Texas A&M Transportation Institute

New Tools for Assessing & Characterizing High RBR Asphalt Concrete Mixtures

A. Epps Martin

FHWA Binder ETG

May 2016

Salt Lake City, UT

Outline

- NCHRP 9-58 Objectives & Research Plan
- Preliminary Phase II Tools
  - **Recycling Agent Dosage Selection Method**
  - **Rejuvenating Effectiveness & Its Evolution**
  - **Binder Availability from Recycled Materials**
- Next Steps

NCHRP 9-58: The Effects of Recycling Agents on Asphalt Mixtures with High RAS and RAP Binder Ratios

TTI

- Amy Epps Martin
- Fujie Zhou
- Edith Arambula
- Jon Epps
- Dave Newcomb
- Charles Glover
- Eun Sug Park
- Arif Chowdury
- Xue Luo
- Fan Yin

UNR

- Elie Hajj
- Nathan Morian

UNH

- Jo Daniel

Consultant

- Gayle King

NCHRP 9-58 Objectives

- Assess effectiveness of RAs to
  - **restore blended binder rheology**
  - **improve mixture cracking**

performance at optimum dosage rates

- Evaluate the **evolution of RA effectiveness**
- Recommend **evaluation tools**

NCHRP 9-58 Research Plan

PHASE I

Identification of Gaps in Knowledge on RA Use with High RBRs

Task 1. Gather Information

Task 2. Design Laboratory Experiment

Task 3. Document Results in First Interim Report

PHASE II

Investigation of Effectiveness of RAs in Restoring Binder Rheology, Development of Blending Protocol, and Associated Mixture Performance

Task 4. Conduct Laboratory Experiment

Task 5. Design Field Experiment and Document Results in Second Interim Report

PHASE III

Validation of RA Use in Mixtures with High RBRs

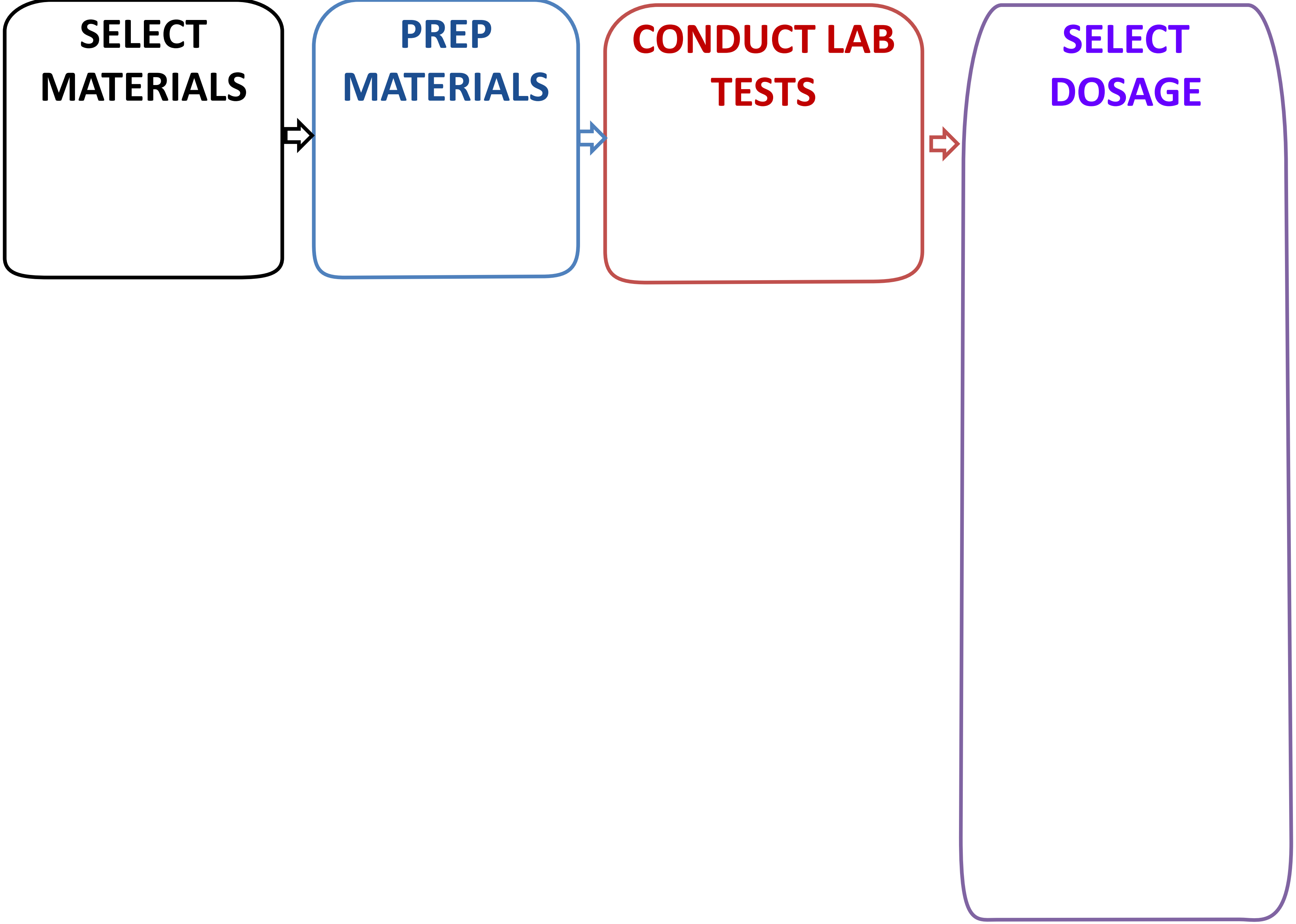
Task 6. Conduct Field Experiment

Task 7. Propose Revisions to AASHTO Specifications and Test Methods

Task 8. Develop Training Materials and Best Practices and Deliver Workshop

Task 9. Document Results in Final Report

RECYCLING AGENT DOSAGE SELECTION METHOD


SELECT MATERIALS
PREP MATERIALS
CONDUCT LAB TESTS
SELECT DOSAGE

SELECT MATERIALS

Target and base binder PG grade

RAP and/or RAS source(s)

Recycling Agent (RA)

RAP and/or RAS Recycled Binder Ratio (RAPBR/ RASBR)

PREP MATERIALS

Extract and recover binder from RAP and/or RAS source(s)

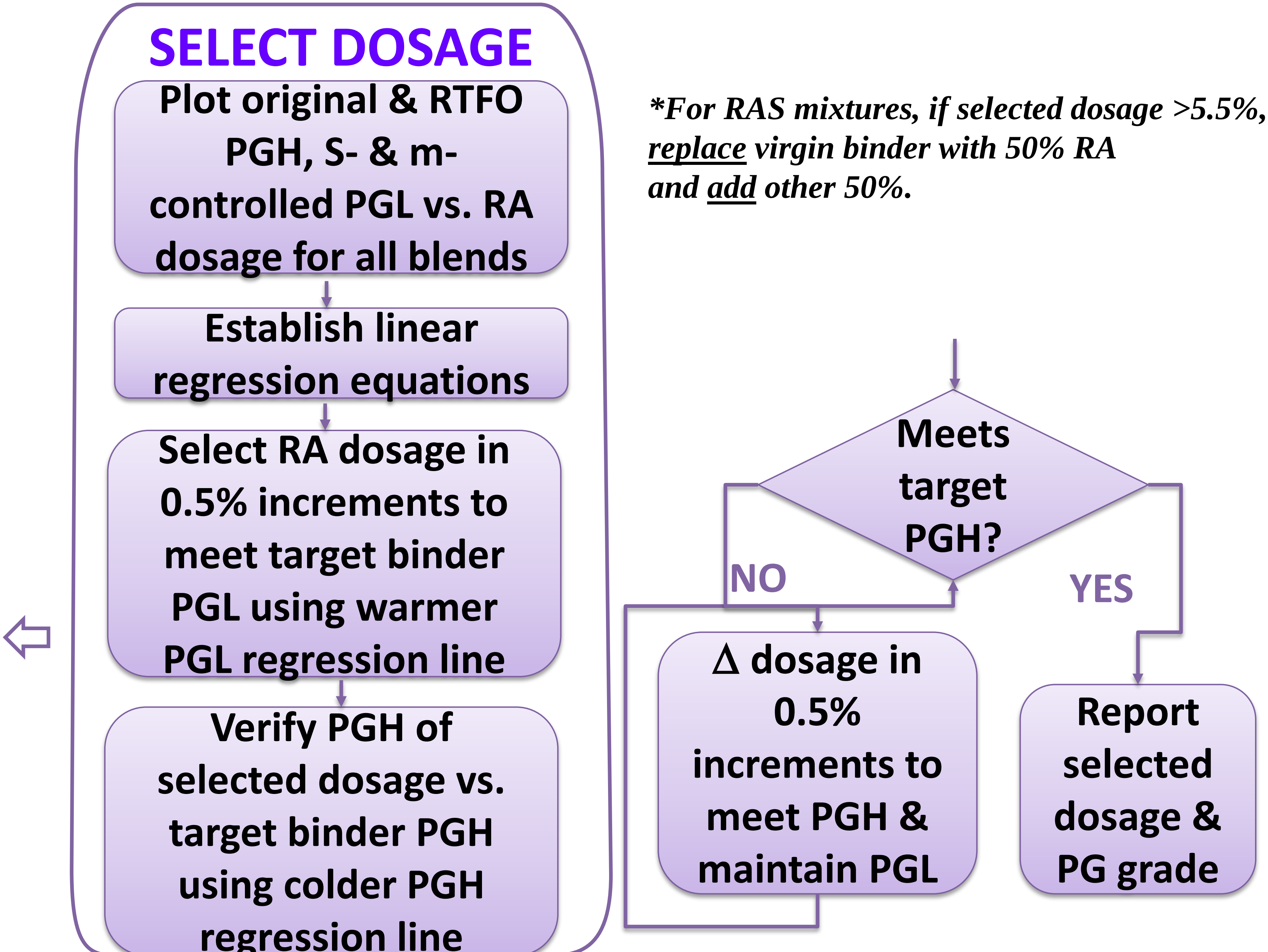
Prepare recycled binder blends:

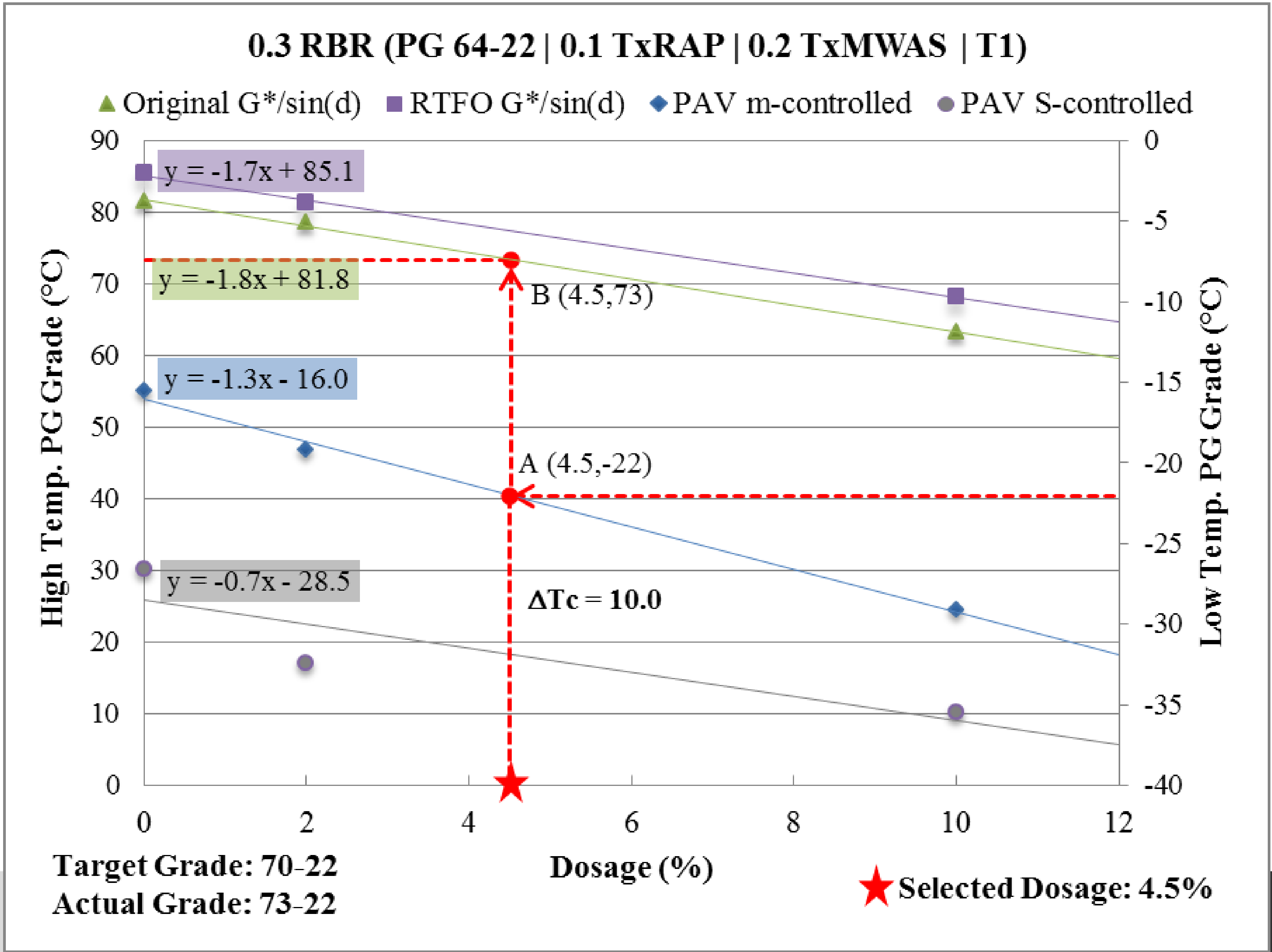
- With no RA (control)
- With low RA dosage
- With high RA dosage

CONDUCT LAB TESTS

Obtain high PG grade (PGH) and low PG grade (PGL) per AASHTO M320:

- Target binder
- Recycled binder blend with no RA (control)
- Recycled binder blend with low RA dosage
- Recycled binder blend with high RA dosage


SELECT DOSAGE
Plot original & RTFO PGH, S- & m-controlled PGL vs. RA dosage for all blends
Establish linear regression equations
Select RA dosage in 0.5% increments to meet target binder PGL using warmer PGL regression line
Verify PGH of selected dosage vs. target binder PGH using colder PGH regression line
*For RAS mixtures, if selected dosage >5.5%, replace virgin binder with 50% RA and add other 50%.
Meets target PGH?
NO
YES
Δ dosage in 0.5% increments to meet PGH & maintain PGL
Report selected dosage & PG grade



0.3 RBR (PG 64-22 | 0.1 TxRAP | 0.2 TxMWAS | T1)
Original G*/sin(d)
RTFO G*/sin(d)
PAV m-controlled
PAV S-controlled
y = -1.7x + 85.1
y = -1.8x + 81.8
y = -1.3x - 16.0
y = -0.7x - 28.5
B (4.5,73)
A (4.5,-22)
ΔTc = 10.0
High Temp. PG Grade (°C)
Low Temp. PG Grade (°C)
Dosage (%)
Target Grade: 70-22
Actual Grade: 73-22
Selected Dosage: 4.5%

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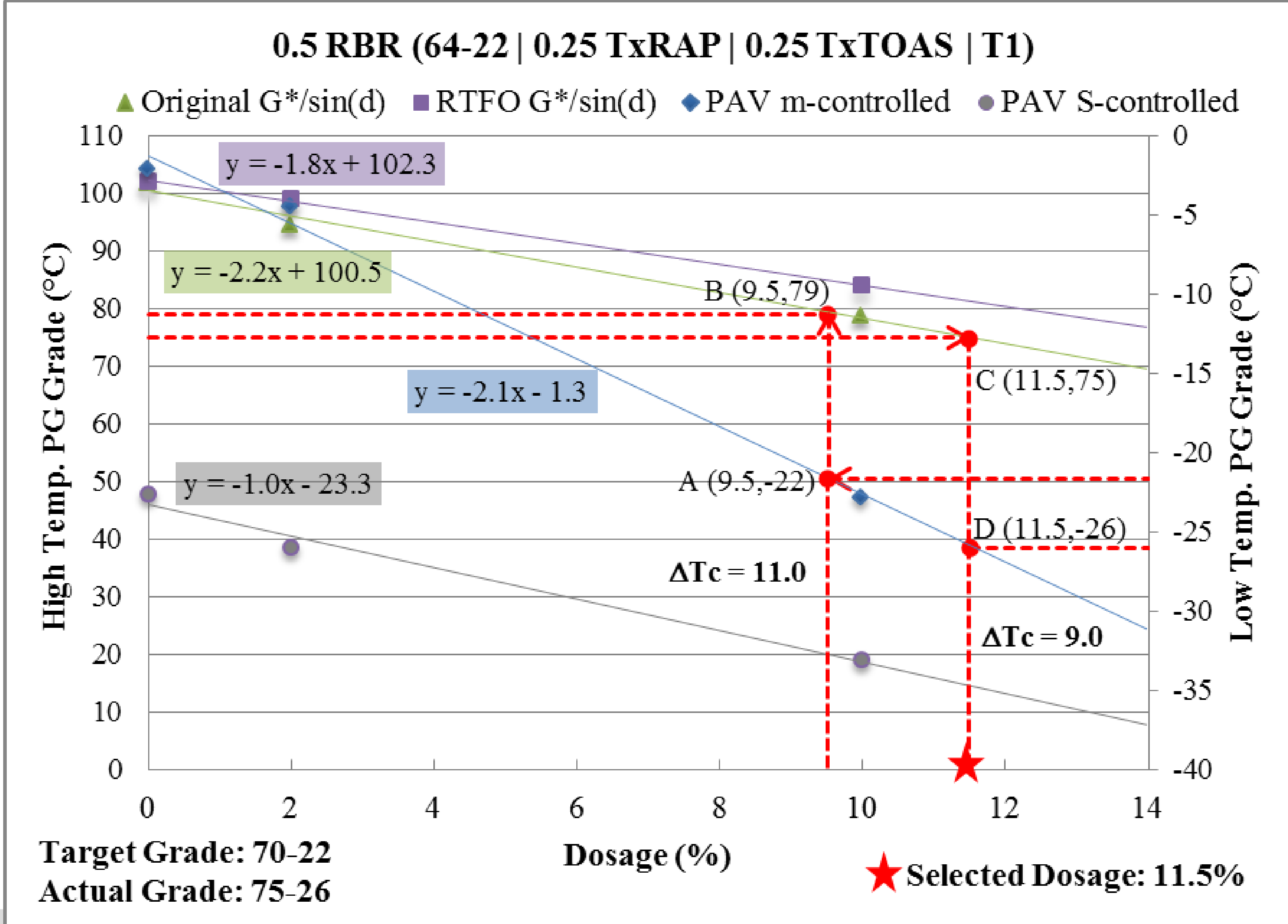


DOSAGE SELECTION

			Materials			Binder	
Virgin	RBR	RAP	RAS	RA	Opt Dosage	Field Dosage	ΔTc @ Opt
64-22 TX	0.3	0.1 TX	0.2 TX MWAS	T1	4.5	2.7	10
64-22 TX	0.3	0.1 TX	0.2 TX MWAS	A1	5.5	-	9
64-22 TX	0.4	0.4 TX	-	T1	7.5	-	8
64-22 TX	0.4	0.4 TX	-	A1	9.5	-	7
64-22 TX	0.5	0.25 TX	0.25 TX MWAS	T1	7.5	-	9
64-22 TX	0.5	0.25 TX	0.25 TX TOAS	T1	11.5	-	9
64-28 NH	0.4	0.4 TX	-	A1	6.0	-	4
64-28 NH	0.5	0.25 TX	0.25 TX TOAS	T1	12.5	-	5
64-28P NV	0.5	0.25 TX	0.25 TX TOAS	T1	11.0	-	7
64-28P NV	0.3	0.3 NV	-	T2	1.5	2.0	3
64-28P NV	0.3	0.3 NV	-	A2	2.0	2.0	2

- 0.5% increments
- Restore PGL, then meet PGH (if possible) & maintain PGL
- High ΔT_c ??
- Aging effects – using optimum w/G-R @ 0, 20, 40hr PAV

RA ADDITION VS. REPLACEMENT

- Current Practice
  - 100% replacement
  - OK at low RA dosage
  - Coating issues at high RA dosage (5.5%A1)
- Example: 0.5 RBR (0.25TXRAP + 0.25TXRAS + **12.5%T1**)
  - 100% addition: P_b = 4.9%
  - 100% replacement: P_b =4.3%
  - **0.6% reduction in P_b (coating issues)**
  - Max% for replacing ?

COATABILITY EVALUATION (NCHRP 9-53)

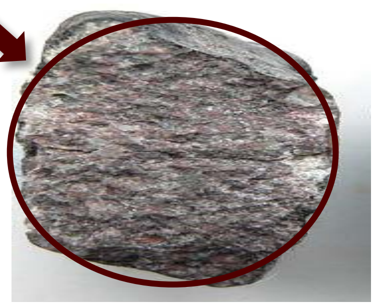
Coarse Aggregate Fraction

VS.

Coarse Foamed Loose Mix Fraction

Soak under water for 1 hour

Water

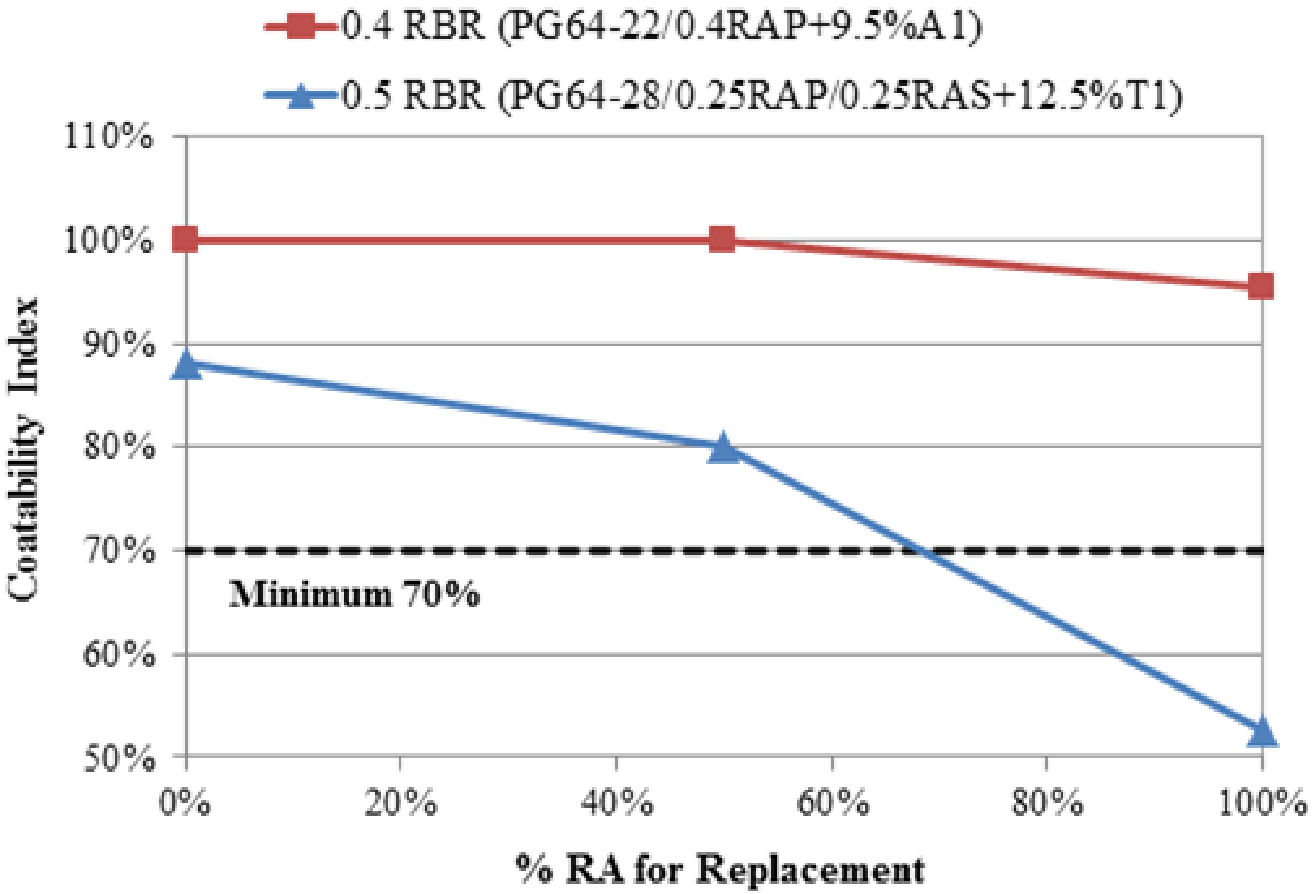


Water

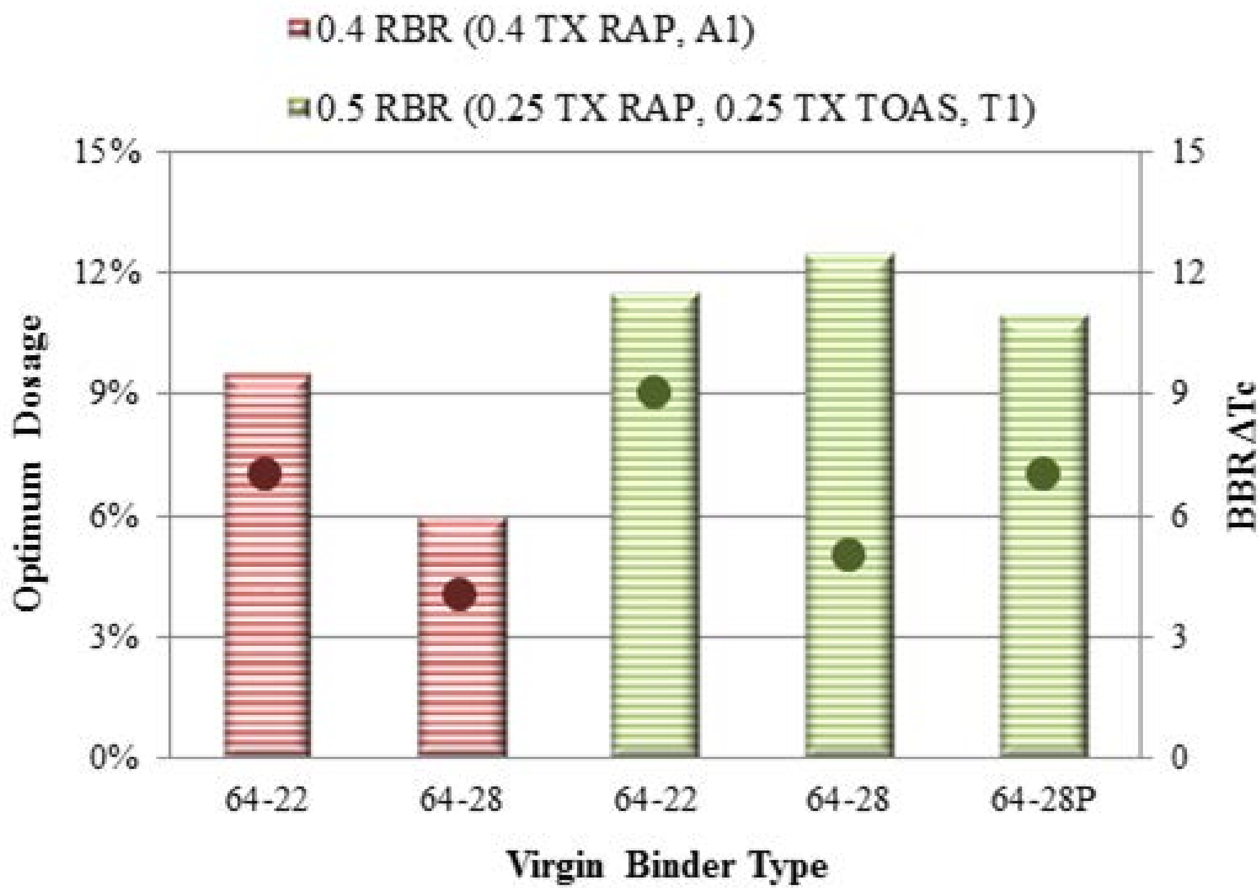
Coatability Index (CI): relative difference in SSD water absorption

Higher CI = better aggregate coating

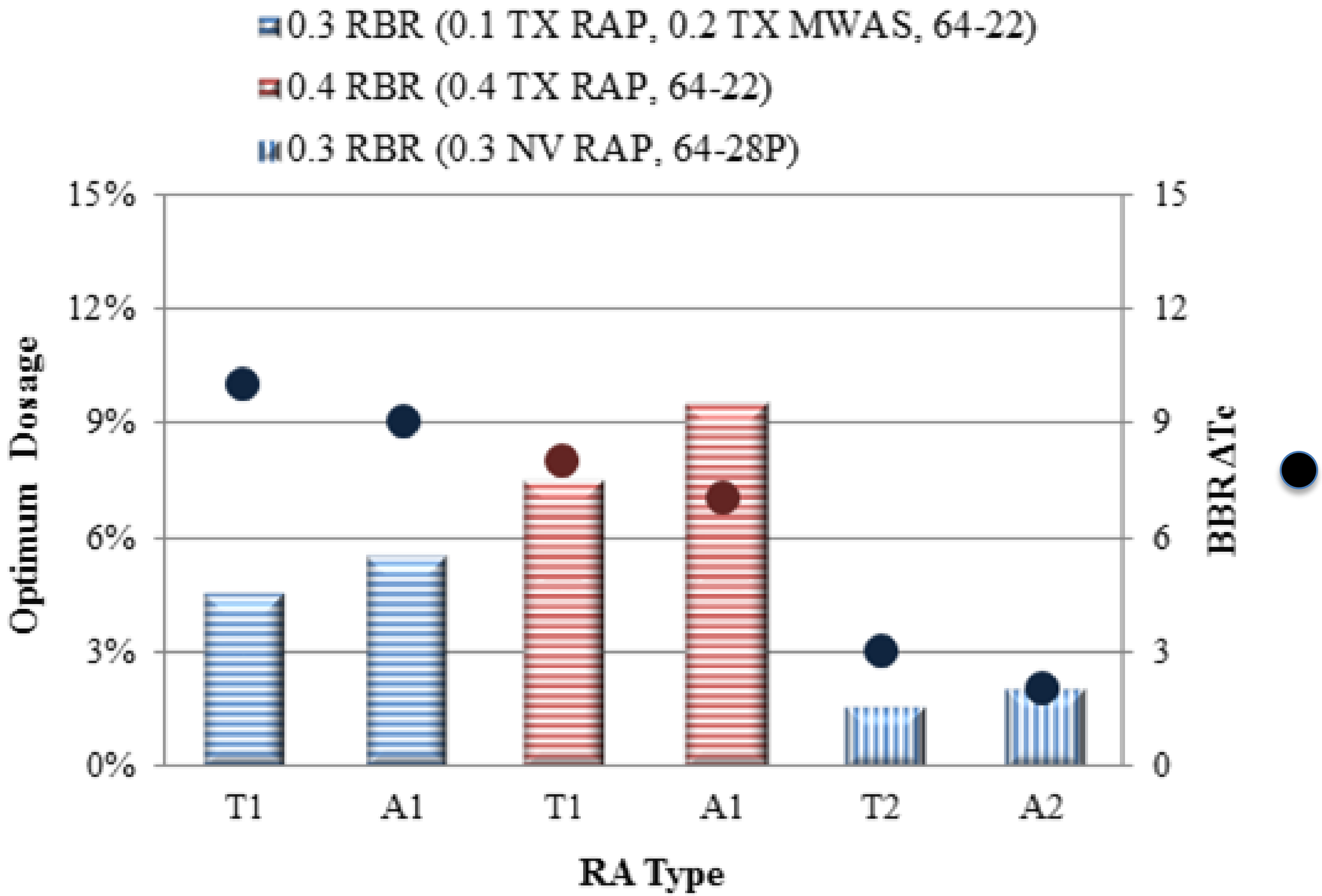
COATABILITY: W/RAP 100% ADD, W/RAS 50/50 ADD/REPLACE



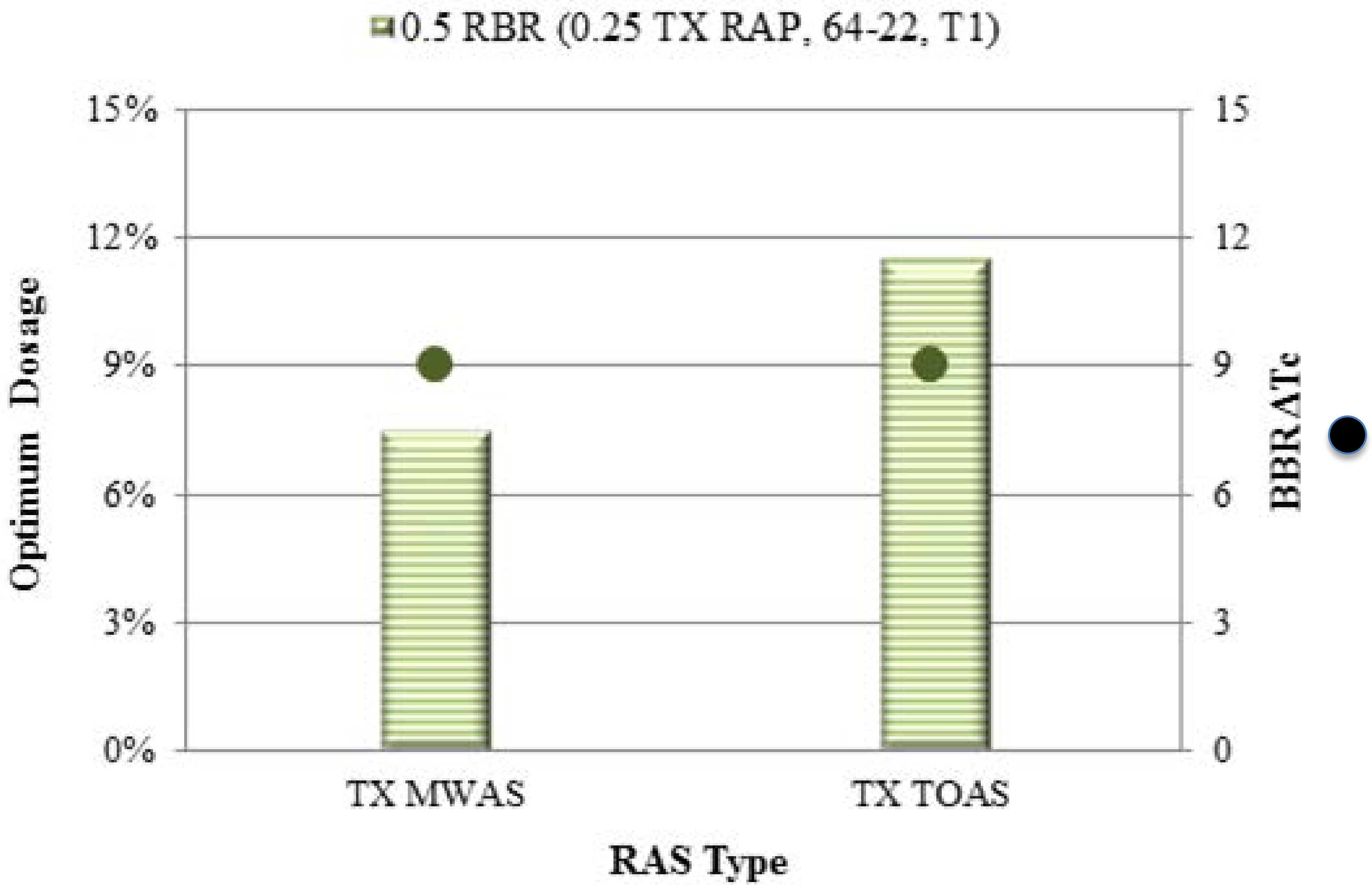
DOSAGE SELECTION – BASE BINDER TYPE



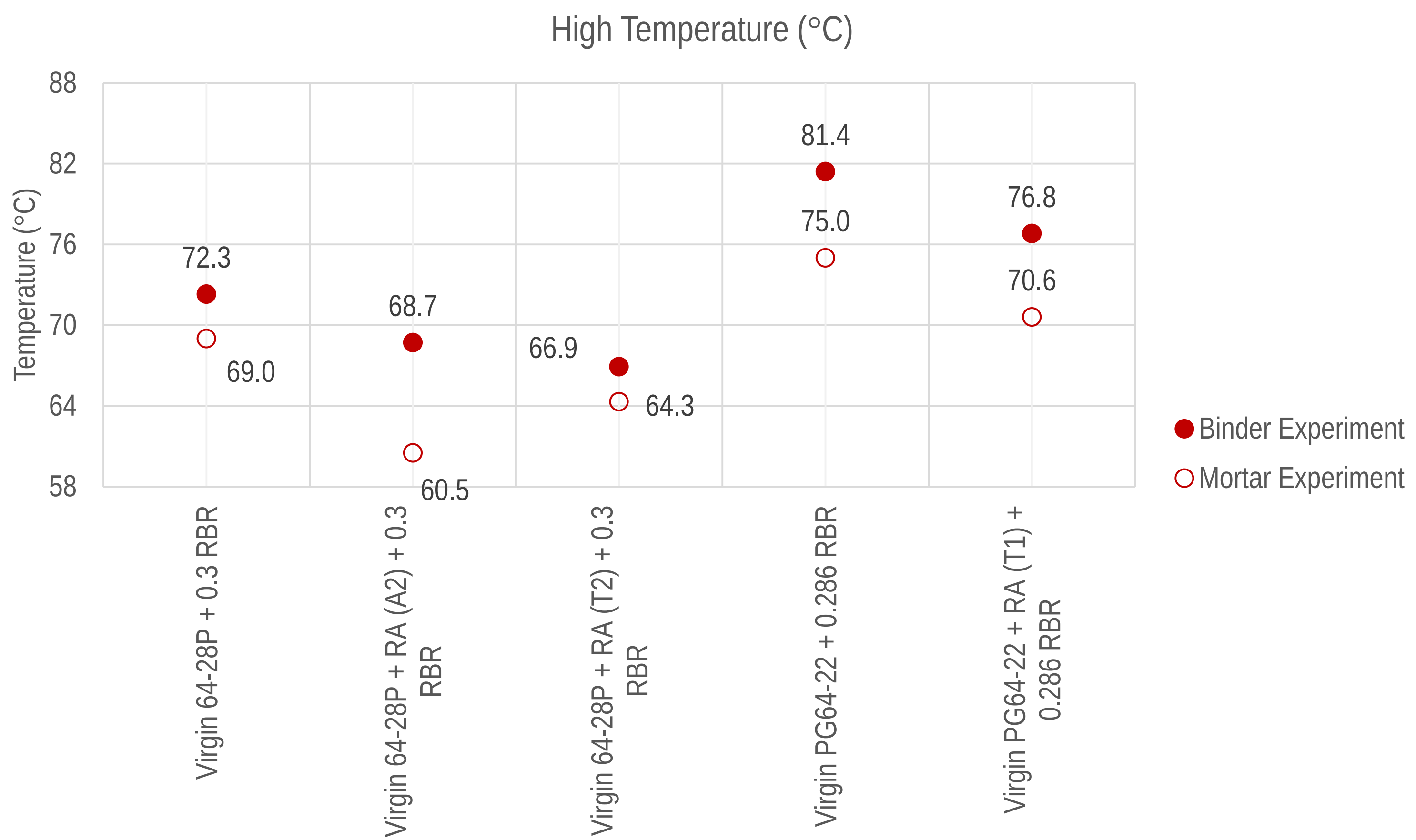
DOSAGE SELECTION – RA TYPE



DOSAGE SELECTION – RAS TYPE



RA Dosage Selection – Mortar Verification



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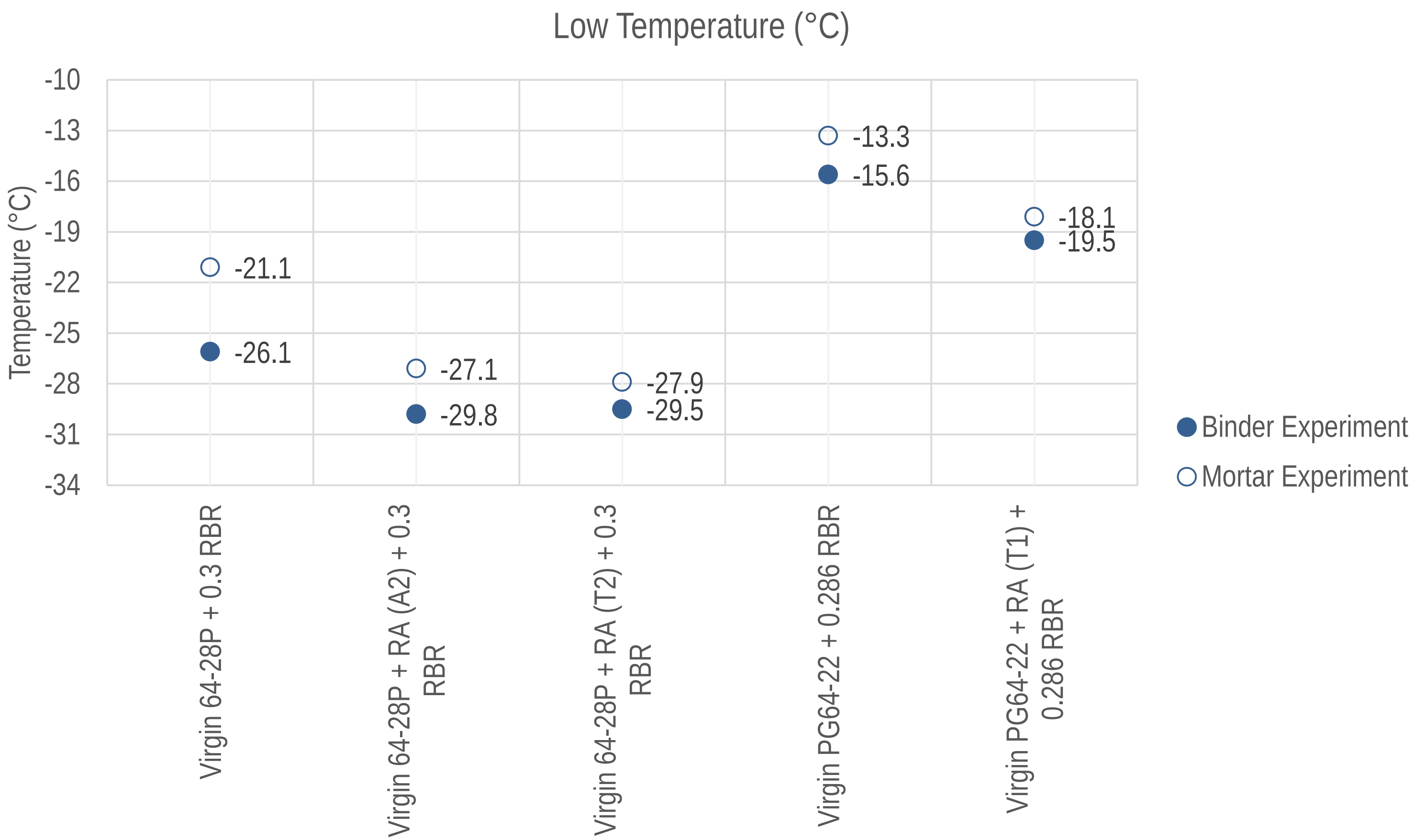
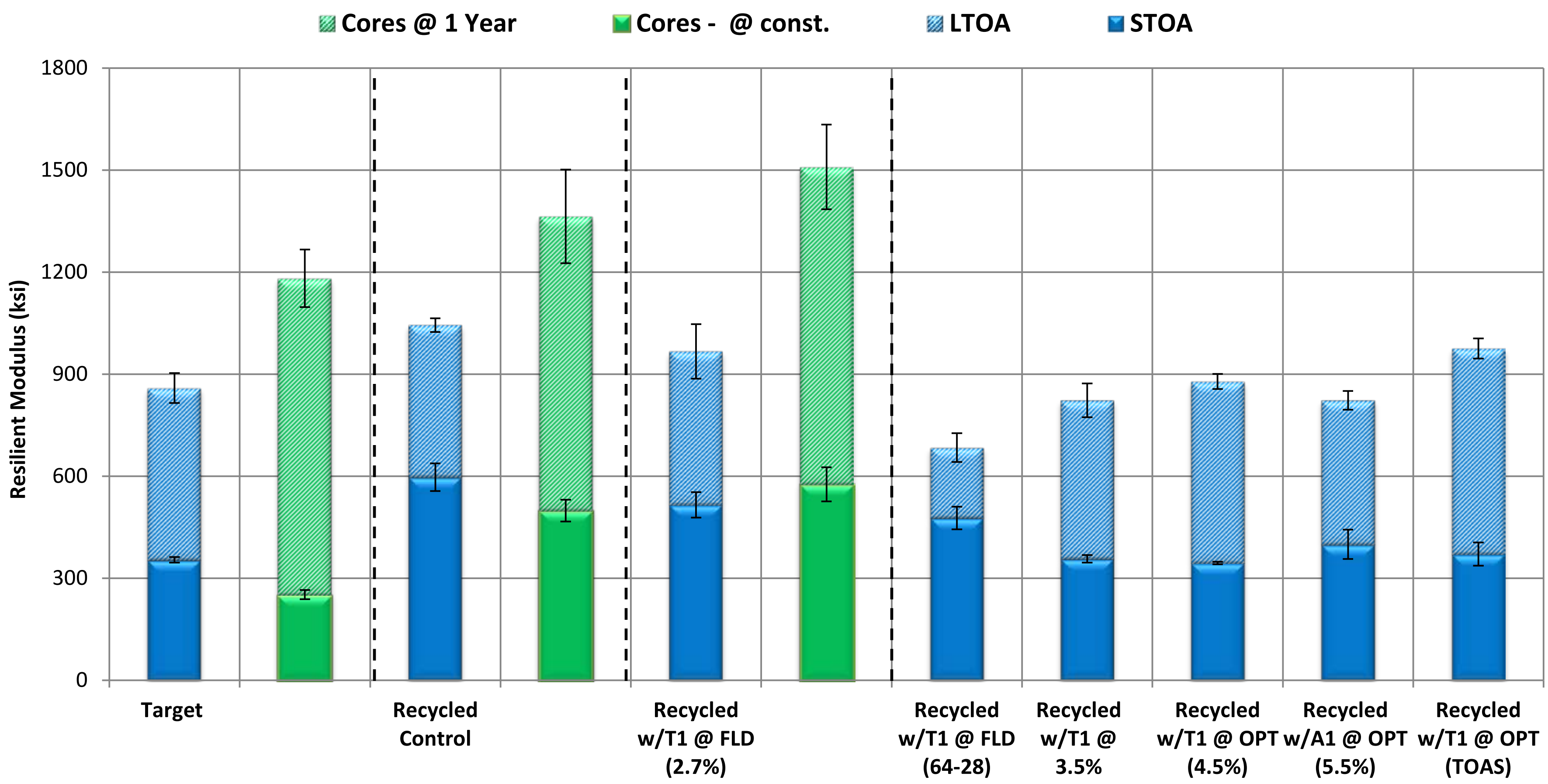
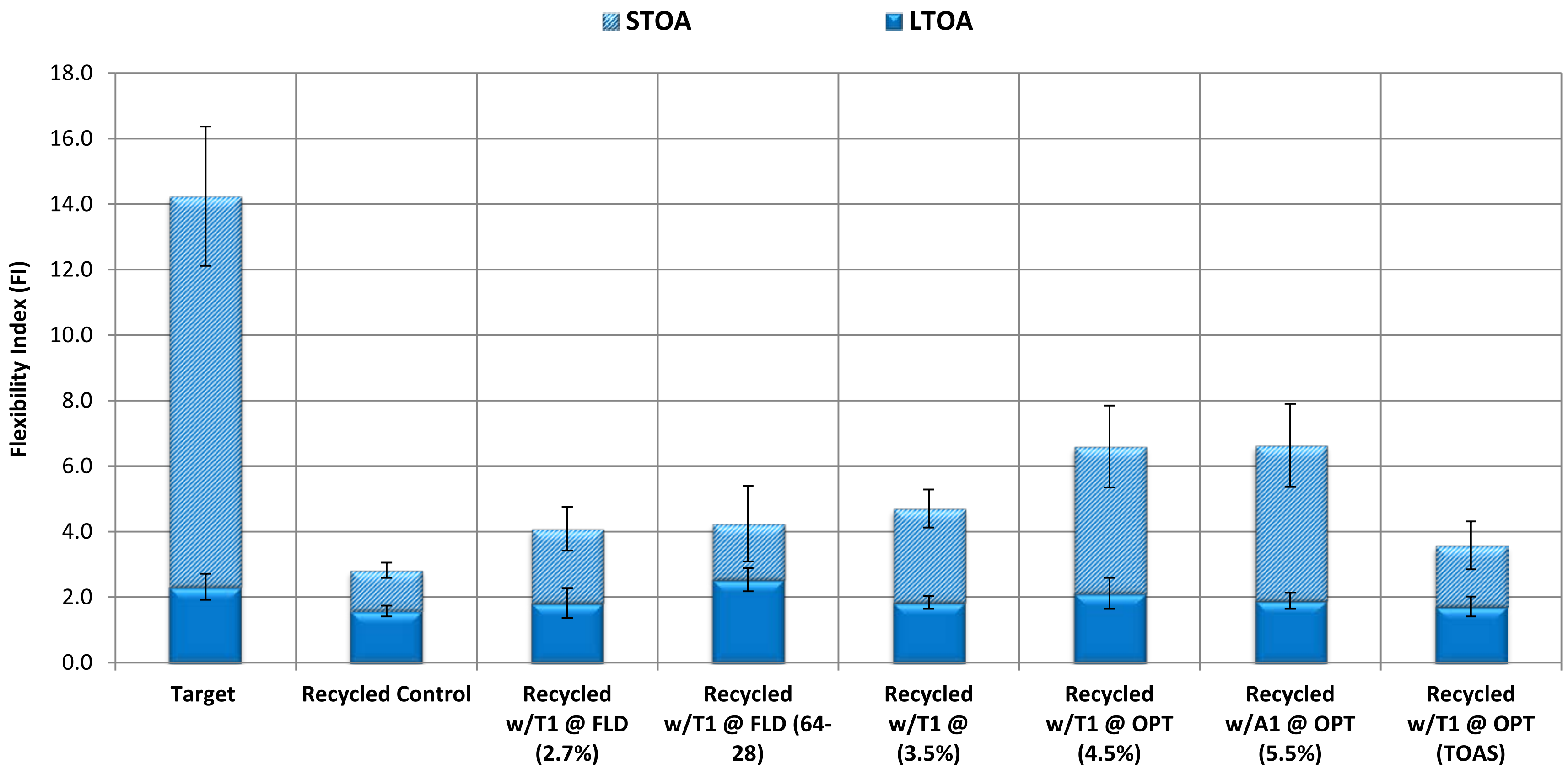


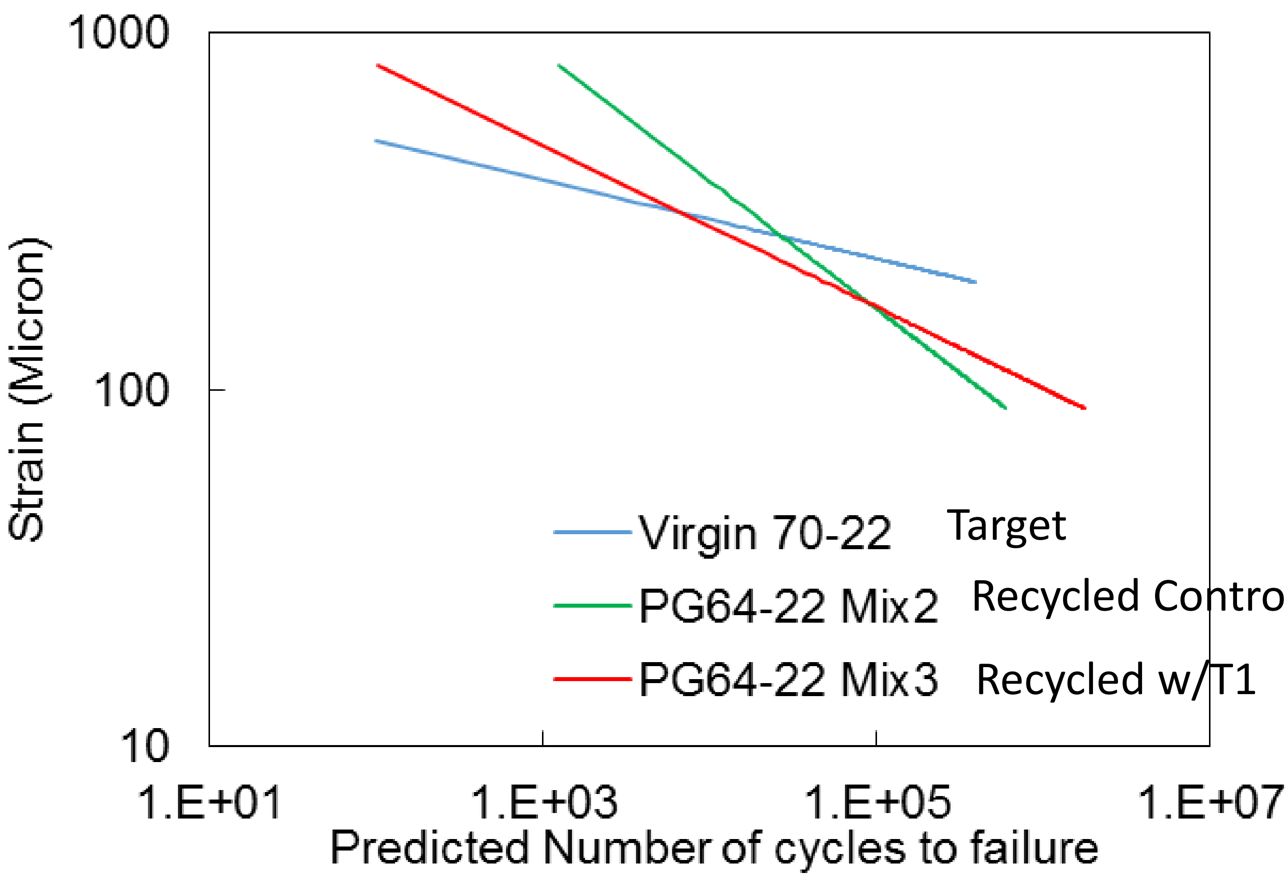
RA Dosage Selection – Mixture Validation - M_R



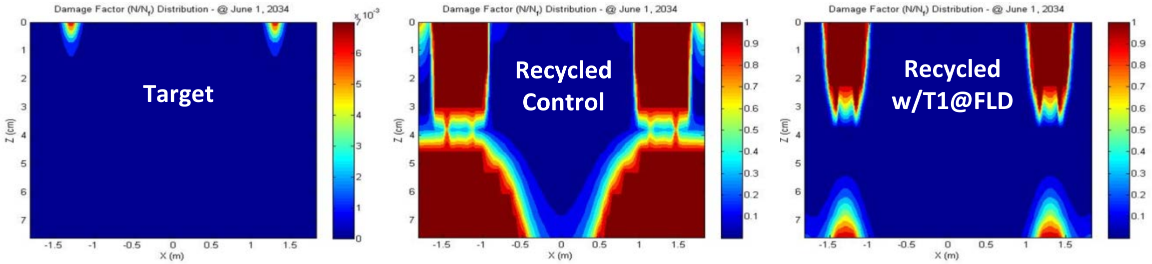
RA Dosage Selection – Mixture Validation - SCB

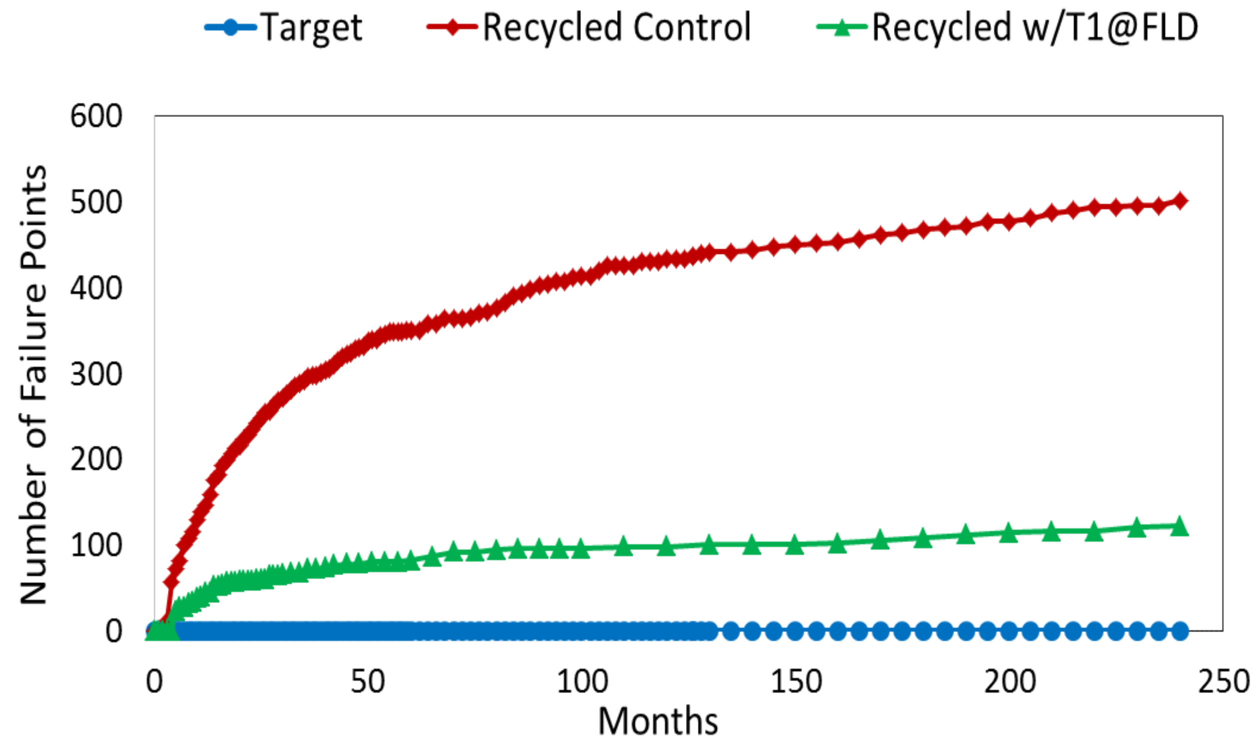


RA Dosage Selection – Mixture Validation S-VECD

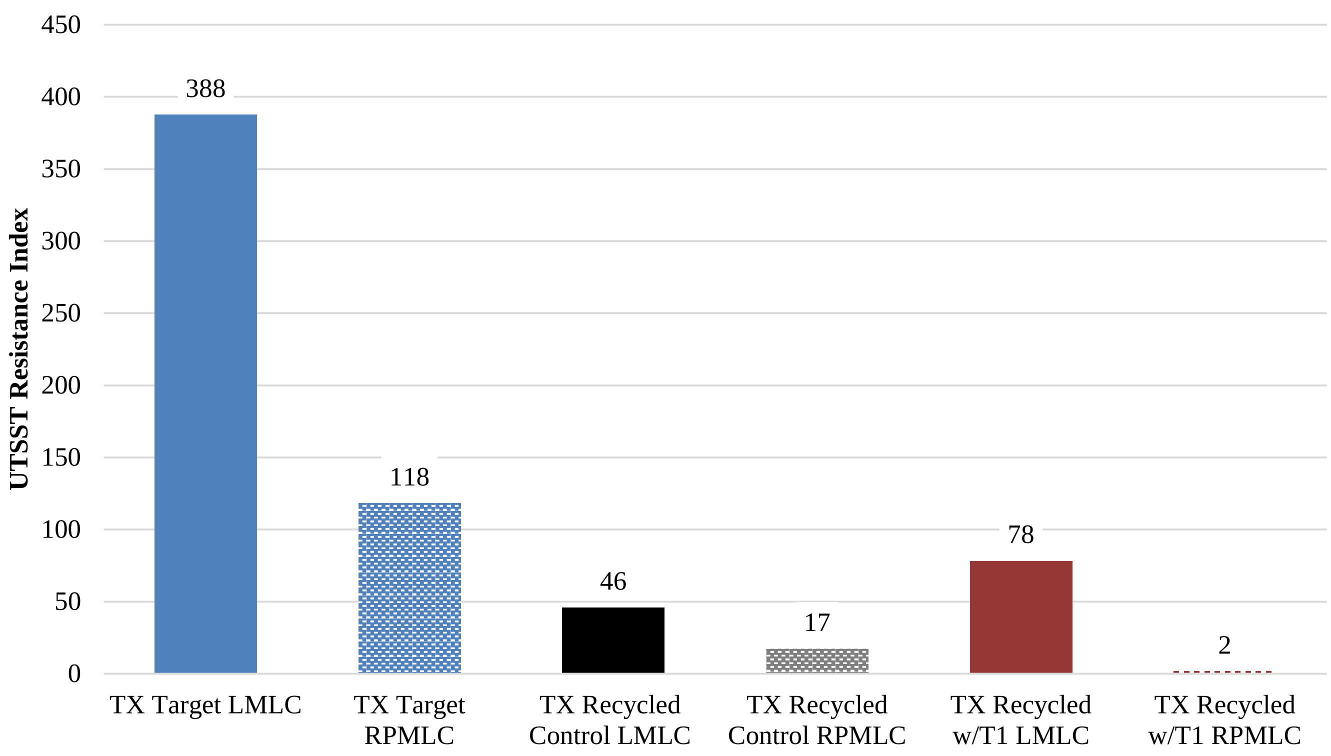


RA Dosage Selection – Mixture Validation LVECD





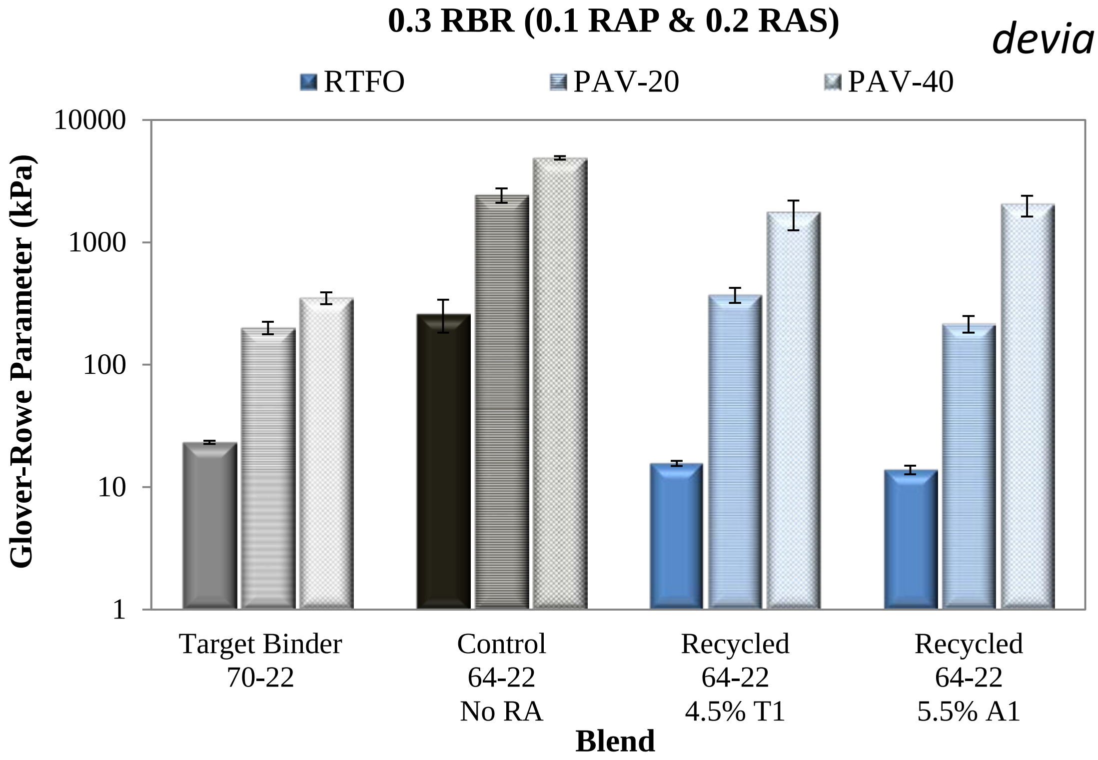
RA Dosage Selection – Mixture Validation UTSST



REJUVENATING EFFECTIVENESS & ITS EVOLUTION

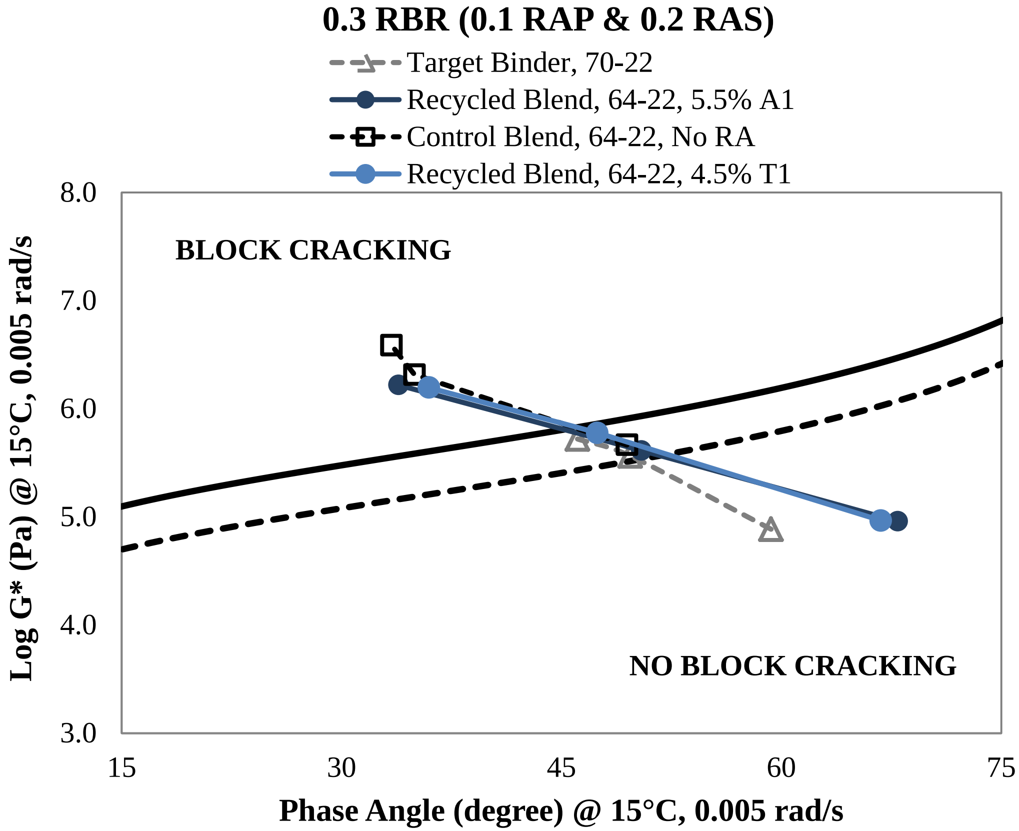
Overall G-R Results

Error bar: standard deviation of 2 replicates

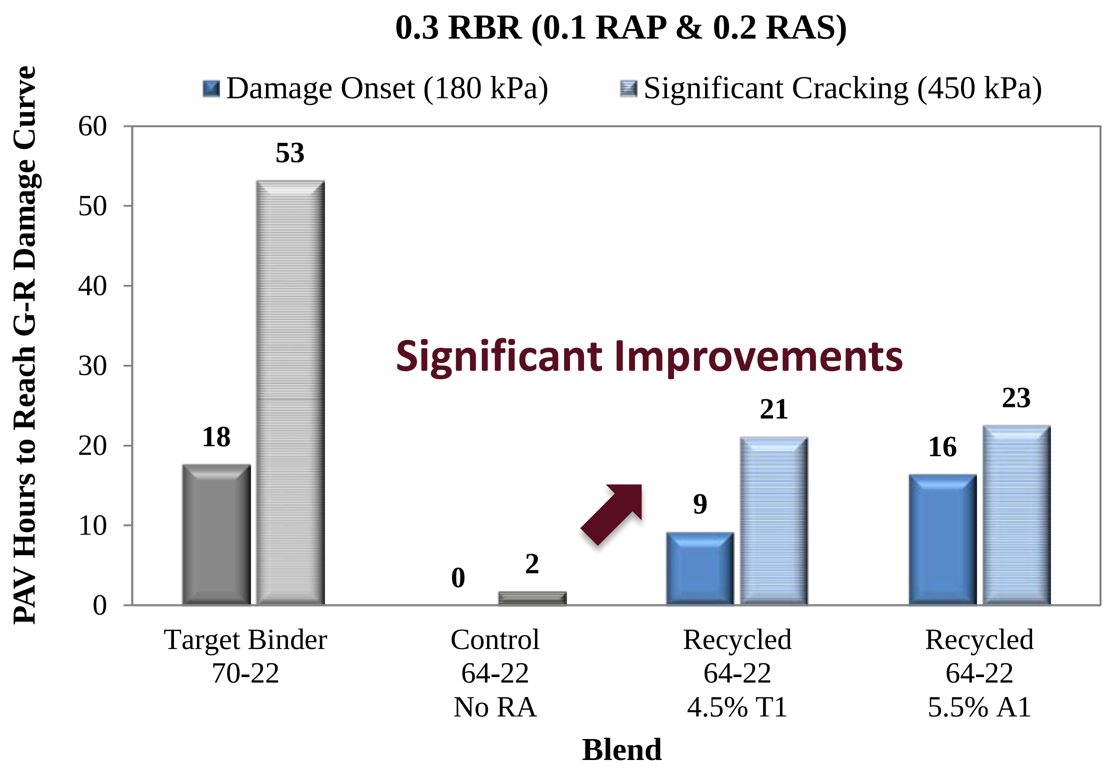


Target Binder ≤ Recycled Blends @ opt RA < Recycled Blend no RA

Black Space Diagram



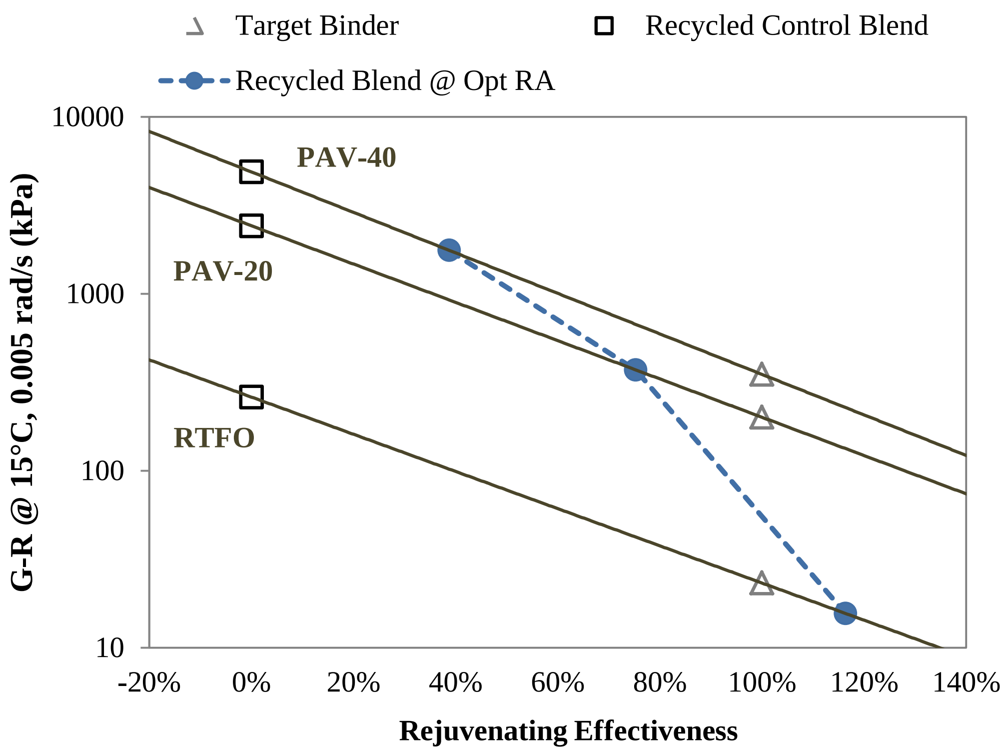
PAV Hours to reach G-R Damage Curve



Target Binder > Recycled Blends @ opt RA > Recycled Blend no RA

Rejuvenating Effectiveness (RE)

- Normalized difference in log(G-R) for recycled blend @ opt RA vs. target binder & recycled blend no RA



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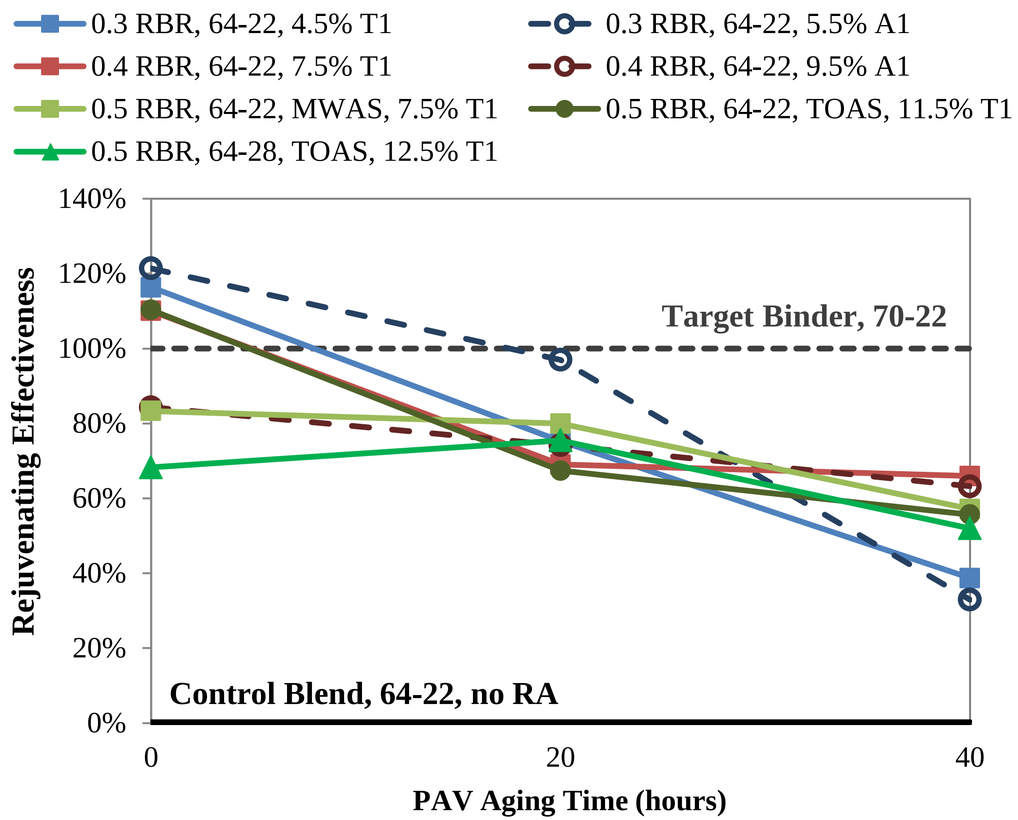
RE Evolution with PAV Aging



The “rejuvenating” effect of RA decreased with PAV aging

BINDER AVAILABILITY FROM RECYCLED MATERIALS

Problem Statement

- ❑ How much RAP binder is available and blends with the virgin binder during the mixing process?
- ❑ DOTs assume 100% of RAP binder will be active and become part of the mix - **100% RAP binder availability – not realistic**
  - a portion of RAP binder participates in the mixing process – **Active RAP binder**
  - a portion of RAP binder forms a stiff coating around the RAP aggregate and produces "black rock" – **Inactive RAP binder**
- ❑ **Partial binder availability – realistic**
  - Effect on performance?

Objective

- Develop a procedure to **quantify** **RAP binder availability**
  - **% active RAP** binder
  - **% inactive RAP** binder
- Evaluate the effect of recycling agents (RAs) on RAP binder availability

Background

- The amount of binder needed to coat the aggregate depends on:
  - **total binder content in the mix (AC%)**
  - **aggregate gradation**

- Each aggregate size will have a different binder content
- For a fixed AC% the binder content in each aggregate size will also remain fixed
  - For HMA mix with **4.5%** binder content:

    Binder contents on **3/8**, **#4**, and **(#8,30)** fractions are **2.7**, **4.0**, and **6.1**%, respectively

Binder Availability Methodology

Virgin Mix

1. Mix virgin binder & aggregate

2. Sieve loose mix

RAP Mix

1 . Mix virgin binder & aggregate + RAP

2. Sieve loose mix

3. Determine P_b of material retained in sieve # 4 using the ignition oven

Labeled as **Reference P_b**

* constant for specific mixture

Labeled as **RAP' P_b**

* varied based on RAP used

Example Binder Availability Calculation

Virgin Mix

P_b = 2.7% P_b = 4.0% P_b = 6.0%

Total P_b = 4.5%

RAP Mix

#4 RAP
(RAP P_b = 4.5%)

P_b < 2.7% P_b > 4.0% P_b < 6.0%

Total P_b = 4.5%
RBR = 0.3

Virgin Mix

Reference P_b = 4.0%

RAP Mix with 0.3RBR

RAP' P_b = 4.0%

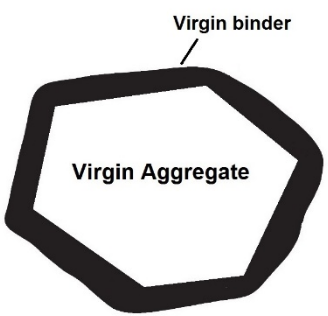
(70%*Reference P_b + 30%*Distributed RAP P_b)

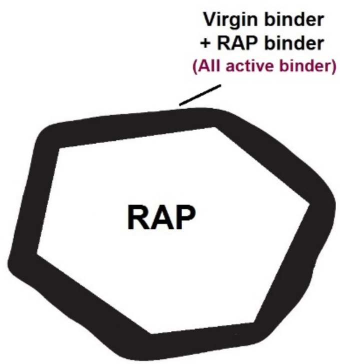
Virgin — RAP

RAP' P_b = 7.3%

(70%*Reference P_b + 100%*RAP P_b)

Virgin — RAP



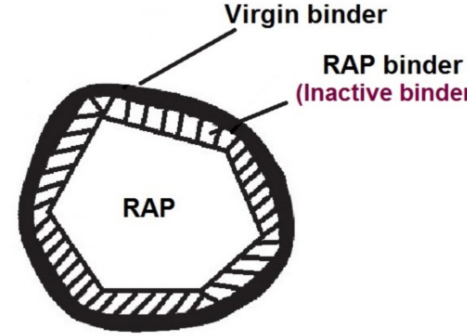


100% Available

Perfect Blending

partial availability

assuming linear relationship



0% Available

Black Rock

Preliminary Verification

- Produce Artificial RAP (#4 agg. + virgin binder)
  - RAP 1: no aging
  - RAP 2: 5 days @ 110°C
  - RAP 3: 10 days @ 110°C
  - RAP 4: 10 days @ 110°C plus 3 days at 150°C

aging

- 0.3 RBR
- Artificial RAP binder content: 4.5%
- Mixture total binder content: 4.5%

Preliminary Verification

Reference P_b = 4.0%

RAP′ P_b:

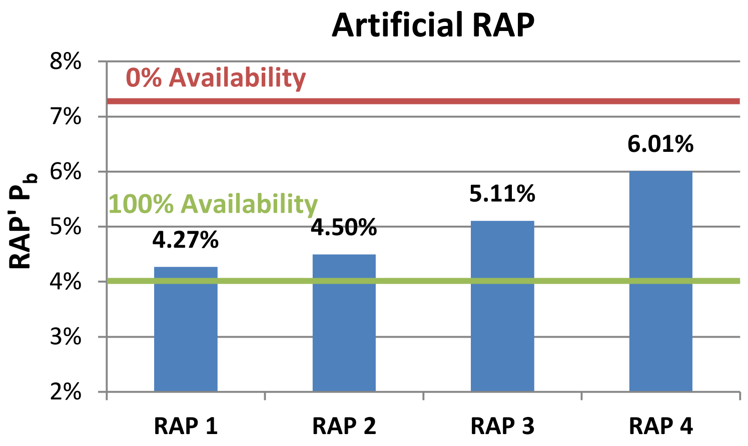
- 4.0%: 100% Availability
- 7.3%: 0% Availability

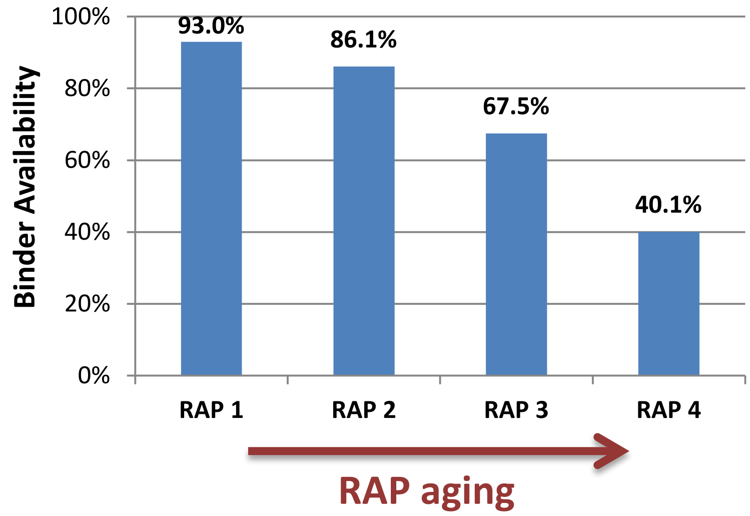
RAP′ (1) P_b = 4.0%

RAP′ (2) P_b = 4.5%

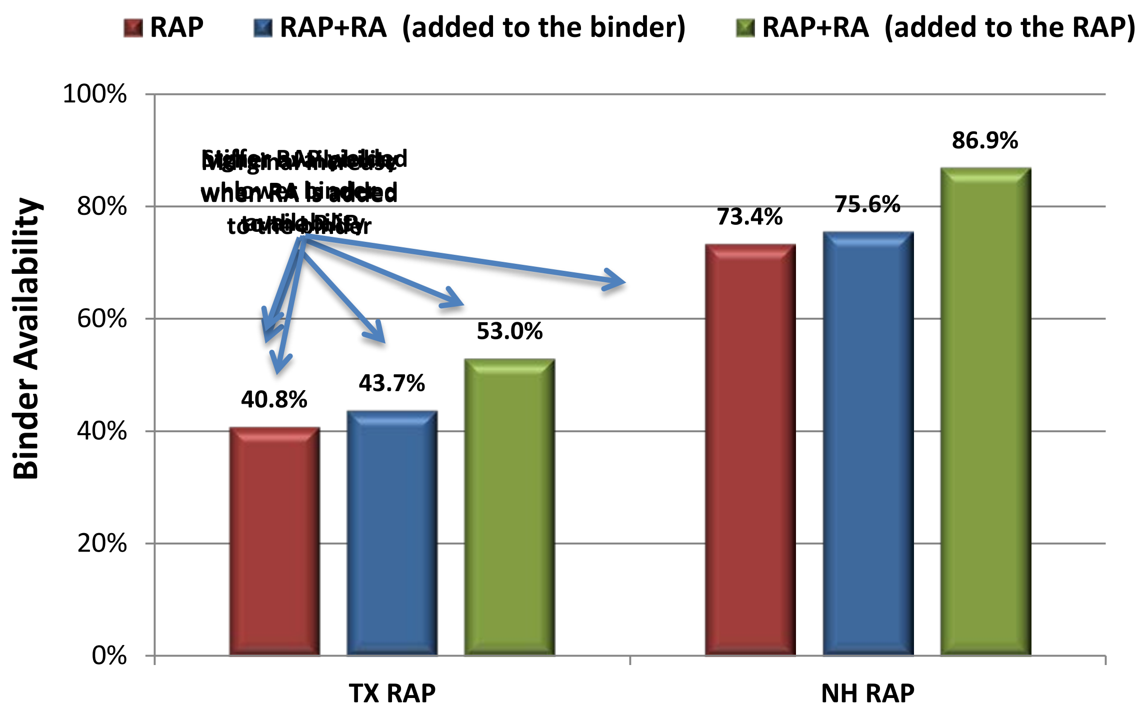
RAP′ (3) P_b = 5.1%

RAP′ (4) P_b = 6.0%





TX & NH RAP with RA



- 0.3 RBR
- TX & NH RAP binder contents are 4.7% and 4% respectively
- Mixture Total binder content: 4.5%

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Next Steps

- G-R Thresholds based on Climate
  - **Change T≠ 15°C**
  - **Change f ≠ 0.005 rad/s**
  - **Change Thresholds**
  - **Change Aging Durations to Reach Thresholds**
- Binder Availability
  - **Different size RAP**
  - **MWAS & TOAS**
  - **Higher RBRs**
  - **Degree of Blending (DOB)**
- Binder Compatibility
- Additional Field Projects – NV, IN, MO?, DE?

BACKUP

Motivation – High Recycled Binder Ratio (RBR)

Economic & Environmental Benefits
- Natural Resources
- Energy
- Emissions

Engineering Concerns
- Compactibility
- Stiffness & Embrittlement
- Cracking Resistance

Mitigation – Recycling Agent (RA)

BENEFITS

Engineering

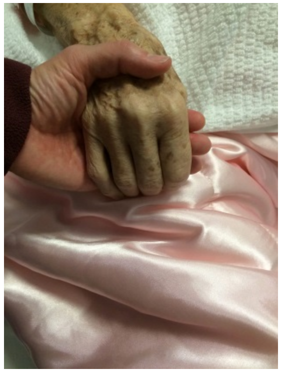
- Reduced Stiffness, Improved Compactibility
- Improved Cracking Resistance

Economic

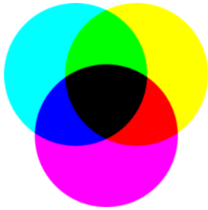
REMAINING ISSUES

Engineering

- Reduced Embrittlement
- Aging



- Blending

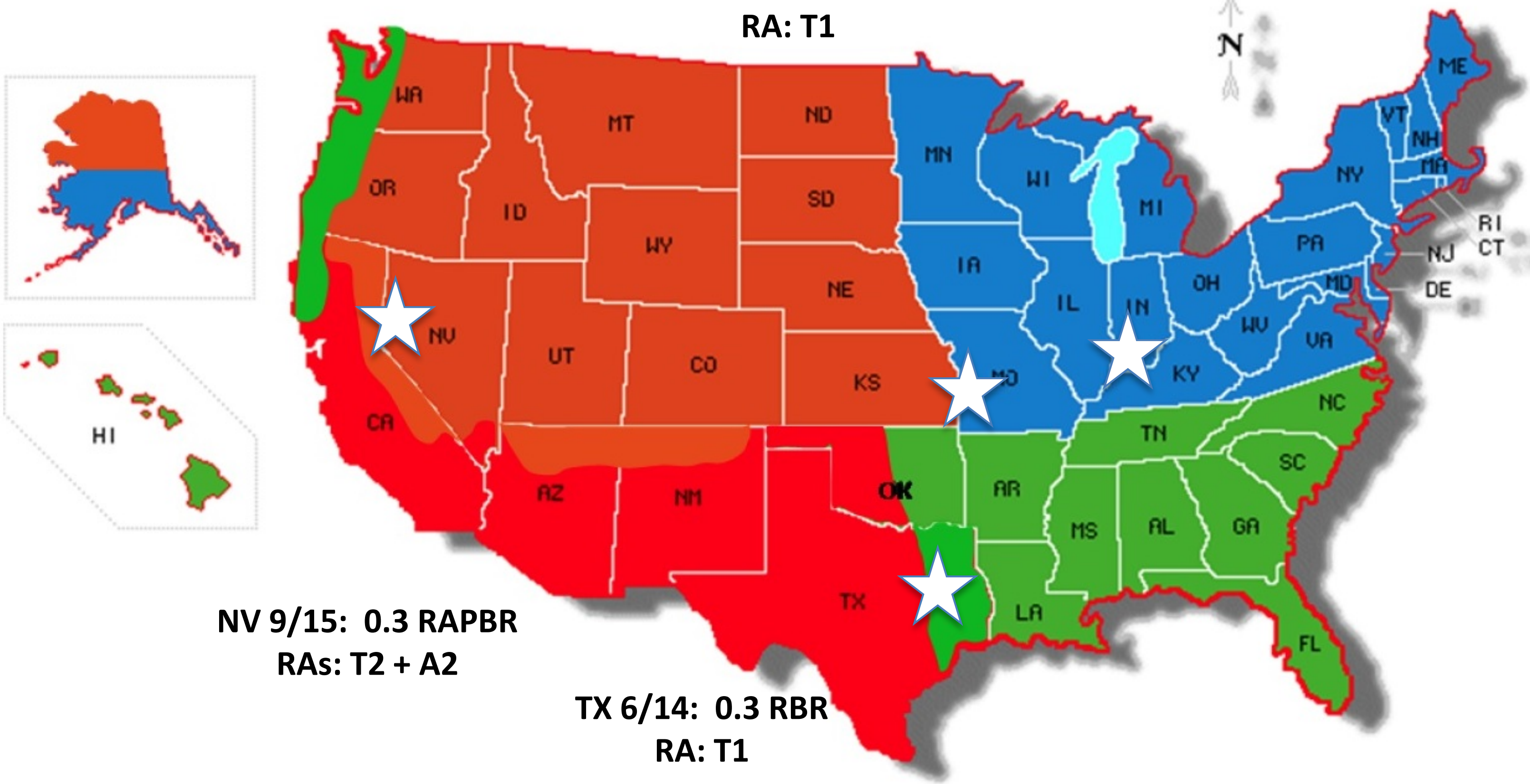


- Mixture Performance

Field Projects

Environmental Zones

- Wet-Freeze
- Dry -Freeze
- Dry -N Freeze
- Wet-No Freeze



MO 2016: 0.45 RBR
RA: T1

IN 9/15: 0.4, 0.5 RBR
RA: T2

NV 9/15: 0.3 RAPBR
RAs: T2 + A2

TX 6/14: 0.3 RBR
RA: T1

TX (Expanded) & NV Field Materials

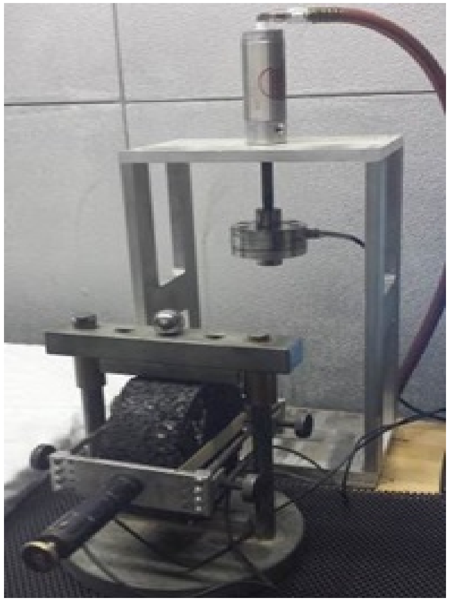
- **TX: PG 64-22 + 0.3 RBR (0.1 RAP+0.2 MWAS) + 2.7% Tall Oil T1 (Target=PG 70-22)**
- **+0.4 RBR** w/RAP only, **0.5 RBR** balanced RAP/RAS
- **+ Aromatic Extract A1**
- **+ NH PG 64-28** & **NV PG 64-28P**
- **+ TX TOAS & NH RAP**
- **NV: PG 64-28P + 0.3 RBR (0.3 RAP) + 2.0% Tall Oil T2 & + 2.0% Tall Oil A2 (Target=PG64-28)**

Laboratory Tests – BINDER & MORTAR

- PG - BOTH
- G-R

Laboratory Tests - MIXTURE

- Stiffness
  - M_R @ 25 °C
  - E*
- Cracking Resistance
  - SCB
  - S-VECD
  - UTSST

RA Dosage Selection – Mortar Verification

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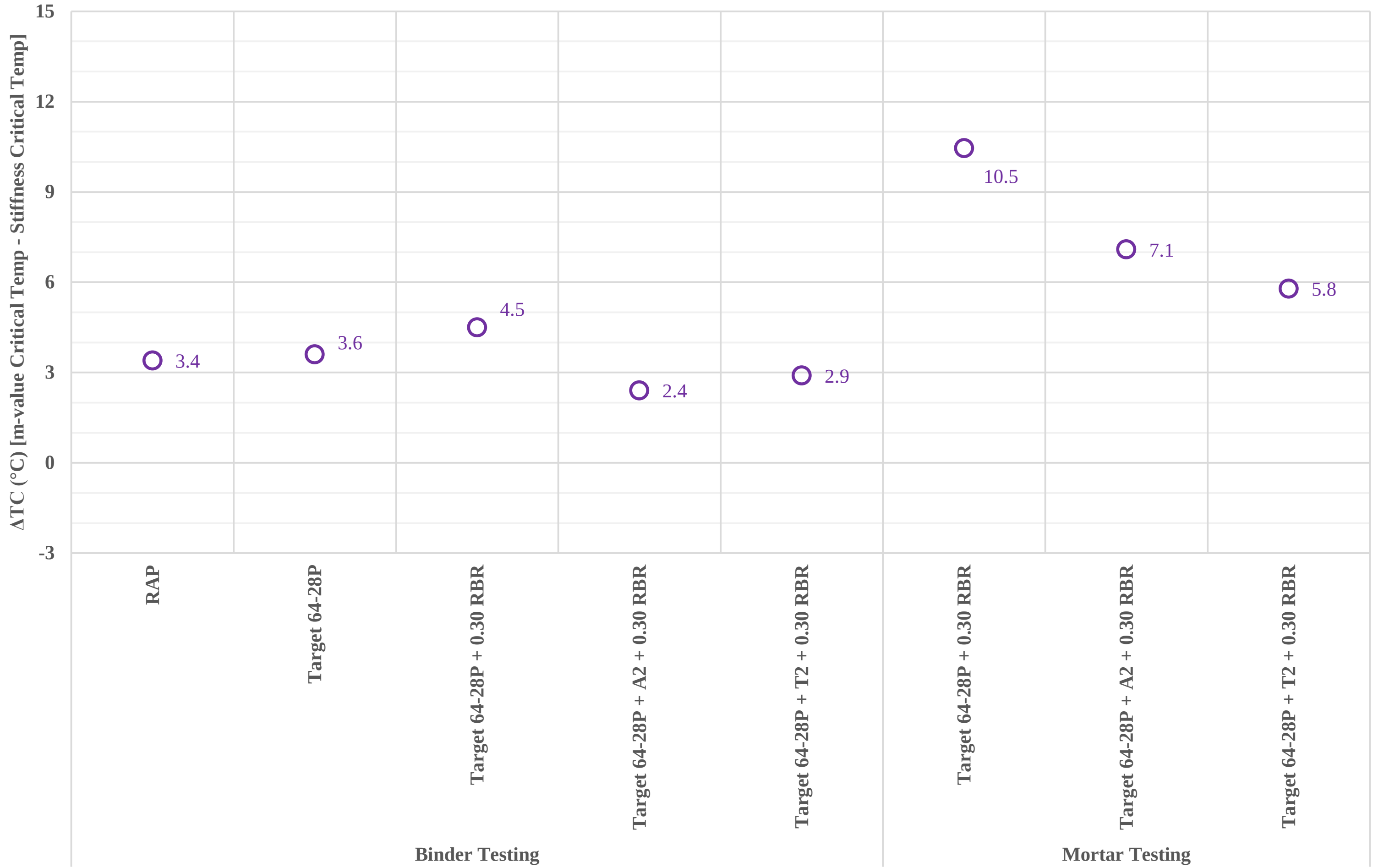
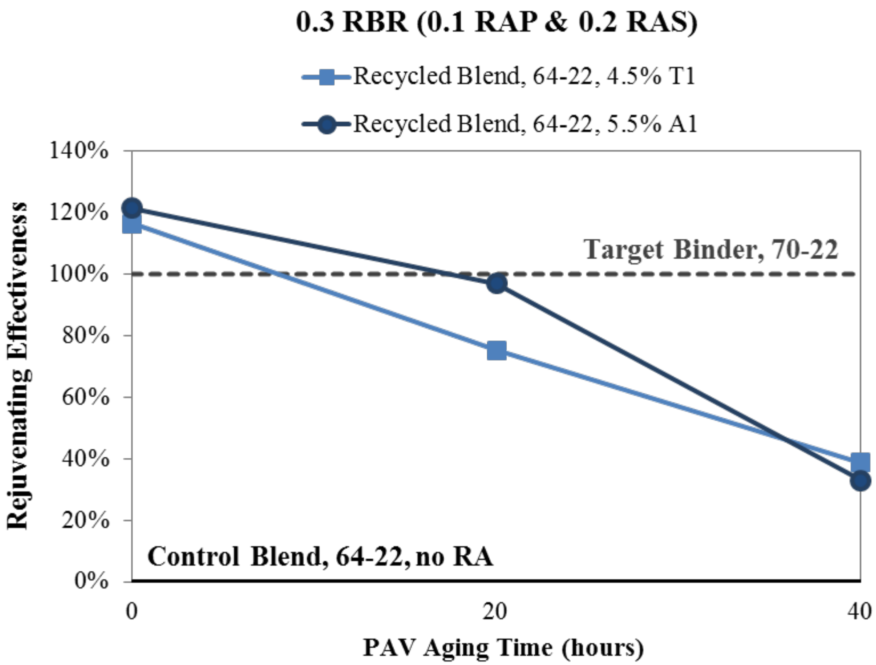
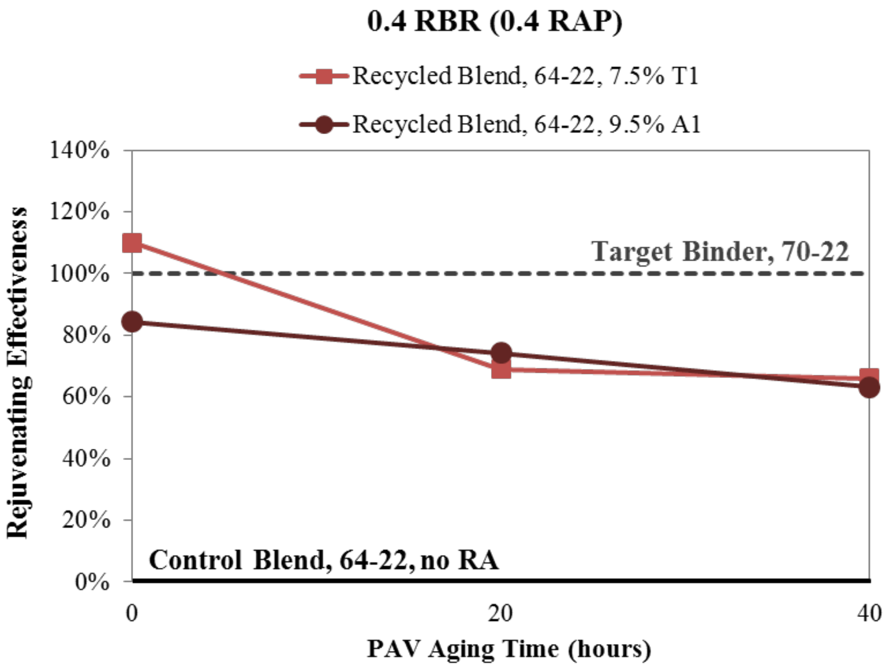


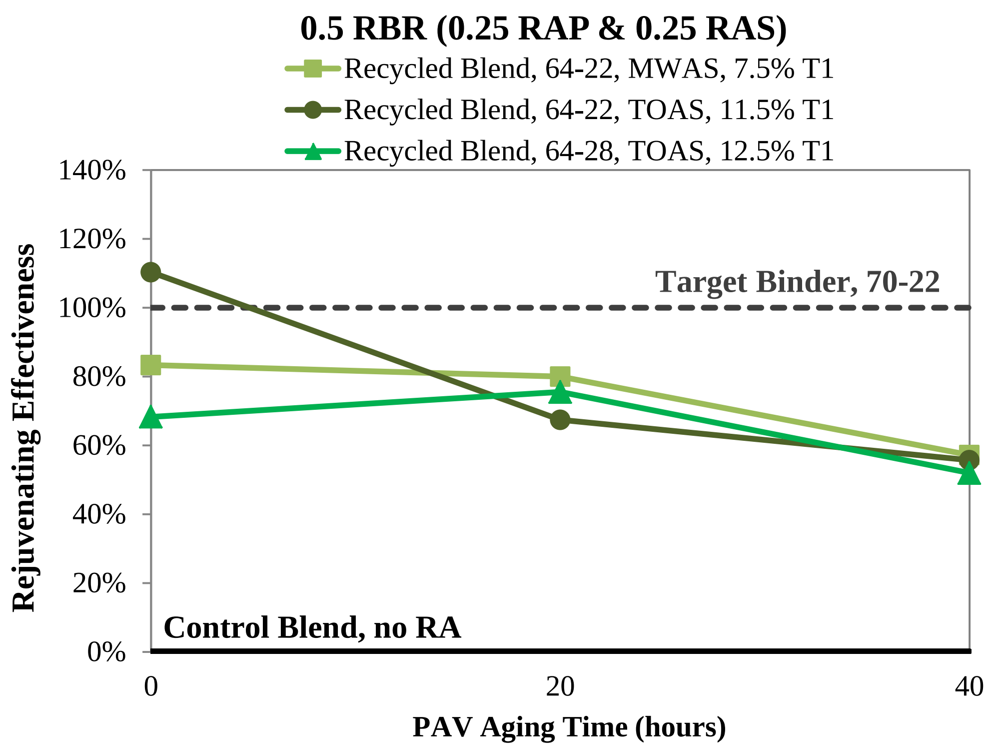
RE Evolution with PAV Aging



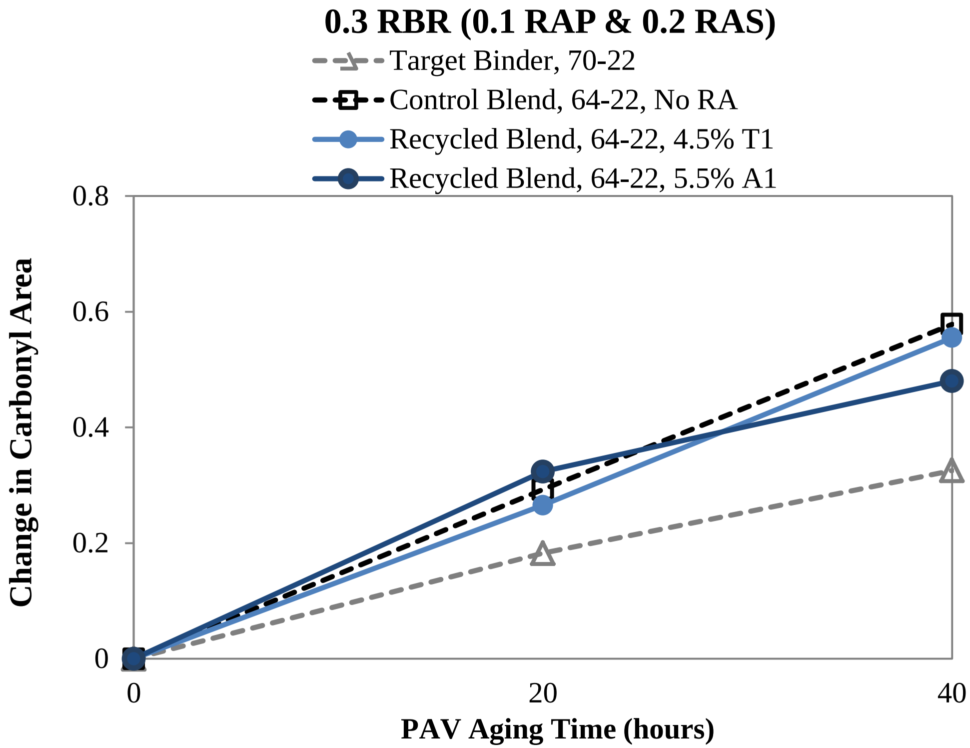


The “rejuvenating” effect of RA decreased with PAV aging

RE Evolution with PAV Aging

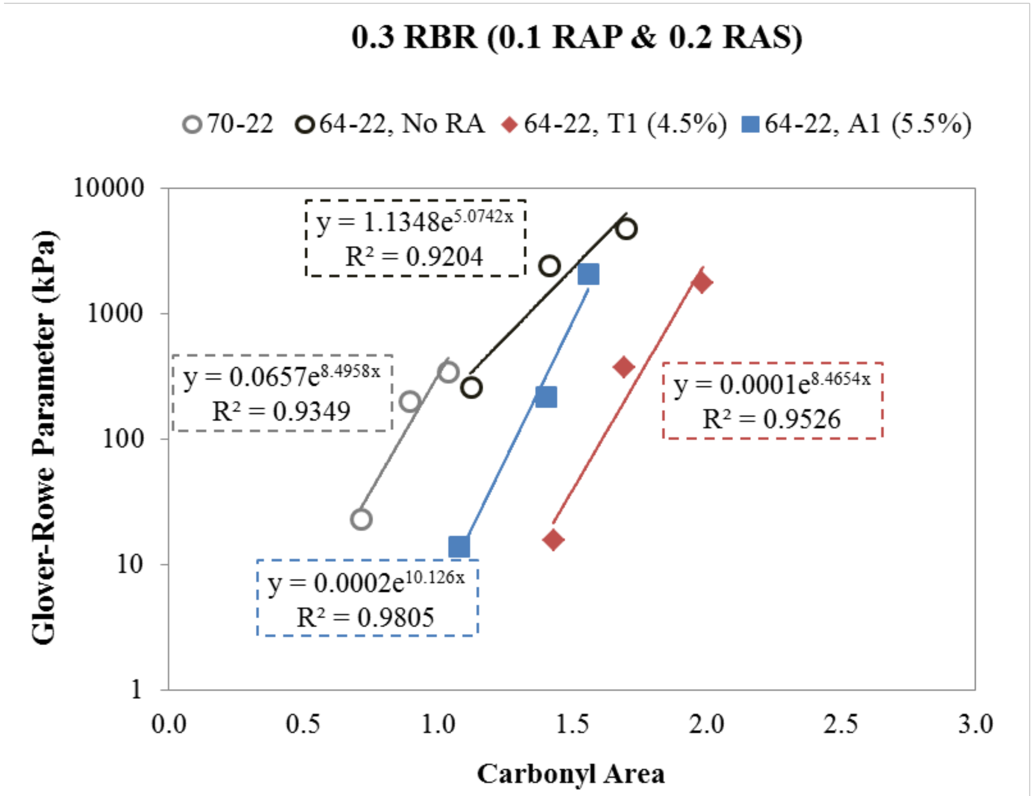


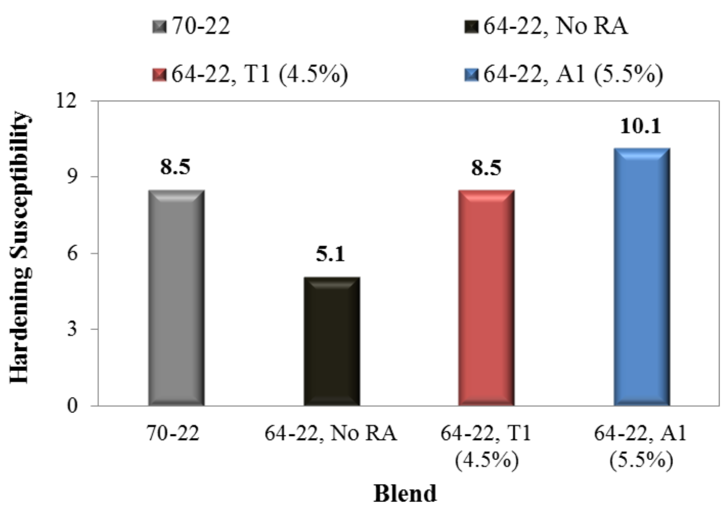
Change in CA with PAV Aging



Recycled Blends @ opt RA = Recycled Blend no RA

G-R Hardening Sensitivity





Recycled Blends @ opt RA > Recycled Blend no RA