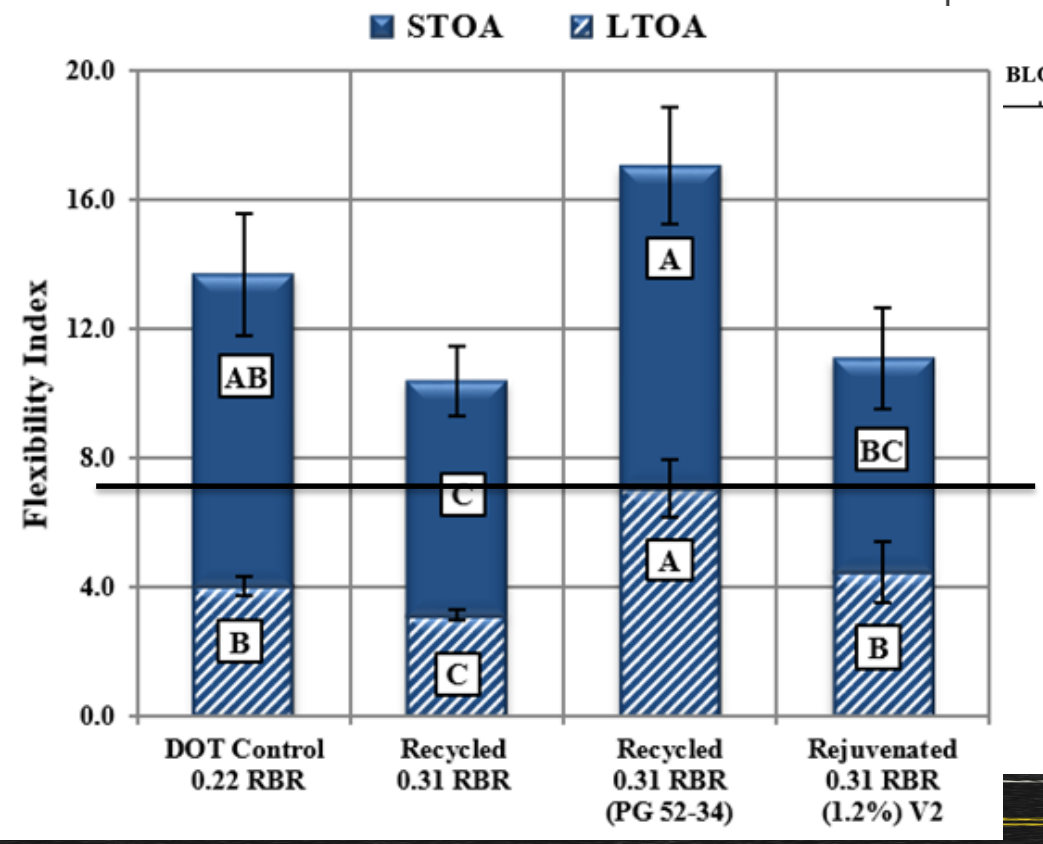
- RAP
  - PGH $\leq$ 100°C
  - ΔT_c @ PAV20 $\geq$ -7.5°C

- RAS
  - PGH $\leq$ 150°C

- RBR $\leq$ 0.5 (RAP_{BR}+RAS_{BR})
- $RAS_{BR} \leq 0.15$
- Recycling Agent Dose $\leq$ 8-10%

Component Materials Selection (WI PG 58-28, PG 52-34)

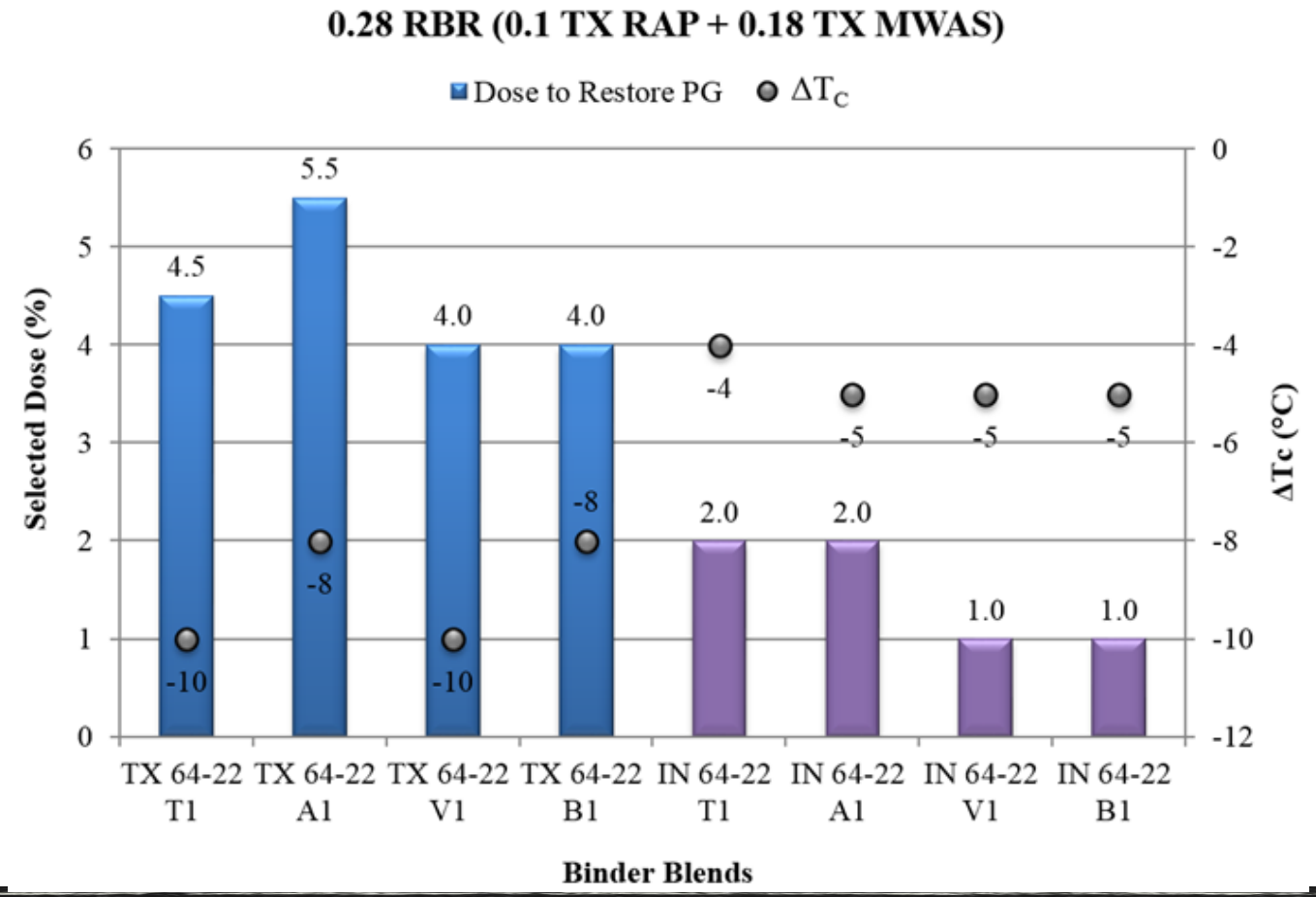




≥ 7 after STOA

Component Materials Selection

(TX PG 64-22 w/ ΔT_c =-4.6, IN PG 64-22 w/ ΔT_c=-1.2)



Materials Proportioning / Balance

$$PGH_{Blend} = (RAP_{BR} \times PGH_{RAP}) + (RAS_{BR} \times PGH_{RAS}) + (B_{BR} \times PGH_{Base})$$

$$\%RA = (PGH_{Blend} - PGH_{Target}) / 1.82$$

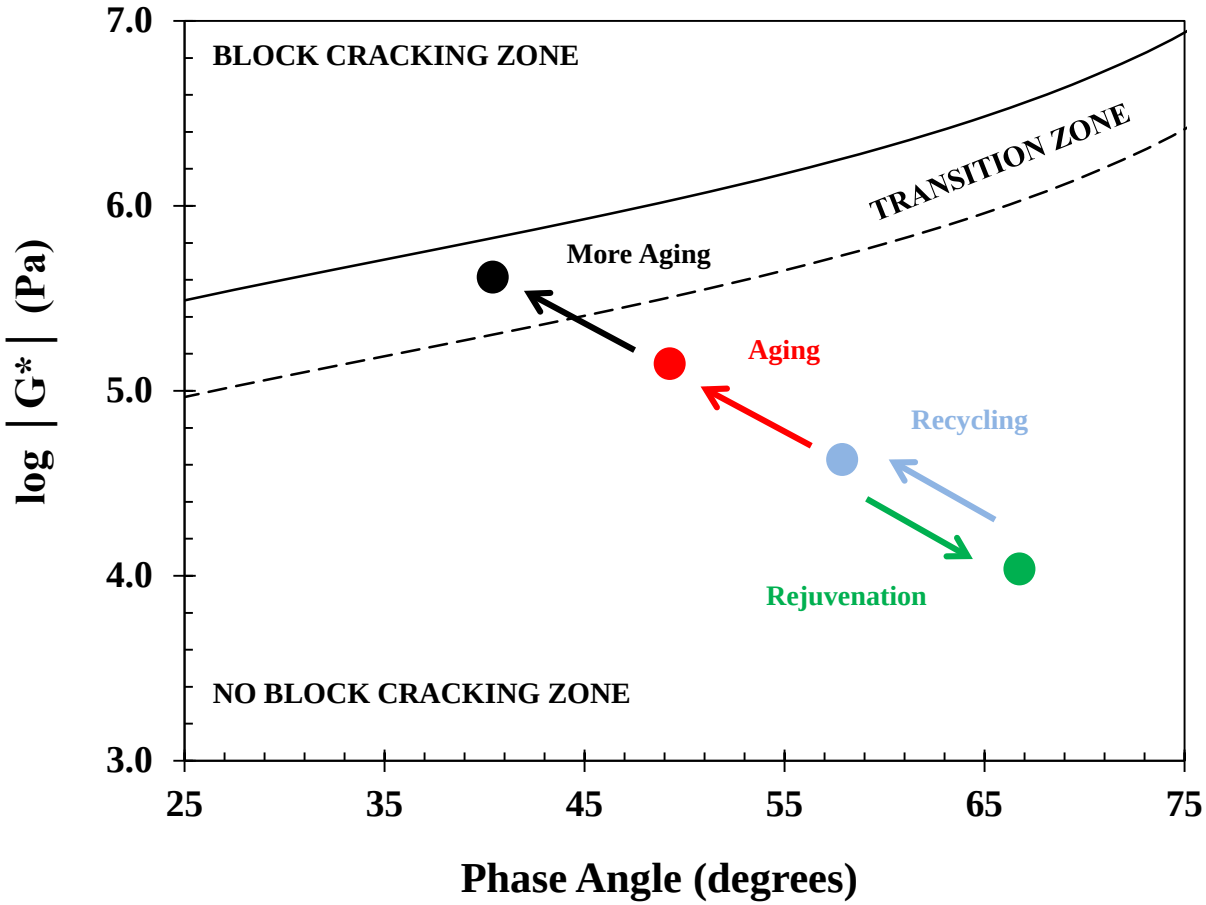
Base Binder	RAP	RAS	RA Dose	Comments
TX PG 64-22	0.25 TX RAP	0.25 TX TOAS	19.4	UNBALANCED Very High Dose
	0.4 TX RAP	0.1 TX TOAS	13.5	Δ RAP/RAS High Dose
	0.4 TX RAP	0.1 TX MWAS	10.9	Δ RAS Type High Dose
	0.4 NH RAP	0.1 TX MWAS	7.3	Δ RAP Type Marginal Dose
MN 58-28	0.4 NH RAP	0.1 TX MWAS	4.6	Δ Base Binder Acceptable Dose

Binder Blend Rheological Evaluation

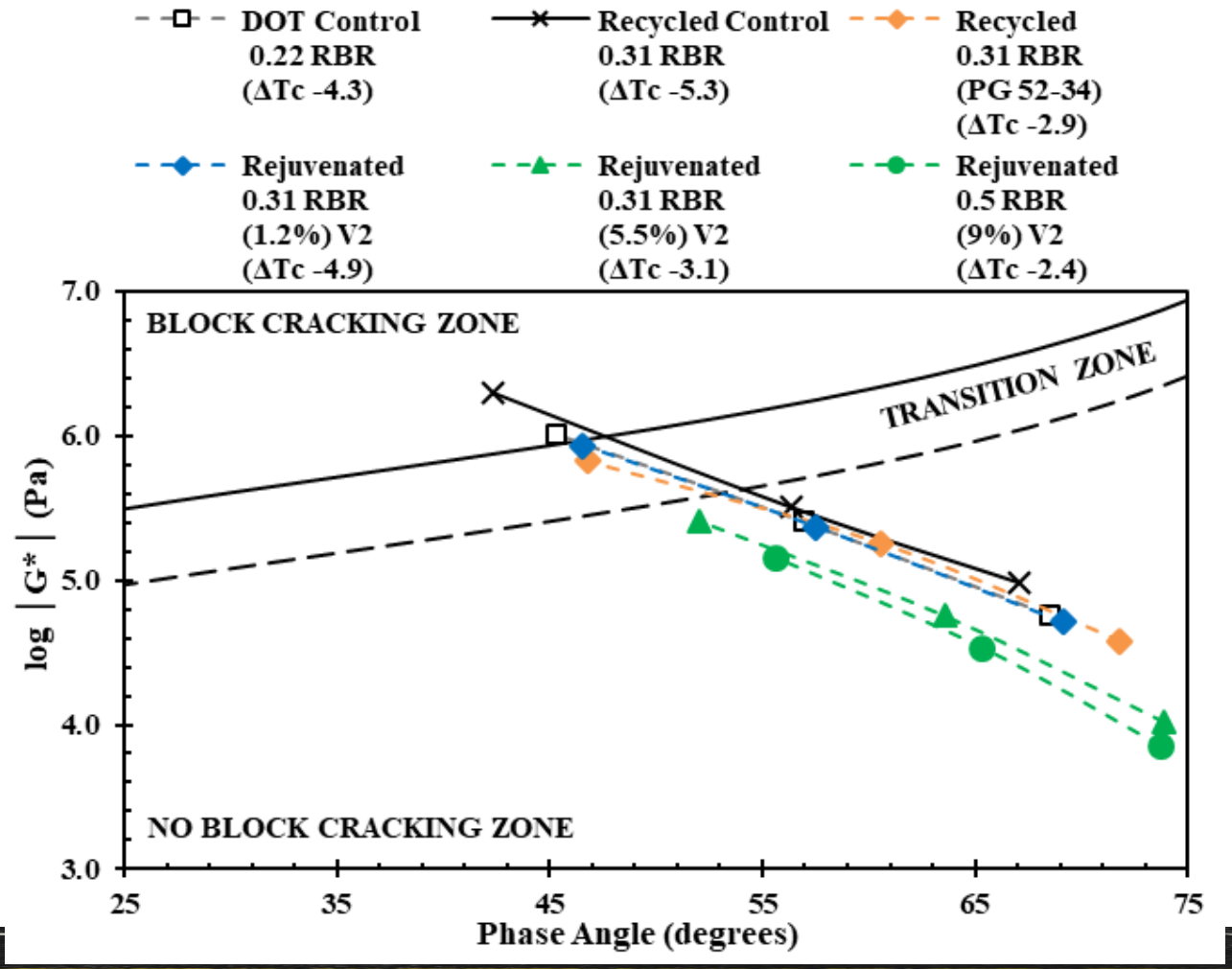
T & Aging Conditions	Test	Parameter	Suggested Performance Threshold
T_{high} Unaged, Short-Term	DSR	PGH	Target Climate
T_{int} Track w/Aging	DSR	G-R	$\leq$ 180 kPa after 20-hr PAV $\leq$ 600 kPa after 40-hr PAV
	DSR	$T_{\delta=45°}$	$\leq$ 32° after 20-hr PAV $\leq$ 45° after 40-hr PAV
T_{low} Long-Term	BBR	ΔT_c	$\geq$ -5.0 after 20-hr PAV

Short-Term Aging = RTFOT; Long-Term Aging = PAV @ 100°C

Binder Blend Rheological Evaluation



G-R Black Space (WI PG 58-28, PG 52-34)



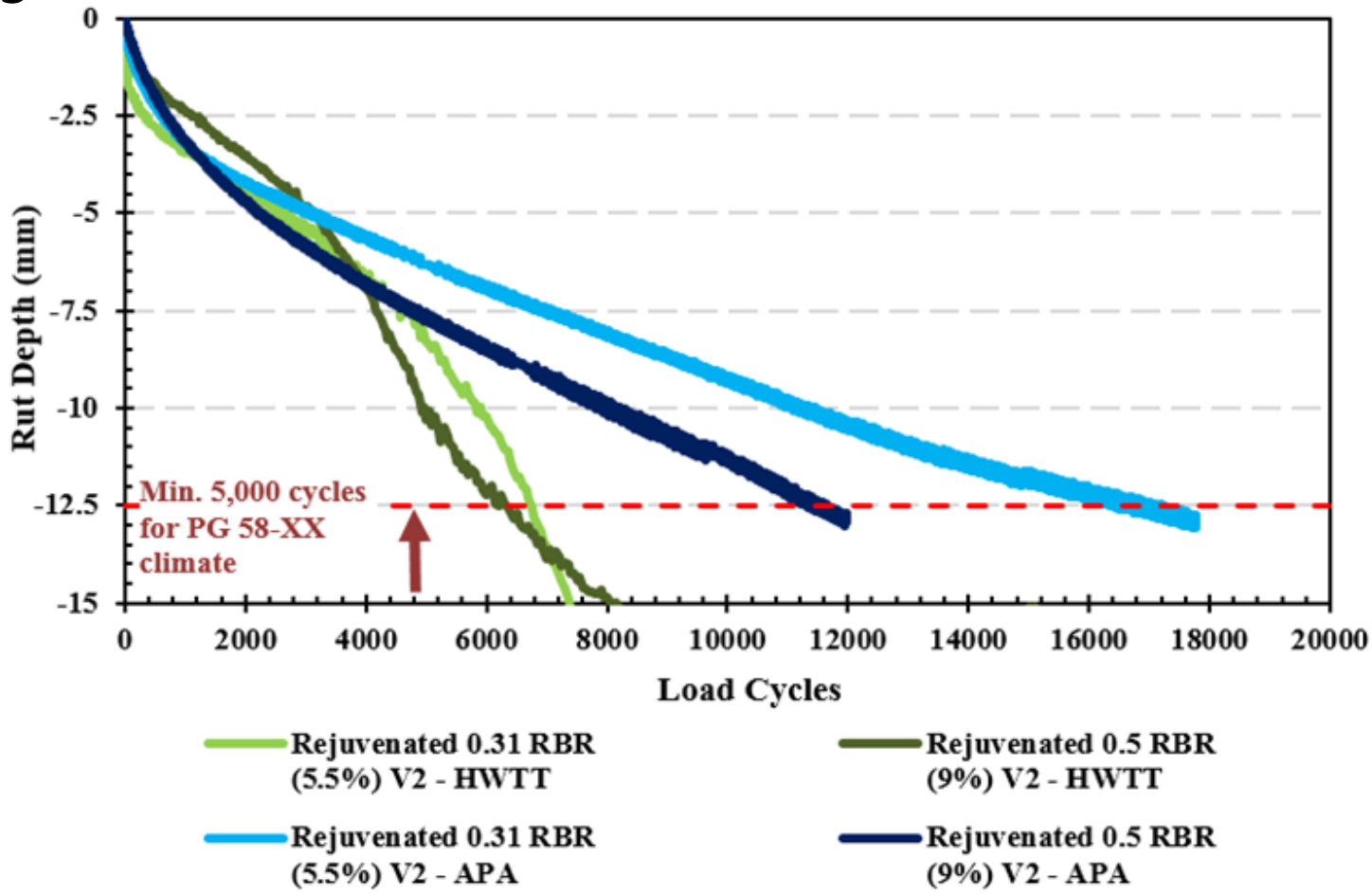
Mixture Performance Evaluation

T & Aging Conditions	Test	Parameter	Suggested Performance Threshold
T_{high} Short-Term	HWTT or APA	$N_{12.5}$	$\geq$ 5000 for PG 58-XX $\geq$ 7500 for PG 64-XX (cold) $\geq$ 10,000 for PG 64-XX (warm) $\geq$ 15,000 for PG 70-XX
T_{int} Track w/Aging & Short-Term	E*	G-R_m	$\leq$ 8000 MPa after STOA $\leq$ 19,000 MPa after LTOA
	I-FIT	FI	$\geq$ 7 after STOA
T_{low} Short- & Long-Term	BBR_m	S_m, m-$value_m$	$\leq$ Utah threshold after STOA
	UTSST	CRI_{Env}	$\geq$ 17 after LTOA

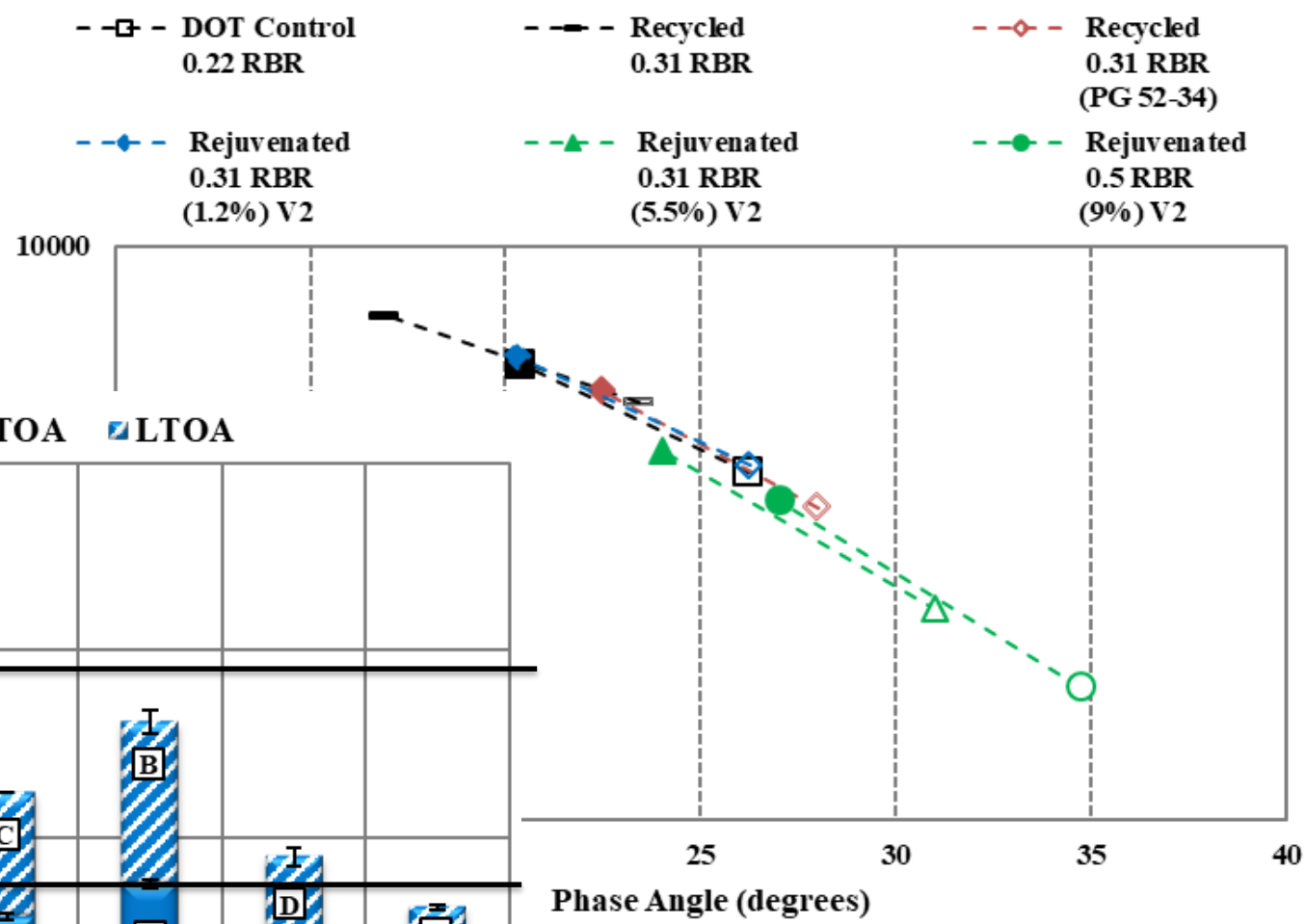
Short-Term Aging = STOA = 2hr @ 135°C; Long-Term Aging = LTOA = 5d @ 85°C

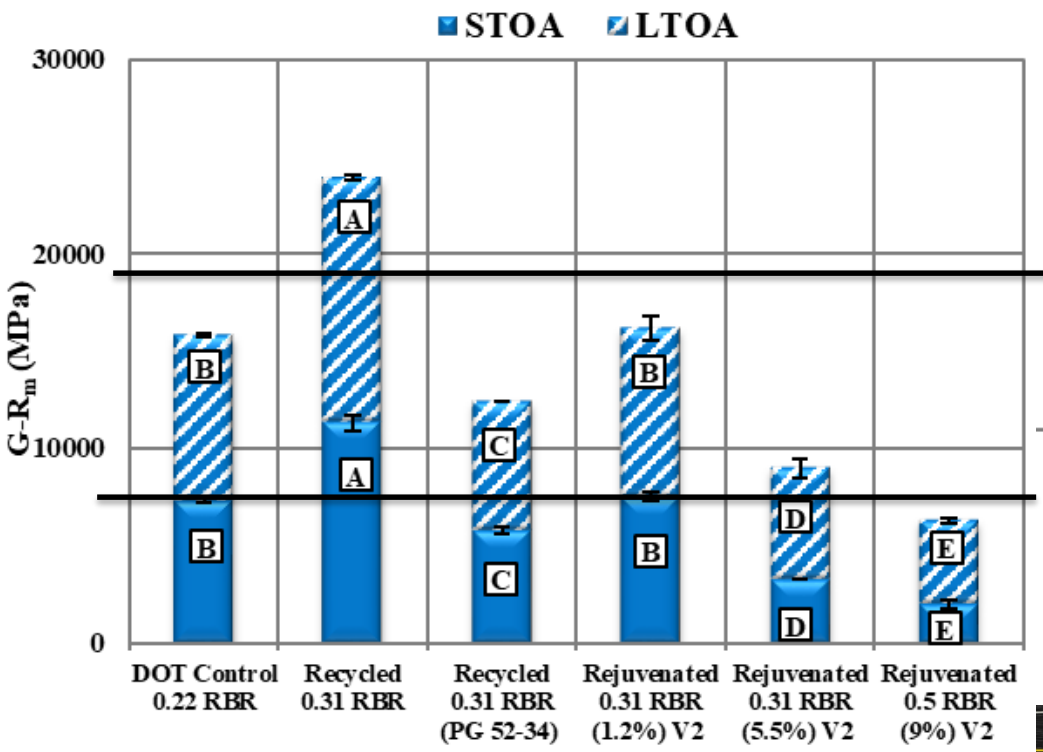
$N_{12.5}$ (WI PG 58-28)

≥ 5000 for PG 58-XX



G-R_m Black Space WI PG 58-28, PG 52-34



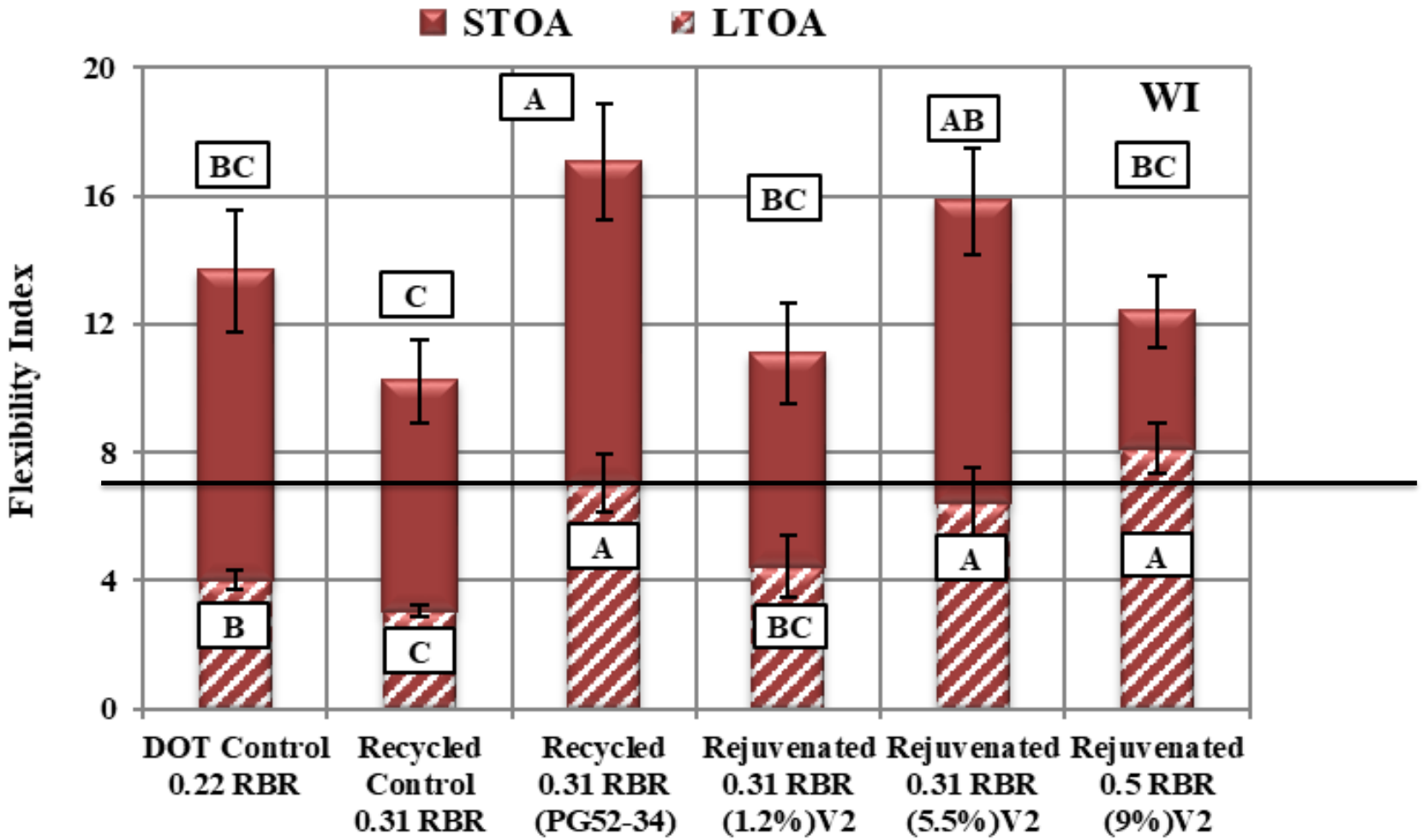


≤ 8000 MPa after STOA

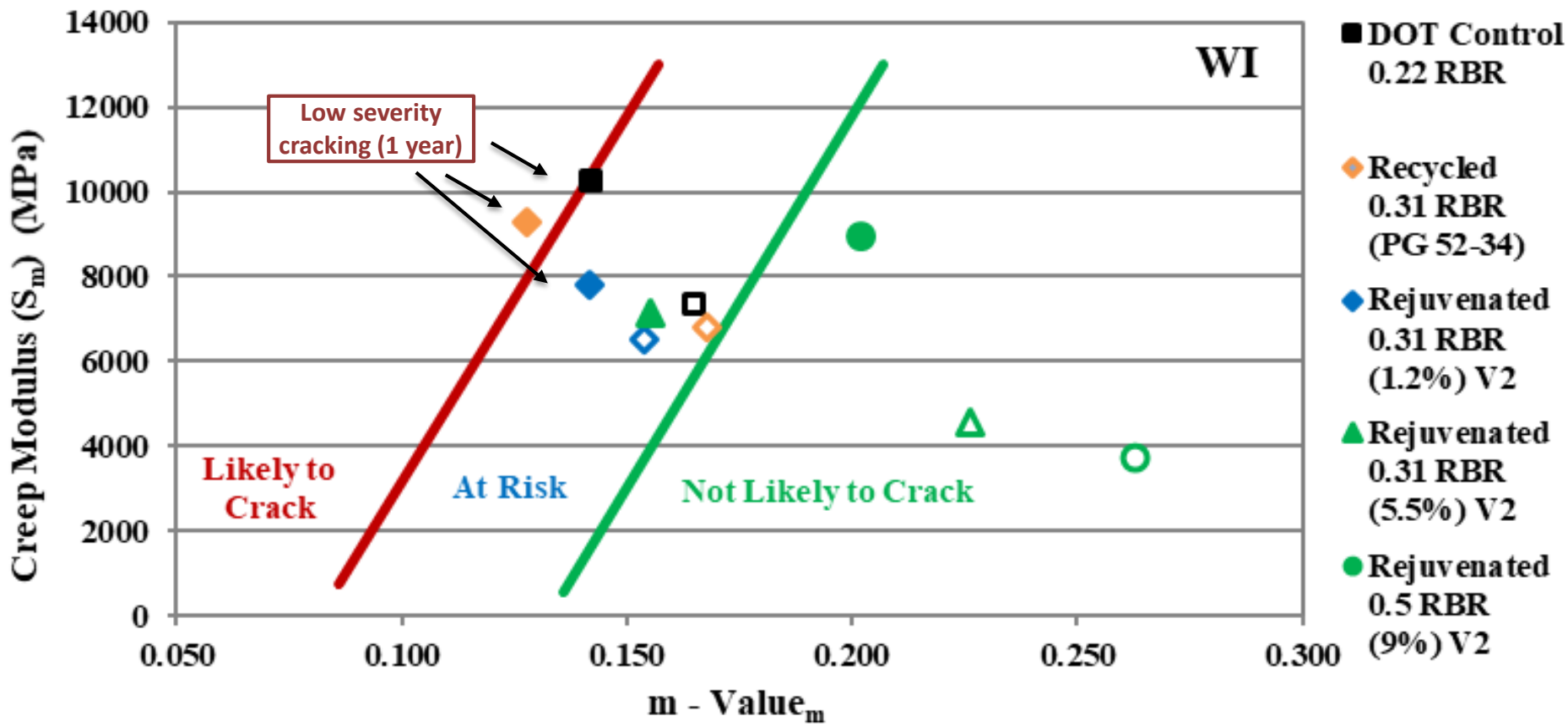
≤ 19,000 MPa after LTOA

FI (WI PG 58-28, PG 52-34)

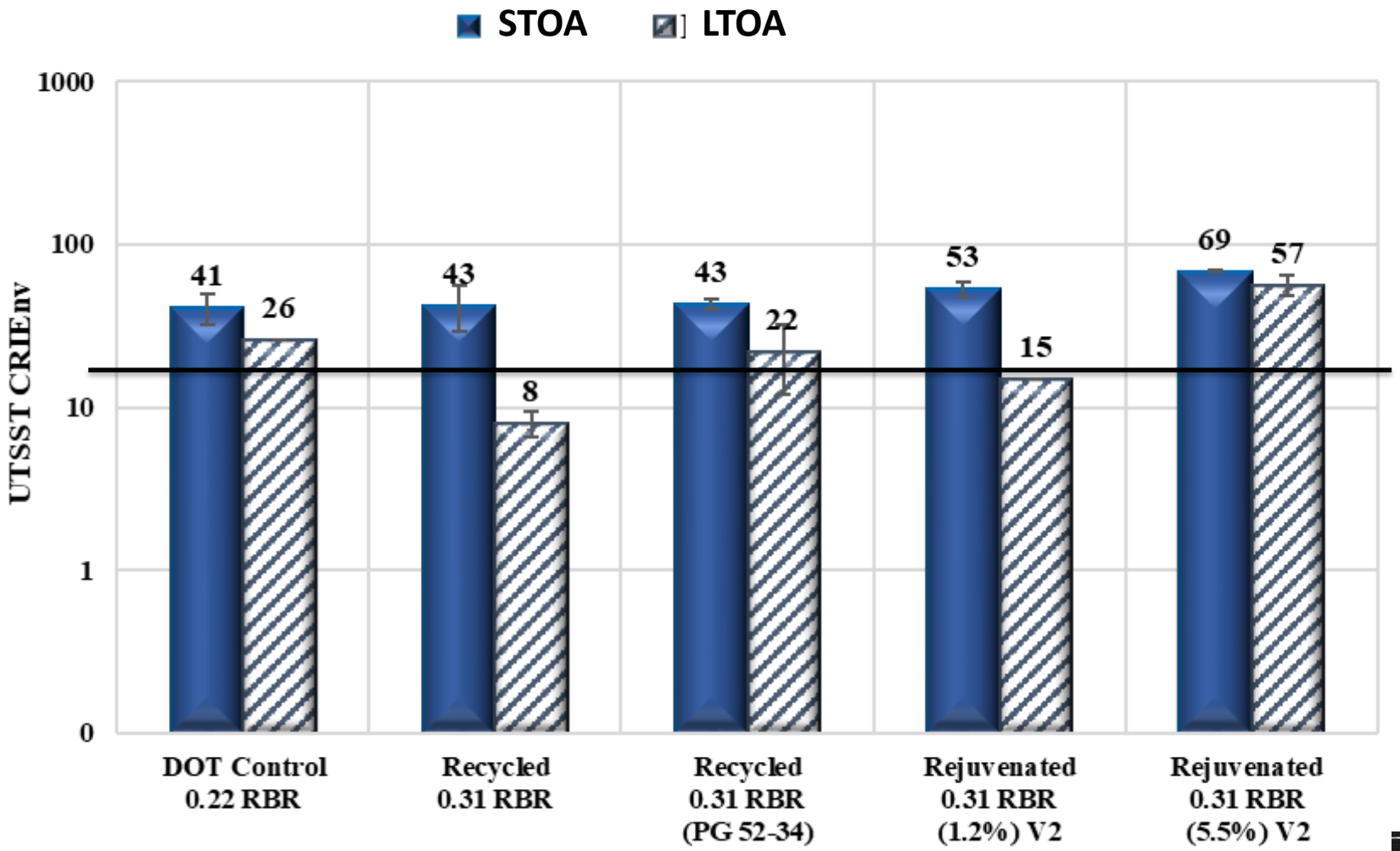
≥ 7 after STOA



S_m, m-value$_m$ (WI PG 58-28, PG 52-34)



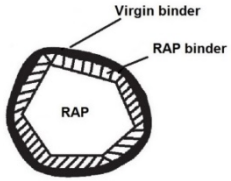
CRI_{Env} (WI PG 58-28, PG 52-34) ≥ 17 after LTOA



RAP Binder Availability Factor

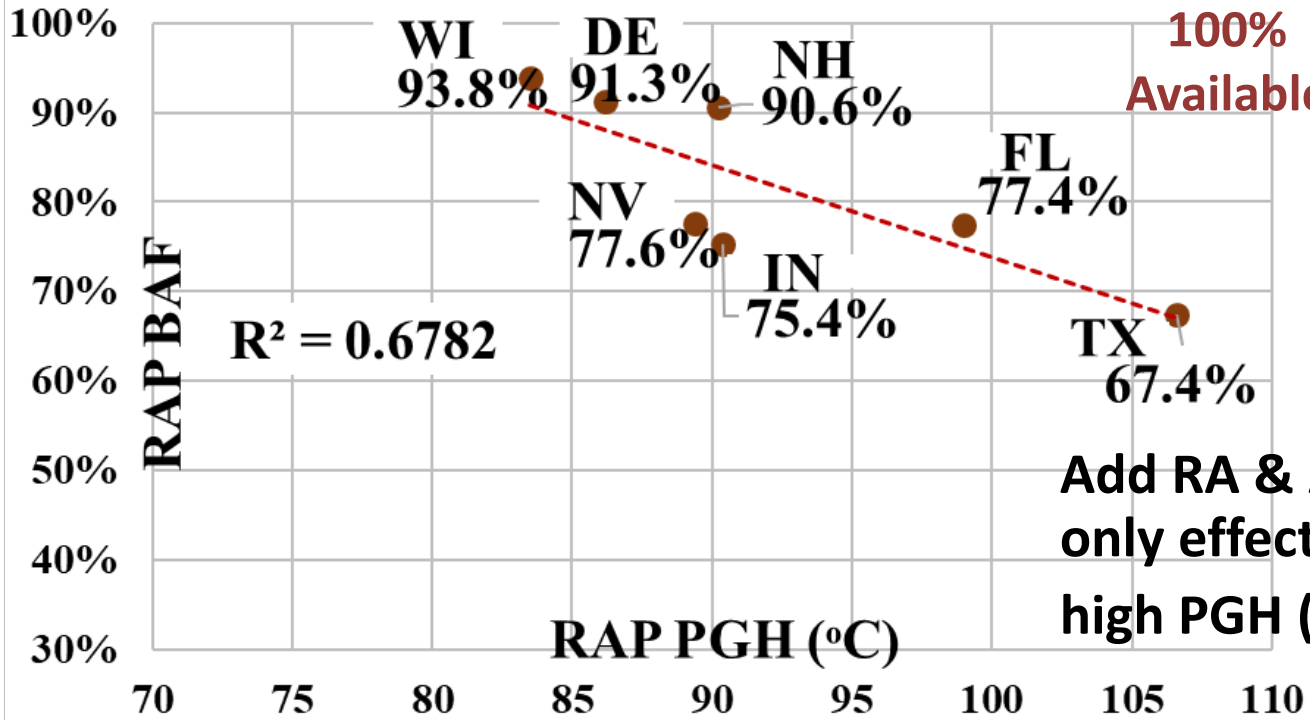
100% Available

PARTIAL BLENDING



0% Available

Black Rock



Add RA & Add RA to RAP only effective for high PGH (FL, TX)

$$RAPBAF = -0.010\ x\ PGH_{RAP} + 1.771 \text{ for 150°C mixing}$$

THANK YOU!

Amy Epps Martin
(979) 862.1750
a-eppsmartin@tamu.edu

Edith Arámbula Mercado
(979) 458-0209
e-arambula@tti.tamu.edu