PENN STATE

Evaluating Testing, Protocols, and Limits for Asphalt Rejuvenating Agents

PennDOT/Penn State Research

Pennsylvania Asphalt Pavement Association 63rd Annual Conference

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PA Asphalt Pavement Assoc.

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Northeast Center of Excellence For Pavement Technology

NECEPT

Acknowledgement

- PennDOT Sponsored Research
- Project Start Date: September, 2019
- Project End Date: September, 2022
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  - Mahsa Tofighian (MS Student)

Outline

1. Background on Rejuvenating Agents (RA)
2. Experimental Study
   - Binder Study
   - Mixture Study
3. Results & Findings
4. Usage Guide

Background on Rejuvenating Agents (RA)

What Are Rejuvenators

- The higher the ratio of asphaltene to maltenes, the higher brittleness and cracking potential of asphalt binder
- Asphalt Rejuvenators peptize and polarize asphaltenes
- Rebalance the ratio of Asphaltenes to Maltenes
- Reduce cracking potential
- Maintain long-term effectiveness

Peptizing: Dispersing and Deflocculating

Where do we need rejuvenators?

- **Most often when the RAP content or RAS content is high, or when a combination of RAP and RAS is used in the asphalt mixture**

- **Need to consider several elements to decide if RA is needed and at what dosage rate:**

  - **RBR (reclaimed binder ratio) from RAP/RAS**
  - **Performance grade of all binders (Virgin, RAP, RAS, and Target)**
  - **Design binder content**

Rejuvenator Types

- **Two Principal Categories:**
  - **Petroleum Based**
    - **Paraffinic oil, aromatic extracts, engine oil**
  - **Plant Based (Bio-Based)**
    - **vegetable oil (virgin, modified, or waste), tall oil**

Dosage Rate Definition

- **Defined in four ways based on ratio of the rejuvenator mass to the material of interest (reported in percentage).**

- **Dosage Rate can be reported as a percentage of**

  - **1. Virgin Binder**
  - **2. Recycled asphalt binder (from RAP/RAS)**
  - **3. Total asphalt content (or total fluid content)**
  - **4. Total mass of the asphalt mixture**

Experimental Study

- **Binder Study**
- **Mixture Study**

Selection of Rejuvenators

Company	Product	Description	Abbreviation Used in this Study
Holly Frontier	Hydrolene H90T	Extracts (petroleum), heavy paraffinic distillate solvent	HT
Cargill	ANOVA 1815	Biobased additive	AN
Ingevity	Evoflex CA-7	Engineered additive designed to work with Evotherm®, production temperatures lower than 275°F	IN
Green Asphalt Tech	Hydrogreen S	100% natural mixtures of plant extracts, Rosins, Rosin Esters, fatty acids, and vegetable oils	HG
Krayton	Sylvaroad RP1000	Crude Tall Oil (CTO), a renewable raw material that is a by-product of the paper industry	SR

- **Selection of Binders**
  - **PG 58S-28 (61.0—30.0)**
  - **PG 64S-22 (69.0-24.5)**
- **Selection of RAP/RAS**
  - **One Source of RAP (PG 90.2-17.9), BC: 5.3%**
  - **One Source of RAS (PG 143.0-11.9), BC: 22.7%**

Binder Testing

Binder Test	AASHTO Standard	Response	Purpose
Dynamic shear rheometer at high and intermediate temperatures	T 315	Modulus and phase angle	Performance grade based on AASHTO M 320
Bending Beam Rheometer at low temperature	T 313	Binder stiffness and relaxation value (m-value)	Critical cracking temperature and ΔTC
Multiple Stress Creep and Recovery	T 350	Creep compliance and percent recovery	Potential for rutting and elastic recovery, Performance Grade based on AASHTO M 332
Short-Term Conditioning (Aging)	T 240	To deliver short-term oxidized aged material for testing and evaluation	Evaluate effect of rejuvenator on short-term aged binder
Long-Term Conditioning (Aging)	R 28	To deliver long-term oxidized aged material for testing and evaluation	Evaluate effect of rejuvenator on long-term aged binder

Dosage Rate for Binder Selection

Type of Blend	Rejuvenator Content as Percent of Total Binder
Rejuvenator + Virgin Binder	3
Rejuvenator + RAP Binder	5 and 10
Rejuvenator + Virgin Binder + RAP Binder	2

Types of Mixtures Used in This Research

Mix Type	%RAP	%RAS	Control Mix (No Rejuvenator)?	Mixes Designed with Rejuvenators			
1	15	5	Yes	IN	AN	HT	HG
2	35	0	Yes	IN	AN	HT	HG
3	0	5	Yes	IN	AN		

Mixtures Containing RA Short Term Aged

Mix Information										
MIX ID	Virgin AC, %	Total AC, %	RAP %	RAS %	Rejuv. Type	Rej. % of Total binder	Rej. % of Virgin binder	RBR from RAP	RBR from RAS	Total RBR
Specimens are short-term aged at 135C for 4 hours, followed by conditioning at 150C for 1 hour before compaction.										
Experimental Mixes (i.e., mixes with the recycling agents)										
#4	3.2	4.7	12.0	4.0	CA-7	2.38	3.54	0.13	0.19	0.33
#5	4.2	5.7	12.0	4.0	CA-7	2.58	3.54	0.11	0.16	0.27
#18	3.8	5.7	15.0	5.0	CA-7	2.35	3.54	0.14	0.20	0.34
#20	3.8	5.7	15.0	5.0	CA-7	2.35	3.54	0.14	0.20	0.34
#21	3.8	5.7	15.0	5.0	CA-7	4.70	7.08	0.14	0.20	0.34
#23	3.8	5.7	15.0	5.0	CA-7	5.30	7.99	0.14	0.20	0.34
#38	3.7	5.6	35.0	0.0	CA-7	3.20	4.80	0.33	0.00	0.33
#24	4.1	6.0	15.0	5.0	Anova	1.30	1.91	0.13	0.19	0.32
#39	3.7	5.6	35.0	0.0	HT	2.88	4.32	0.33	0.00	0.33
#40	3.7	5.6	35.0	0.0	HG	2.50	3.75	0.33	0.00	0.33
#42	3.7	5.6	35.0	0.0	Anova	1.10	1.65	0.33	0.00	0.33
#35	4.6	5.7	0.0	5.0	CA-7	1.90	2.37	0.00	0.20	0.20
#36	4.6	5.7	0.0	5.0	Anova	0.80	1.00	0.00	0.20	0.20
#25	4.1	6.0	15.0	5.0	HT	2.88	4.24	0.13	0.19	0.32
#26	4.1	6.0	15.0	5.0	HG	2.50	3.68	0.13	0.19	0.32

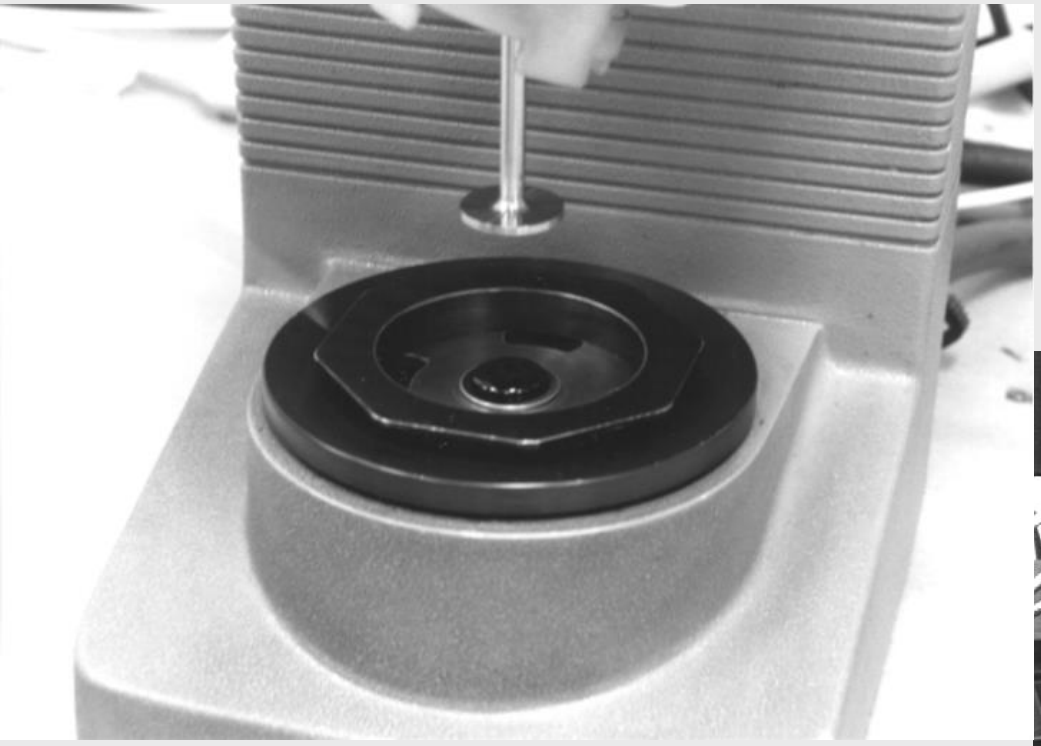
Mixtures Containing RA Long-Term Aged

Mix Information										
MIX ID	Virgin AC, %	Total AC, %	RAP %	RAS %	Rejuv. Type	Rej. % of Total binder	Rej. % of Virgin binder	RBR from RAP	RBR from RAS	Total RBR
Specimens are long-term aged at 135C for 8 hours, followed by conditioning at 150C for 2 hours before compaction.										
Experimental Mixes (i.e., mixes with the recycling agents)										
#24	4.1	6.0	15.0	5.0	Anova	1.30	1.91	0.13	0.19	0.32
#33	3.8	5.7	35.0	0.0	None	0.00	0.00	0.33	0.00	0.33
#39	3.7	5.6	35.0	0.0	HT	2.88	4.32	0.33	0.00	0.33
#23	3.8	5.7	15.0	5.0	CA-7	5.30	7.99	0.14	0.20	0.34
#38	3.7	5.6	35.0	0.0	CA-7	3.20	4.80	0.33	0.00	0.33

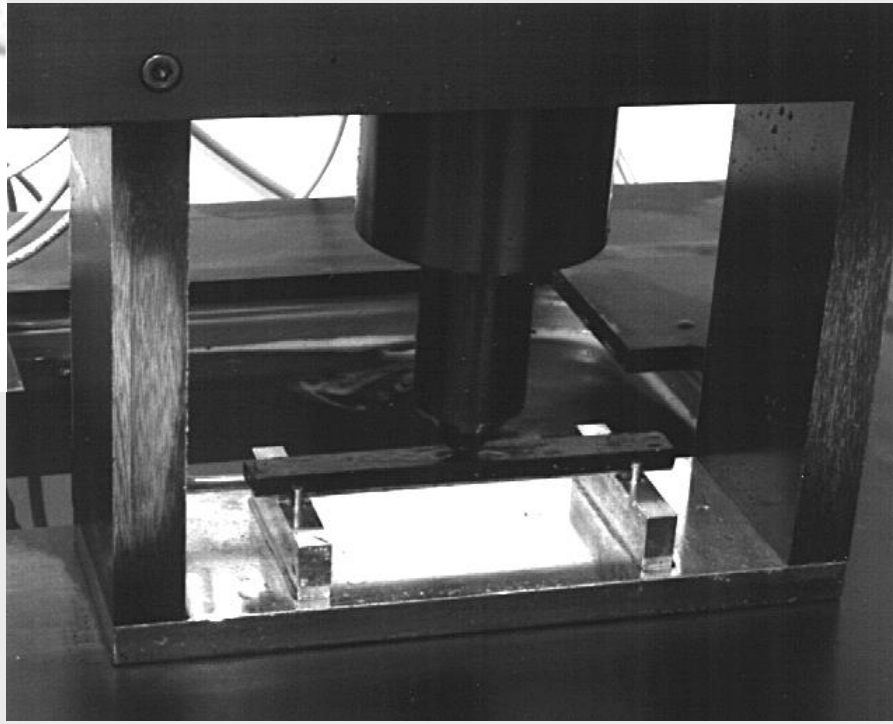
Control Mixtures (NO RA)

Mix Information										
MIX ID	Virgin AC, %	Total AC, %	RAP %	RAS %	Rejuv. Type	Rej. % of Total binder	Rej. % of Virgin binder	RBR from RAP	RBR from RAS	Total RBR
Specimens are short-term aged at 135C for 4 hours, followed by conditioning at 150C for 1 hour before compaction.										
Control Mixes (i.e., mixes without recycling agents)										
#19	3.8	5.7	15.0	5.0	None	0.00	0.00	0.14	0.20	0.34
#33	3.8	5.7	35.0	0.0	None	0.00	0.00	0.33	0.00	0.33
#37	4.6	5.7	0.0	5.0	None	0.00	0.00	0.00	0.20	0.20

Characterizing the Binders



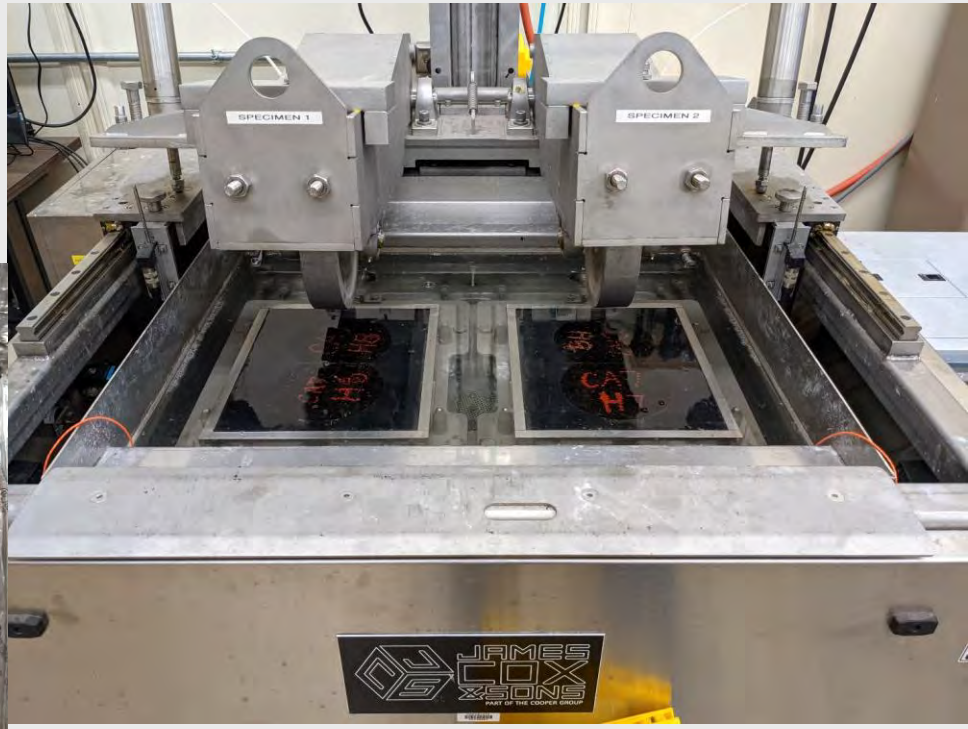
DSR

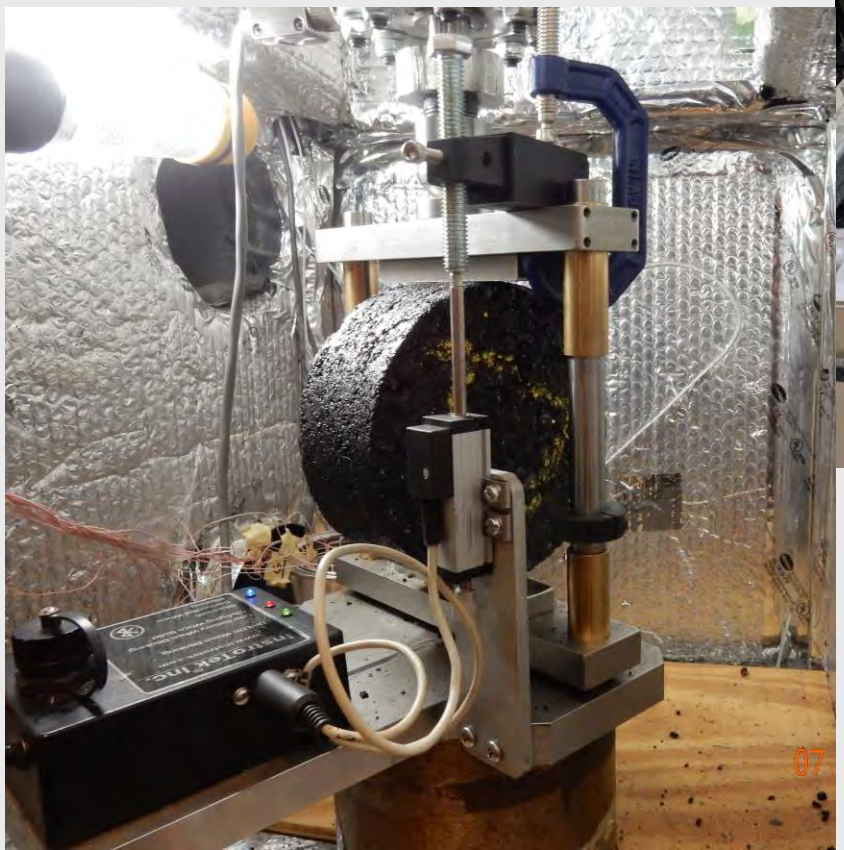


BBR

Mixture Performance Index Tests

HWT



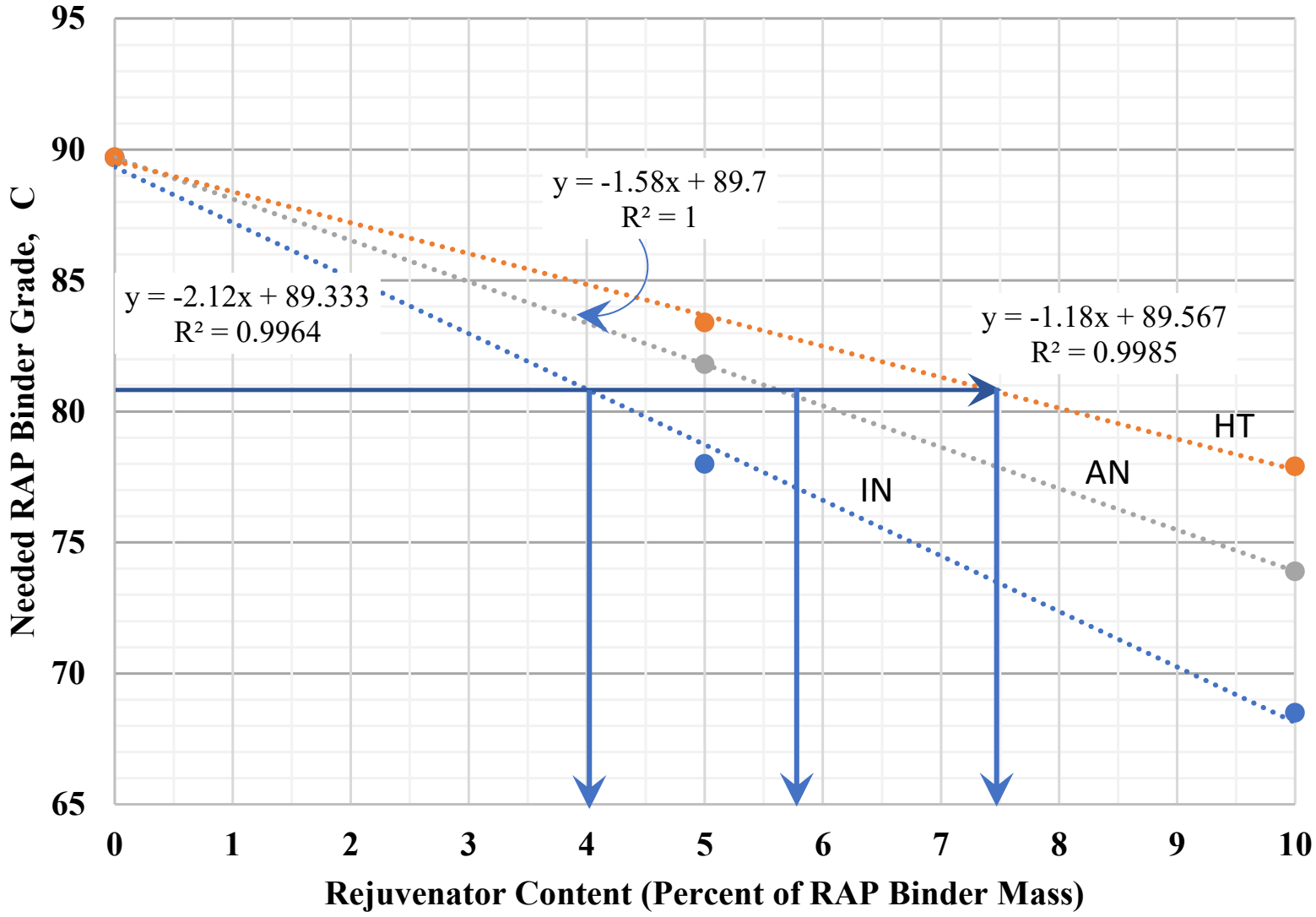


IDEAL-CT

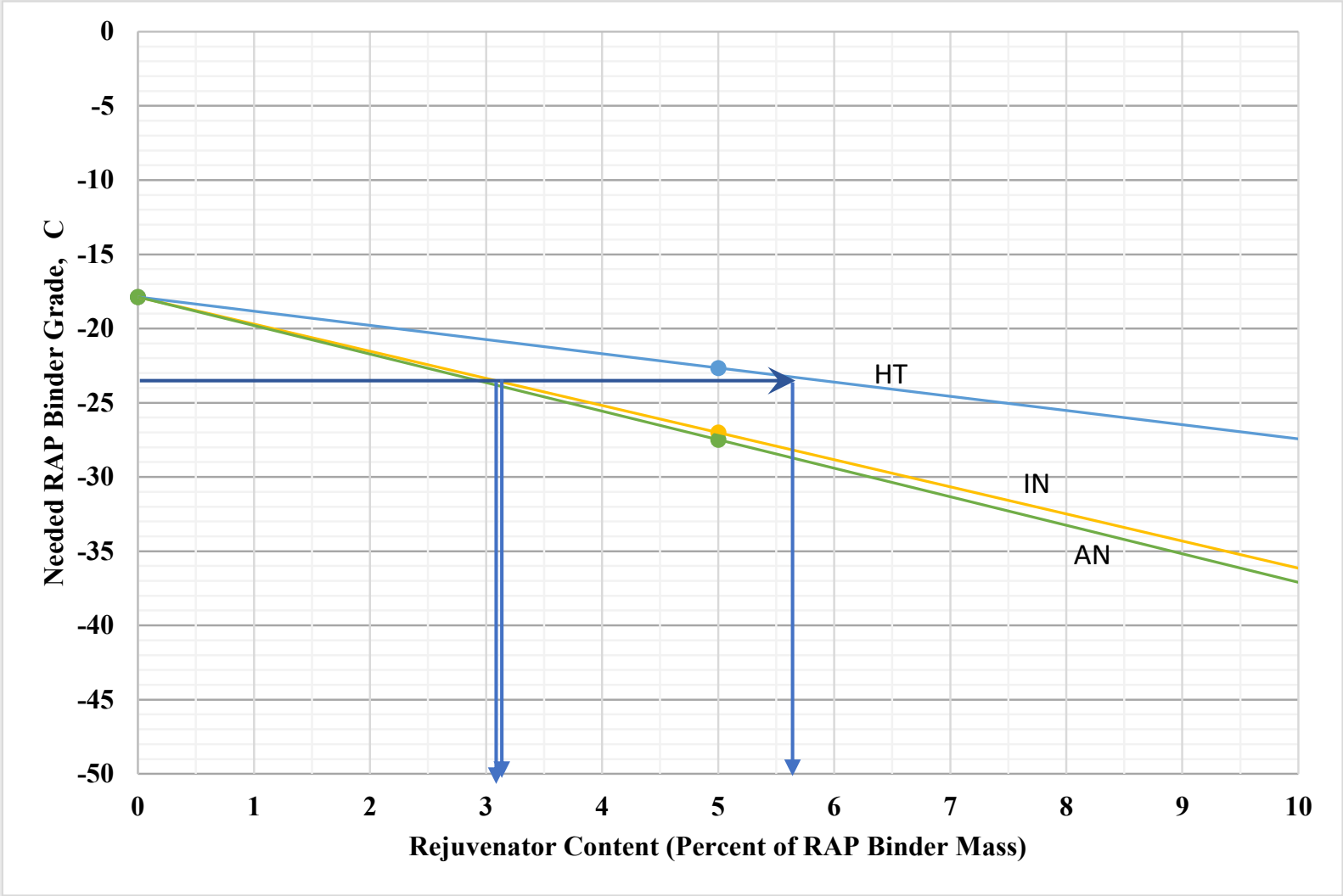
Results & Findings

Testing the Binders

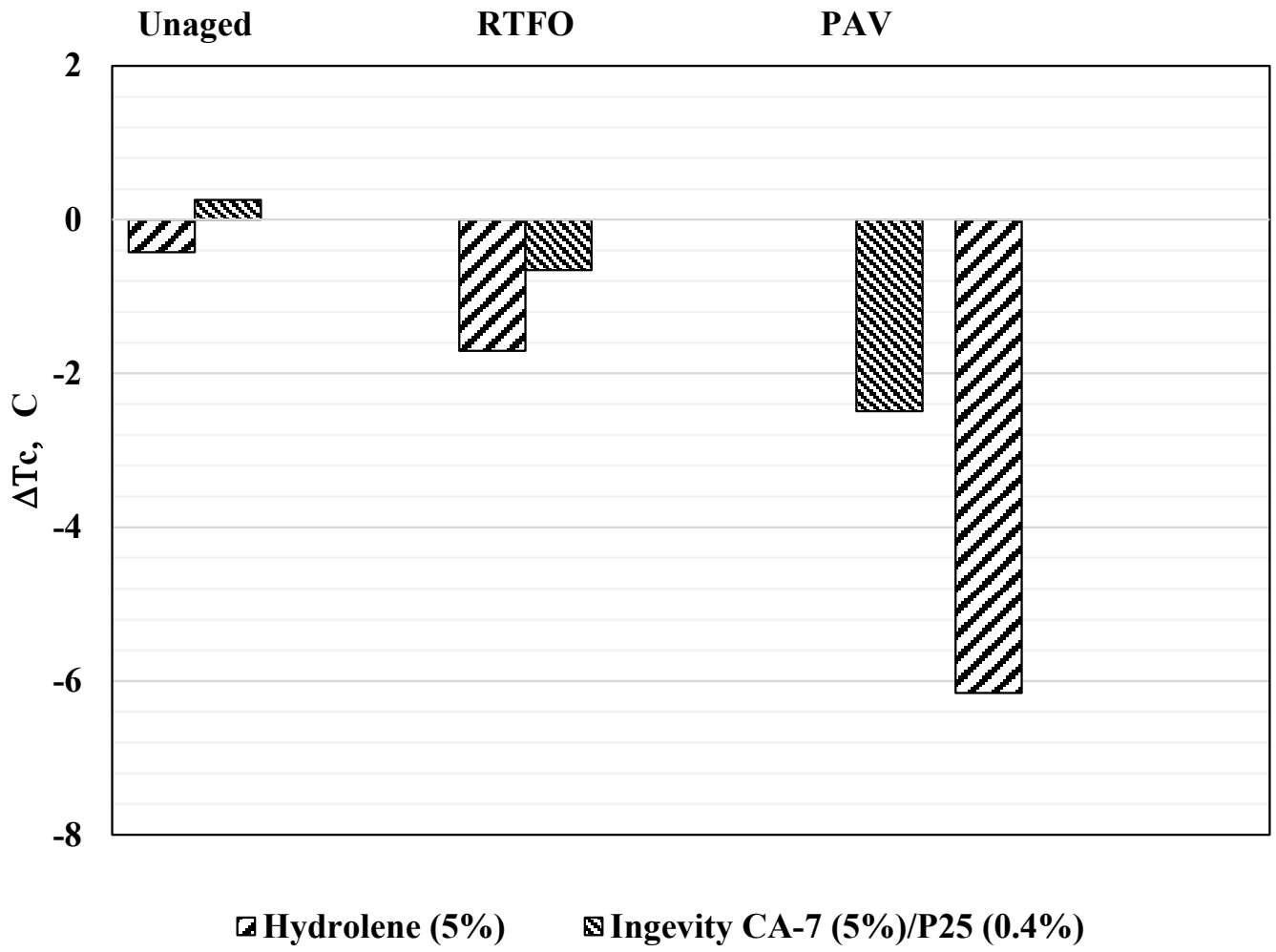
Effect on RAP Binder (High Temp.)



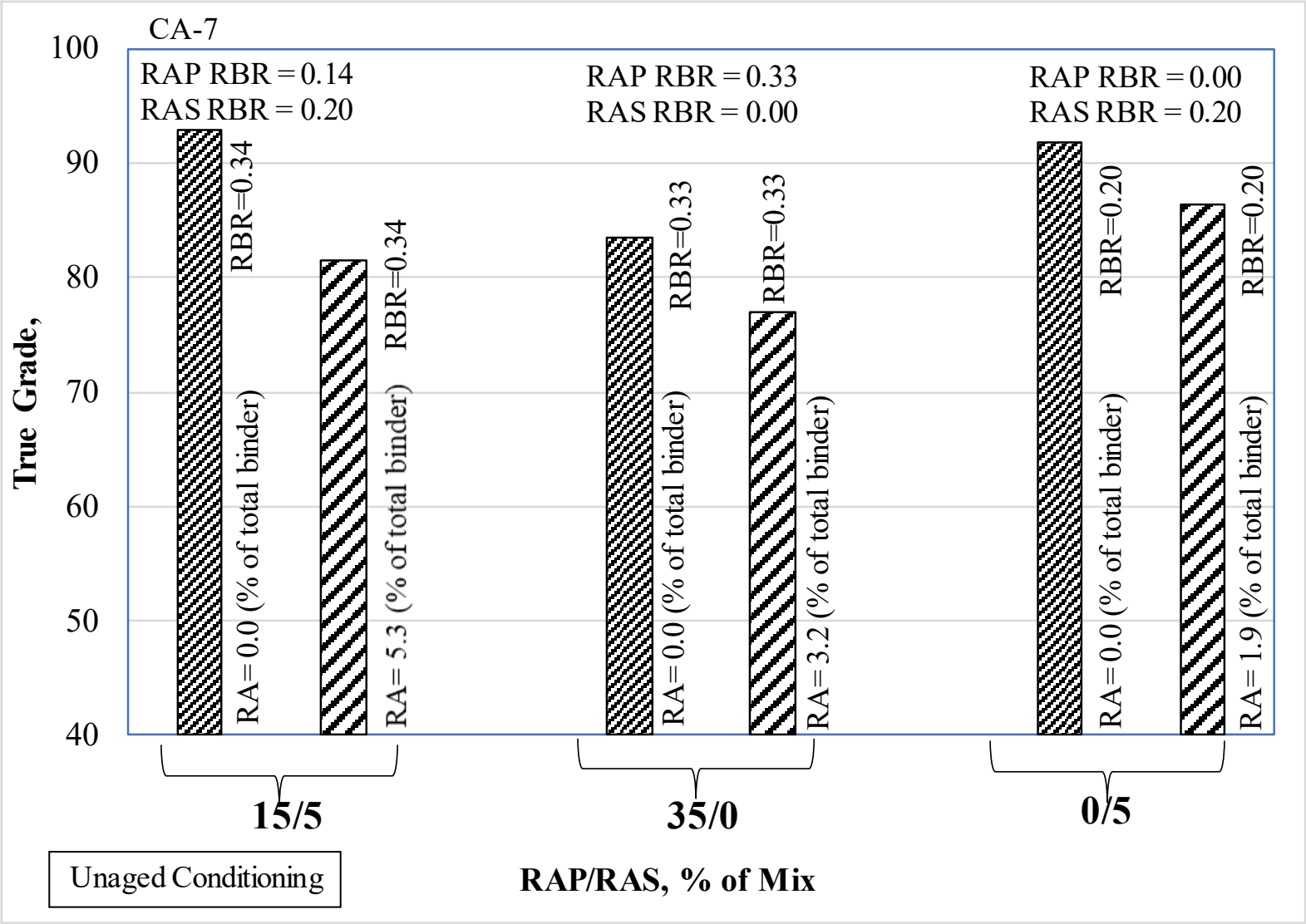
Effect on RAP Binder (Low Temp.)



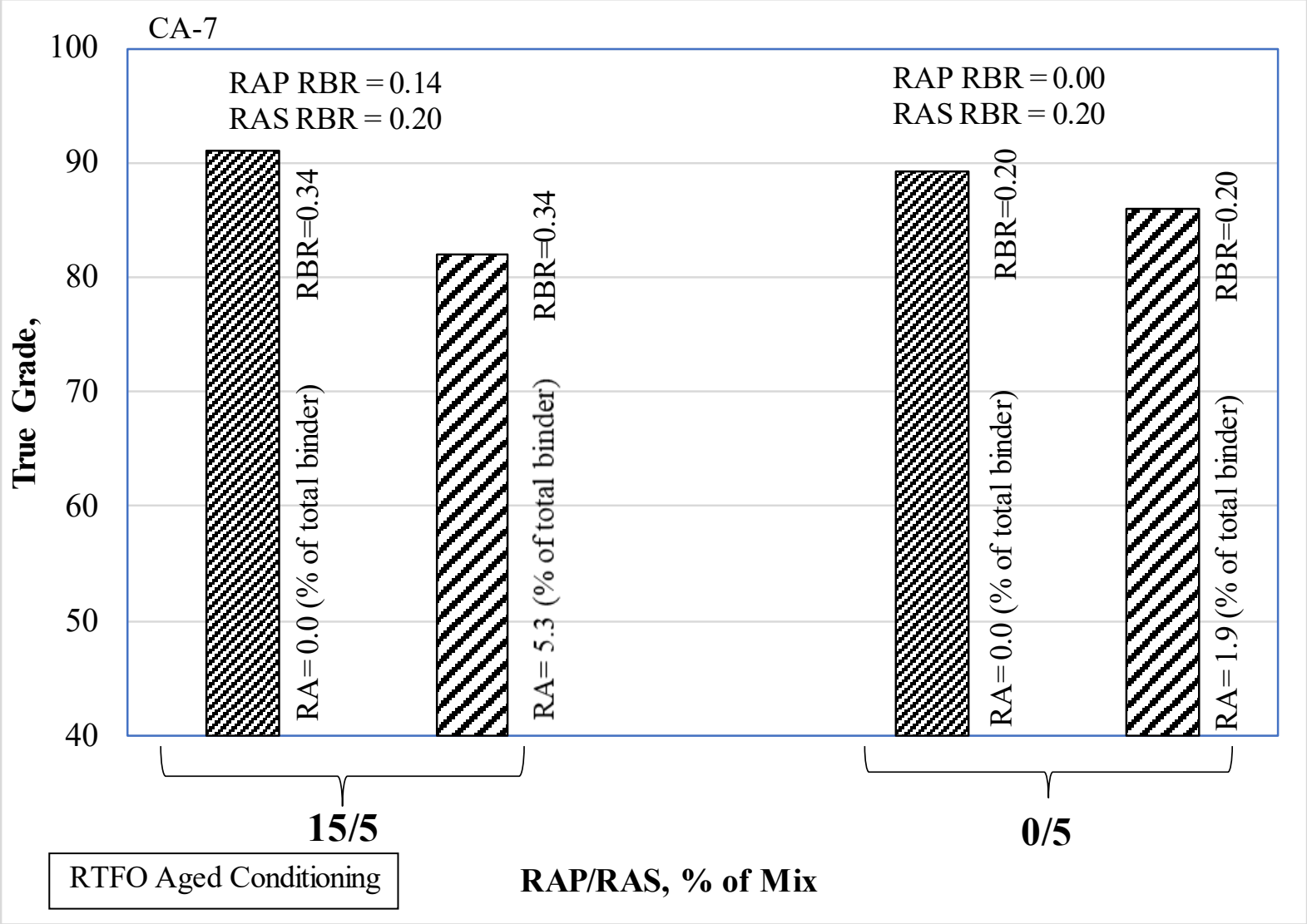
Effect on ΔTc (RAP Binder)



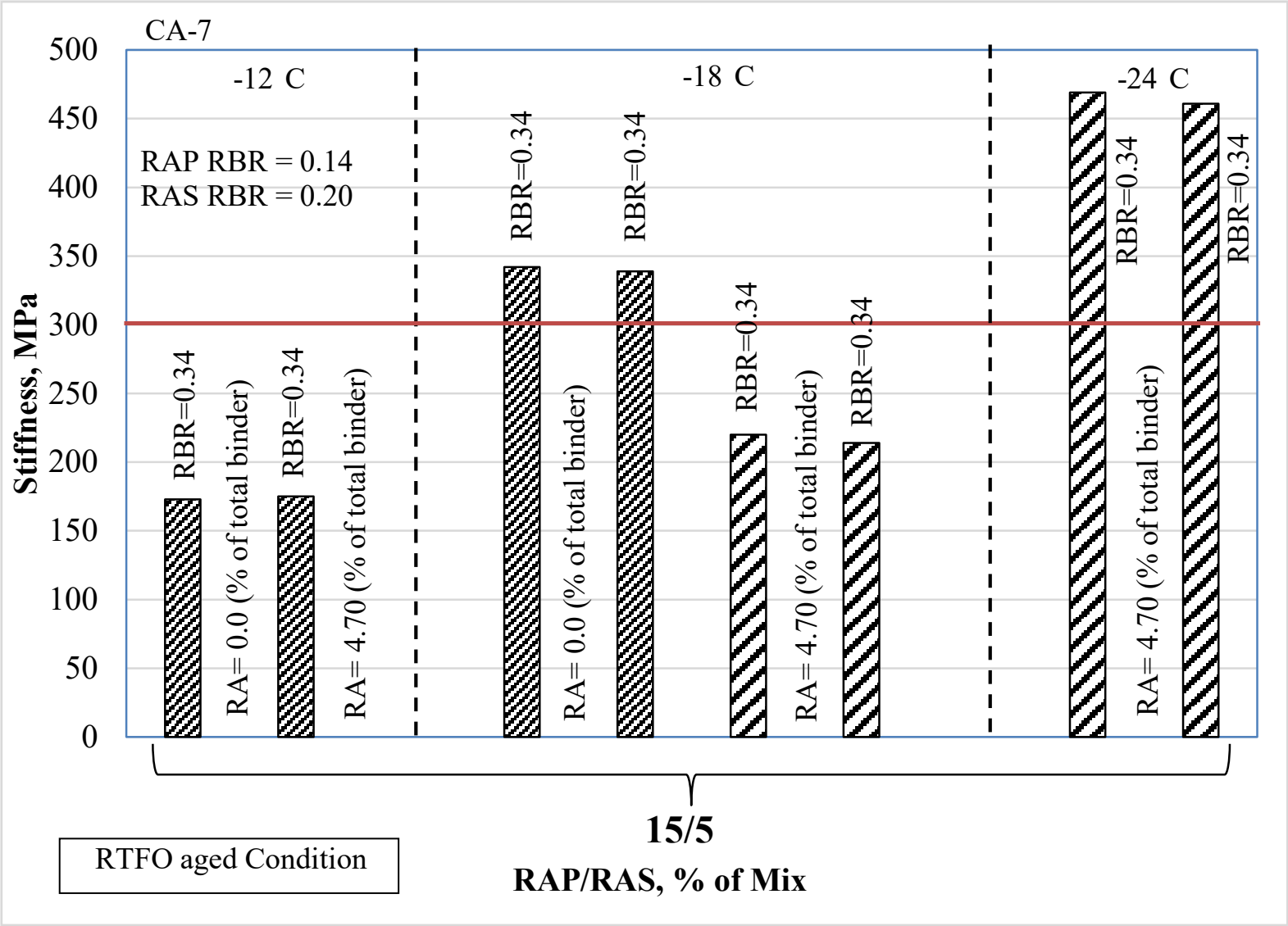
Recovered Binder High Temp. Grade



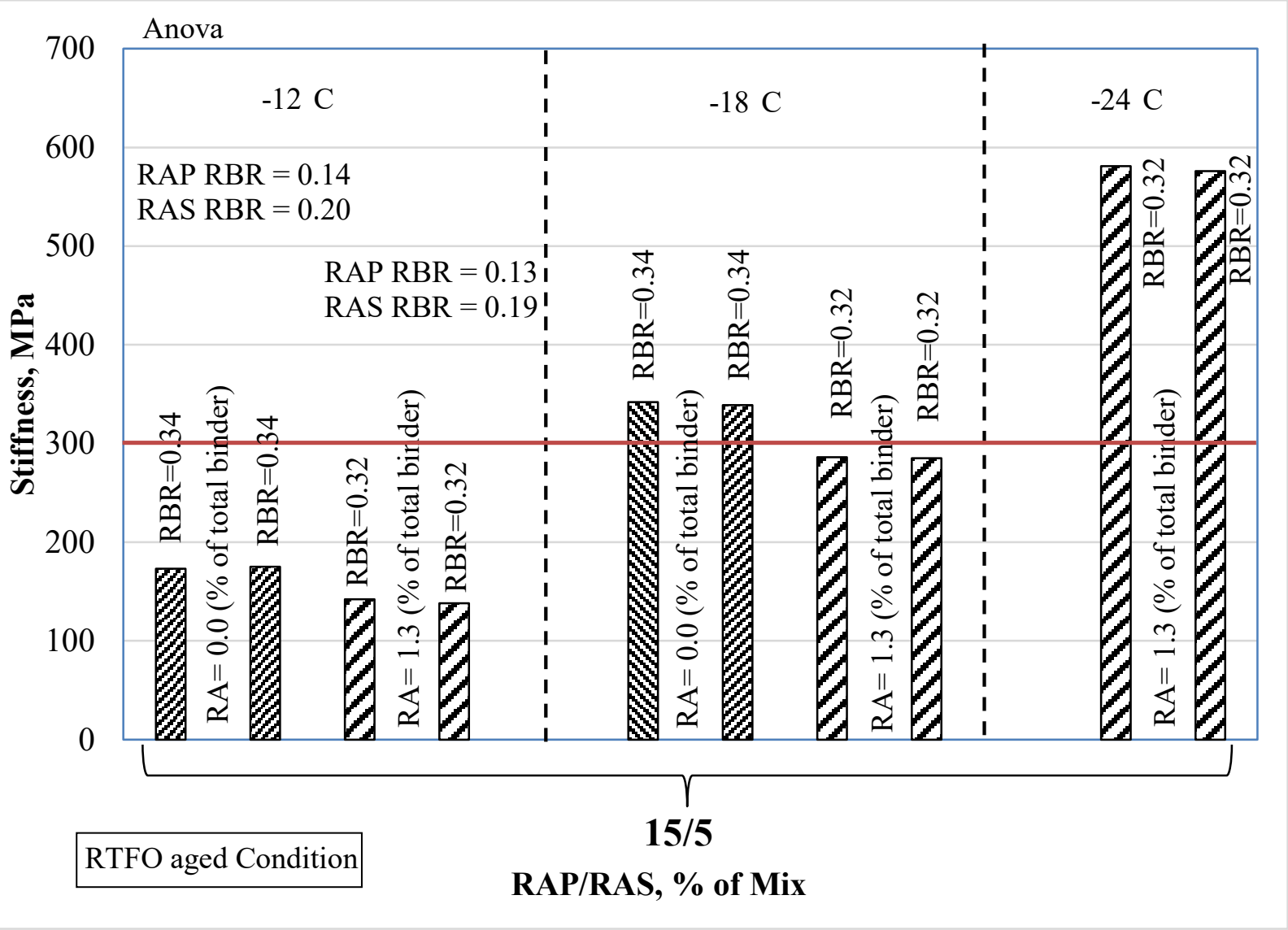
Recovered Binder High Temp. Grade



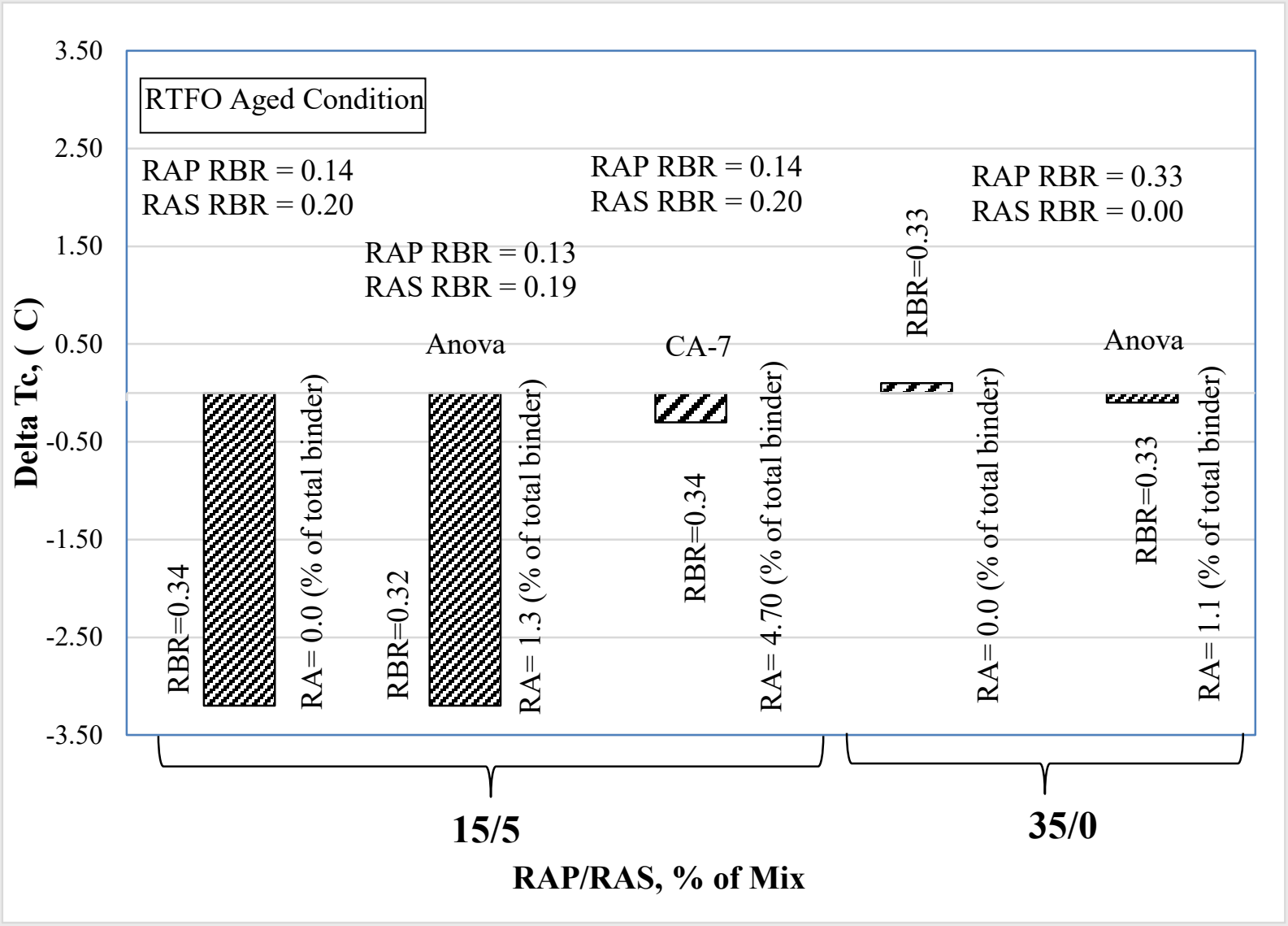
Recovered Binder Low Temp. Stiffness



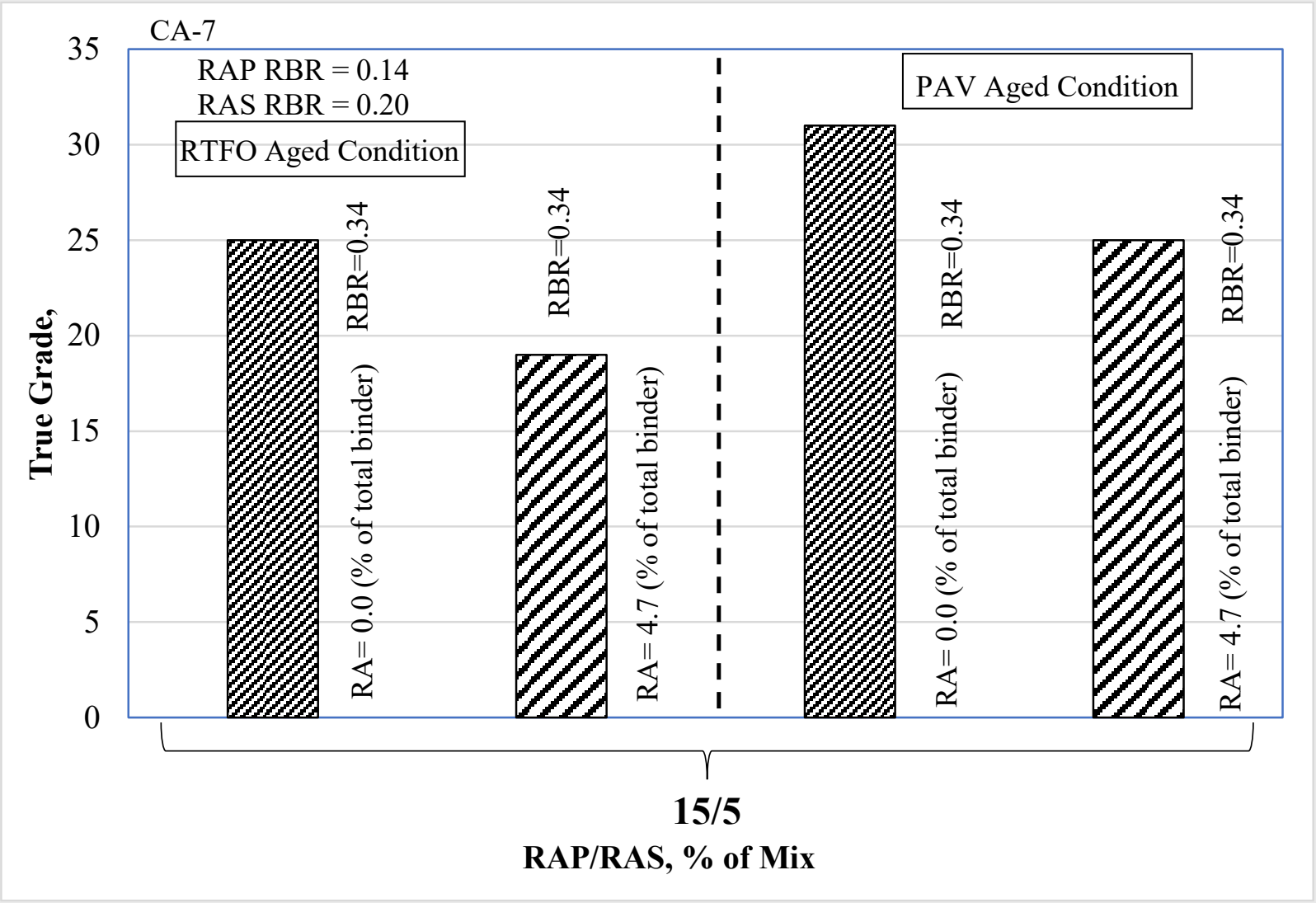
Recovered Binder Low Temp. Stiffness



Recovered Binder Low Temp. Stiffness



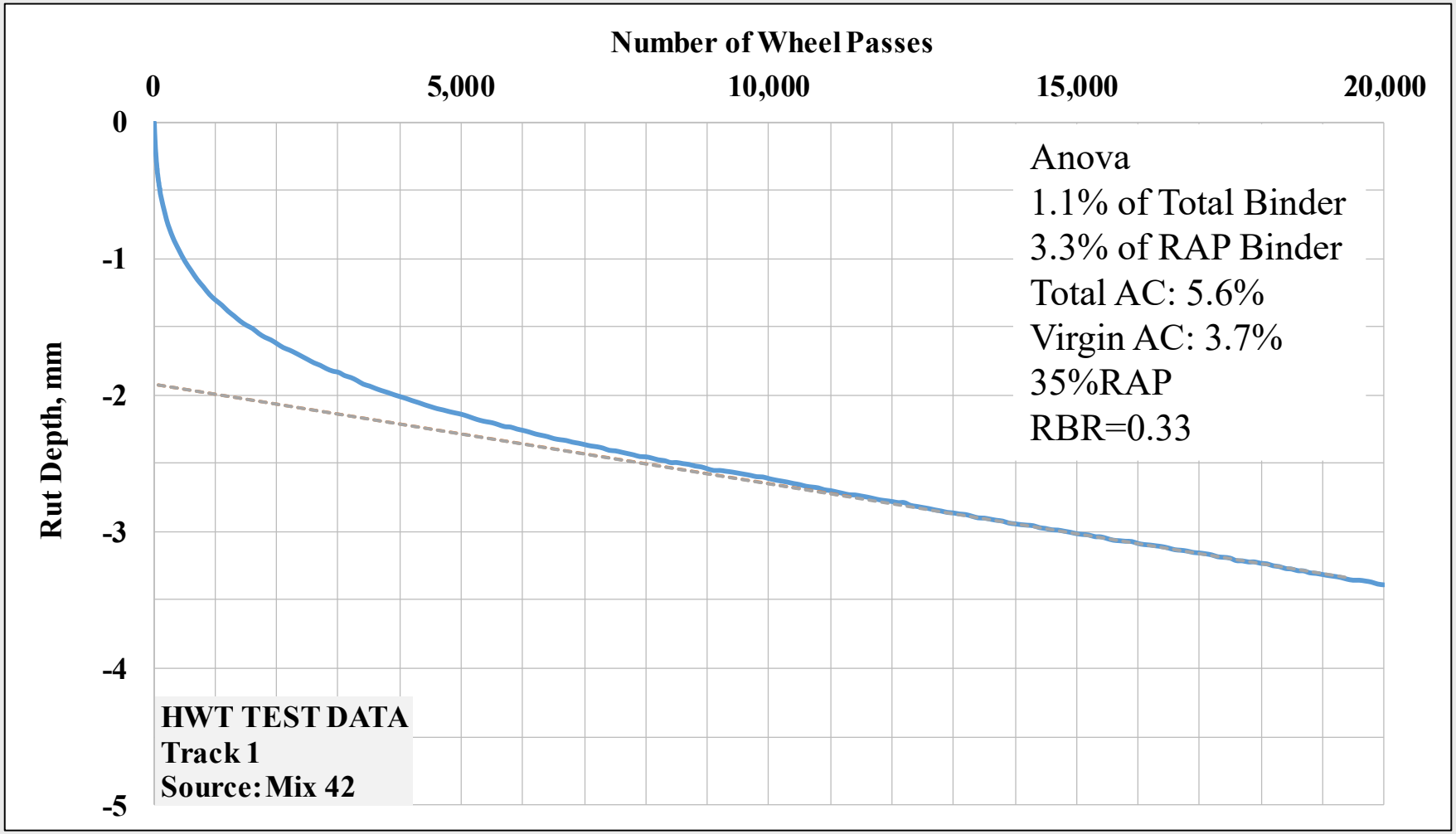
Recovered Binder Interm. Temp. Grade



Results & Findings

Testing the Mixtures

Results from HWT Test



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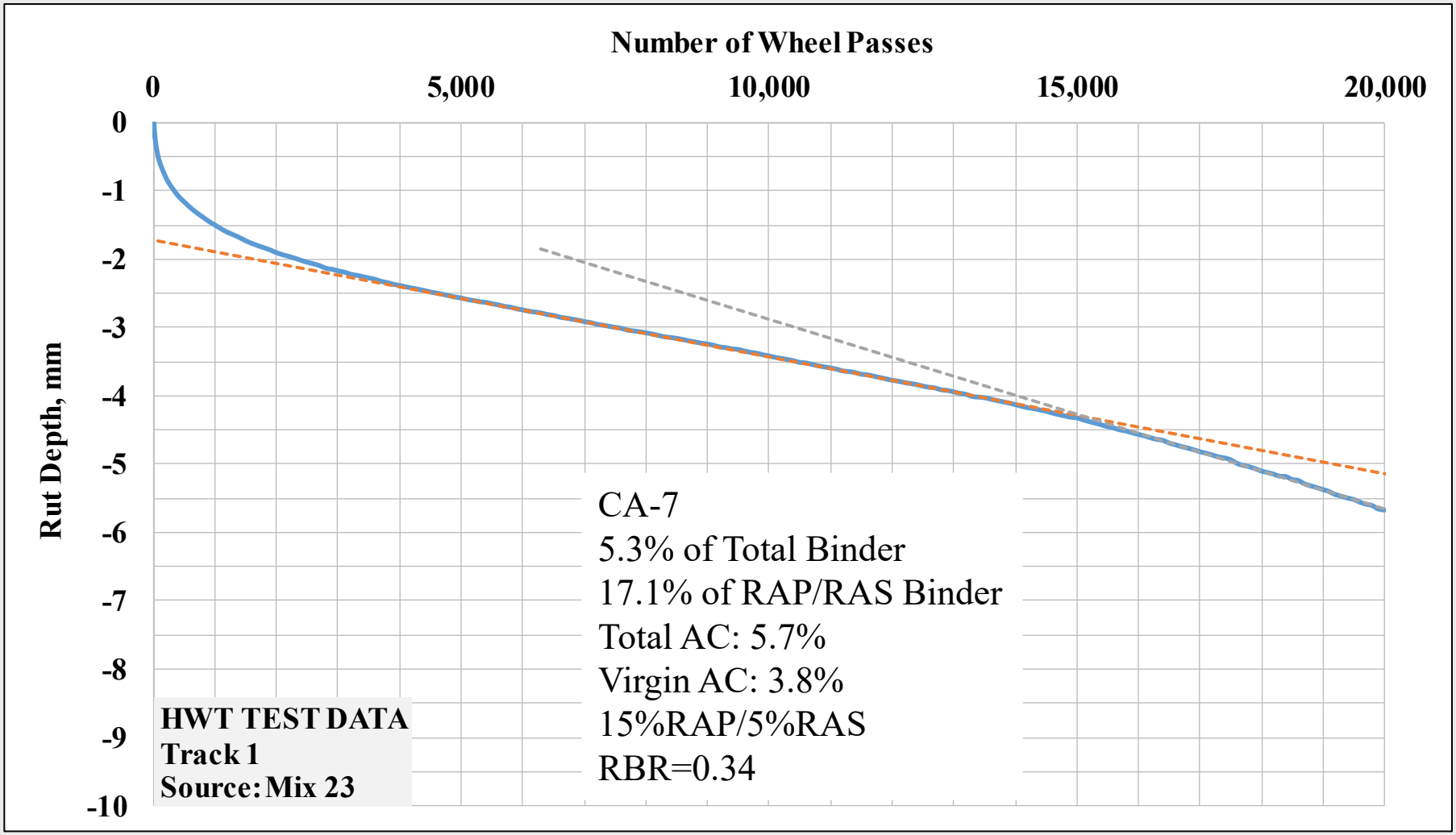

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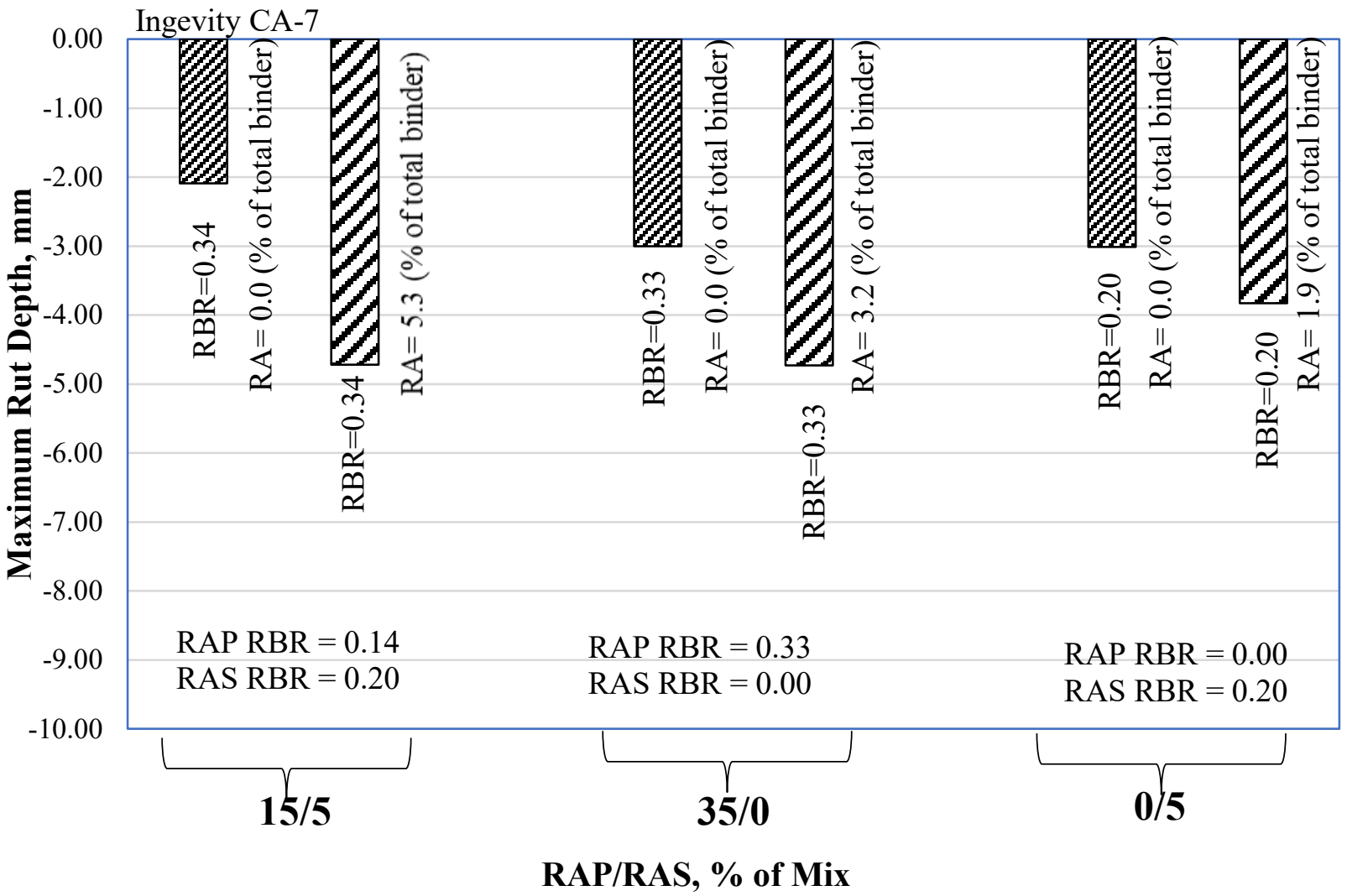

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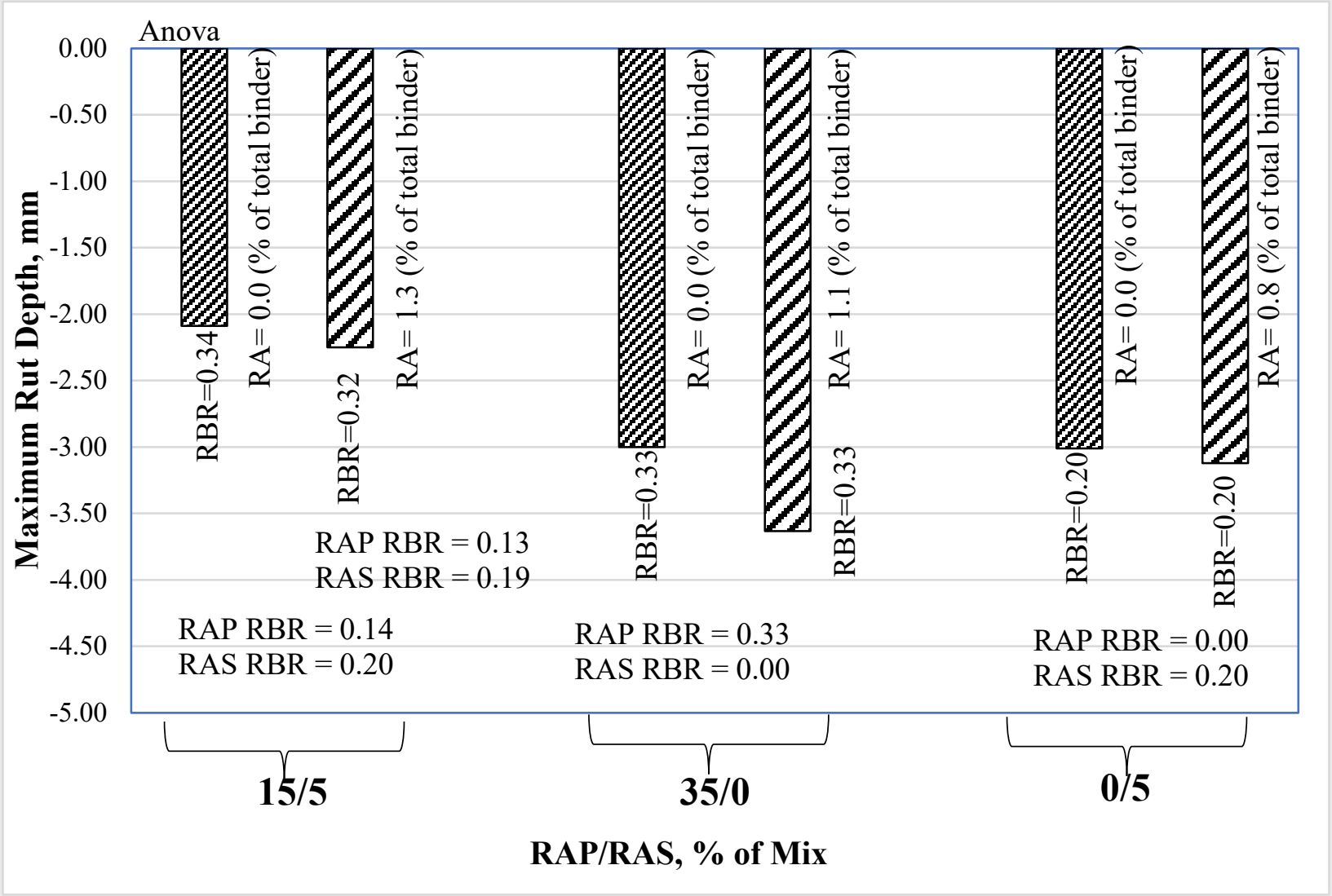

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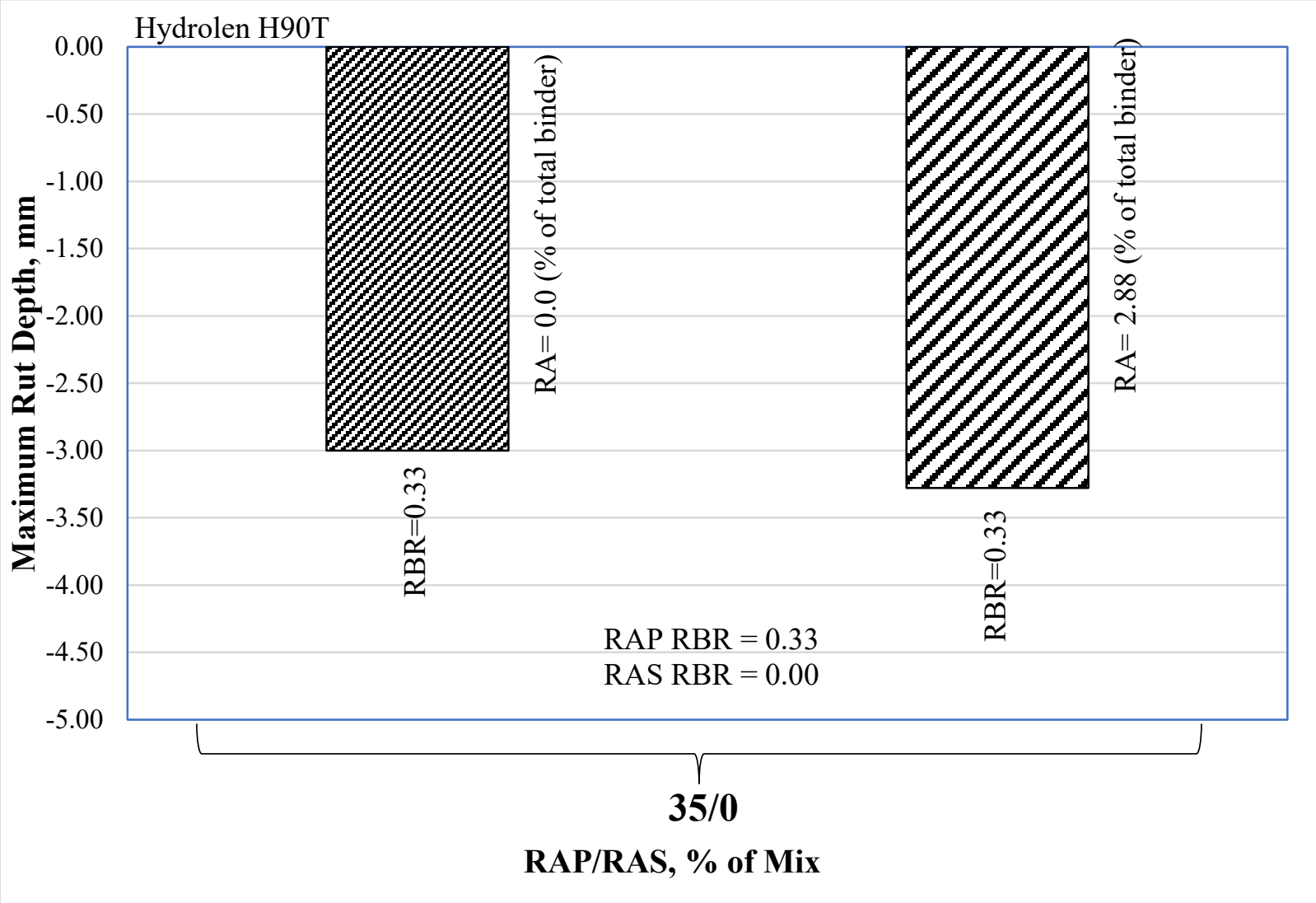

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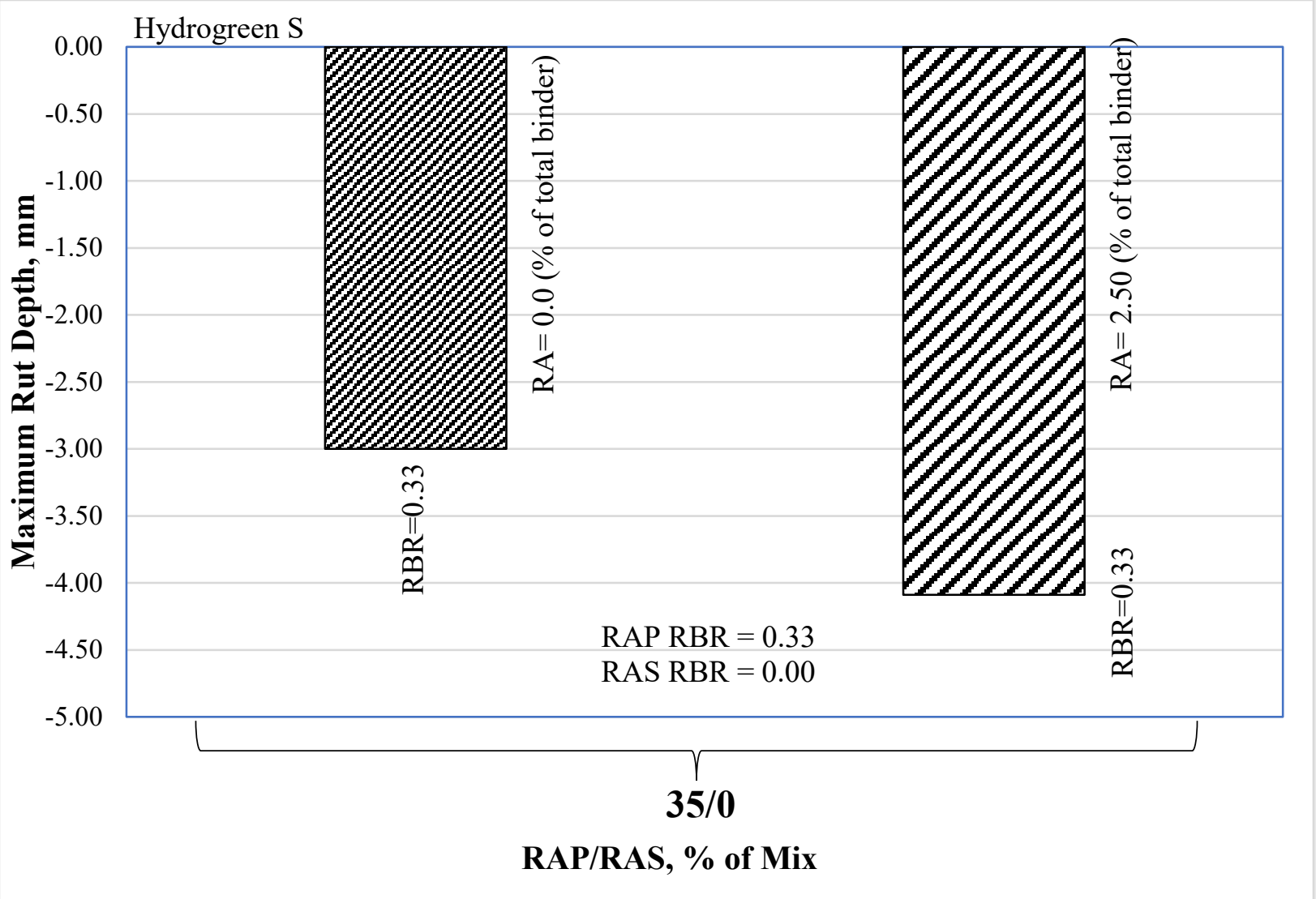
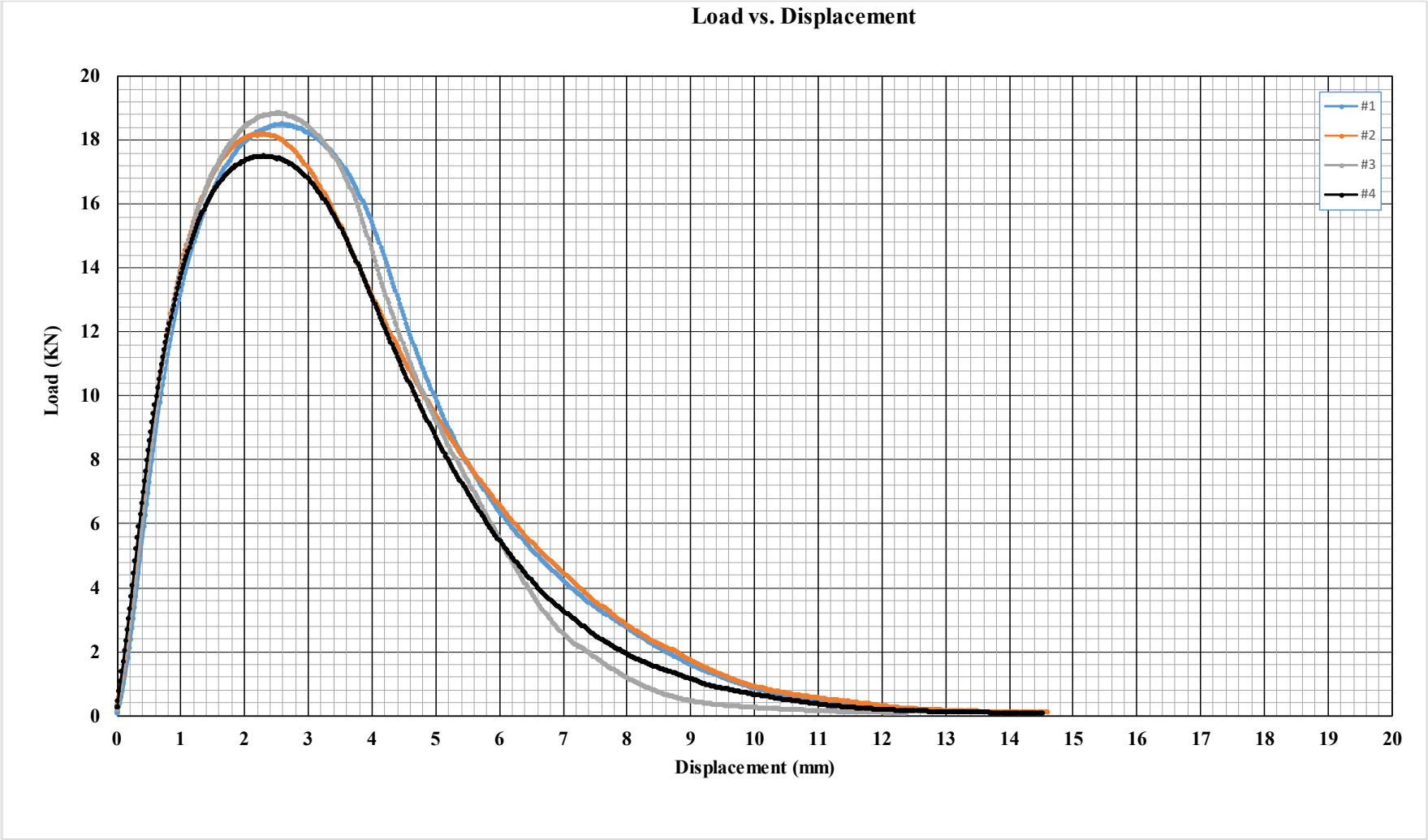
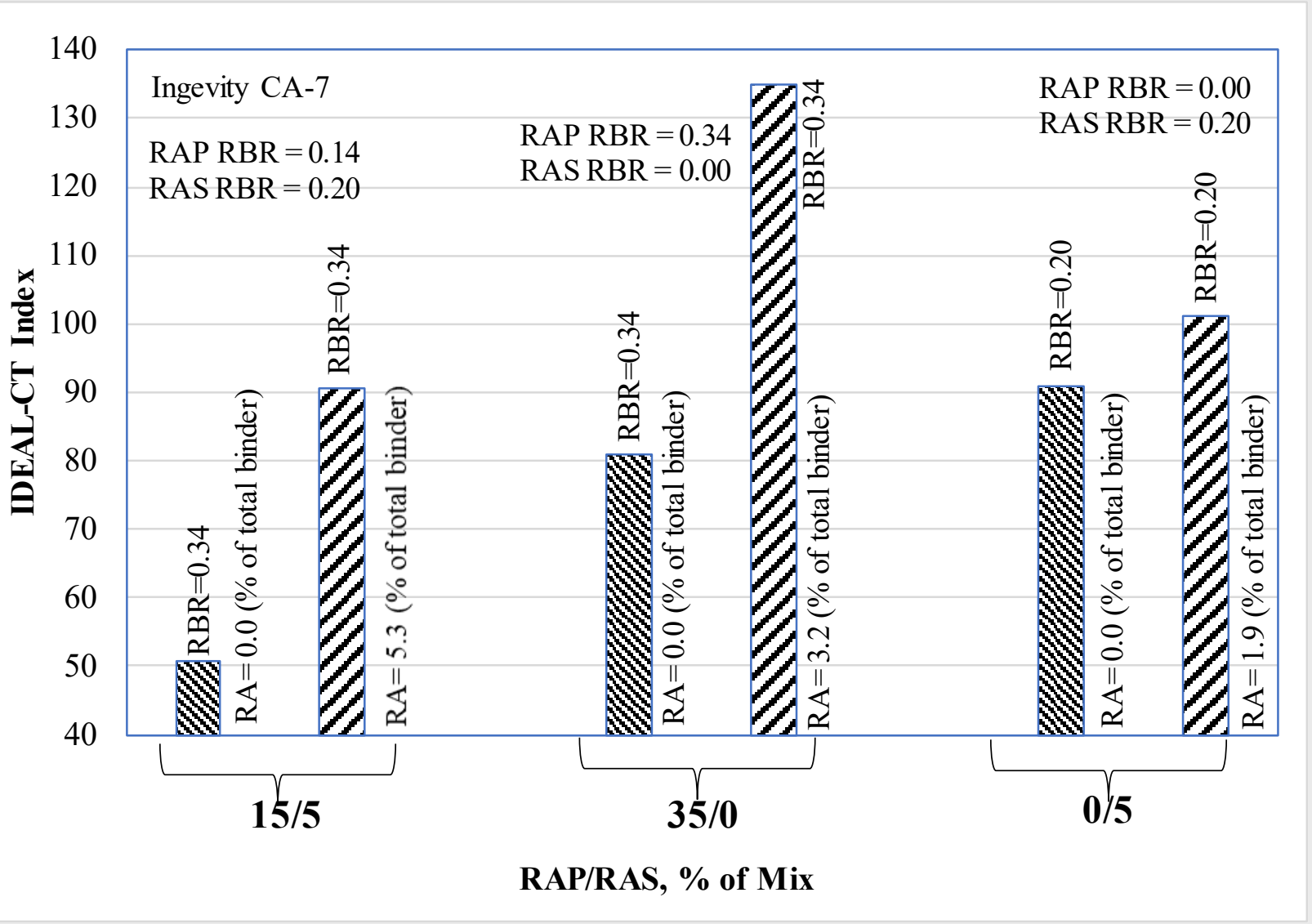


Results from IDEAL-CT Test



Results from IDEAL-CT Test



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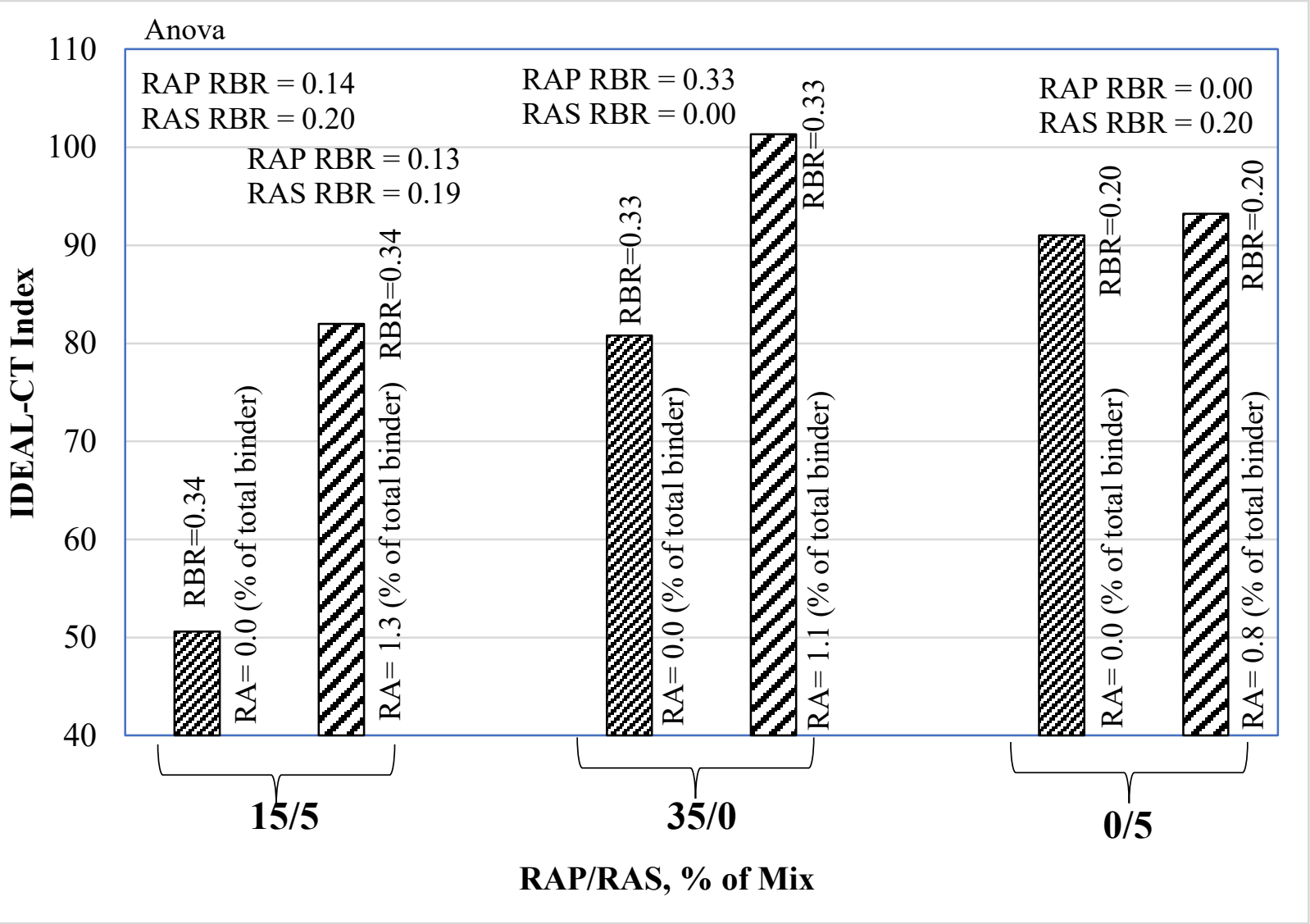

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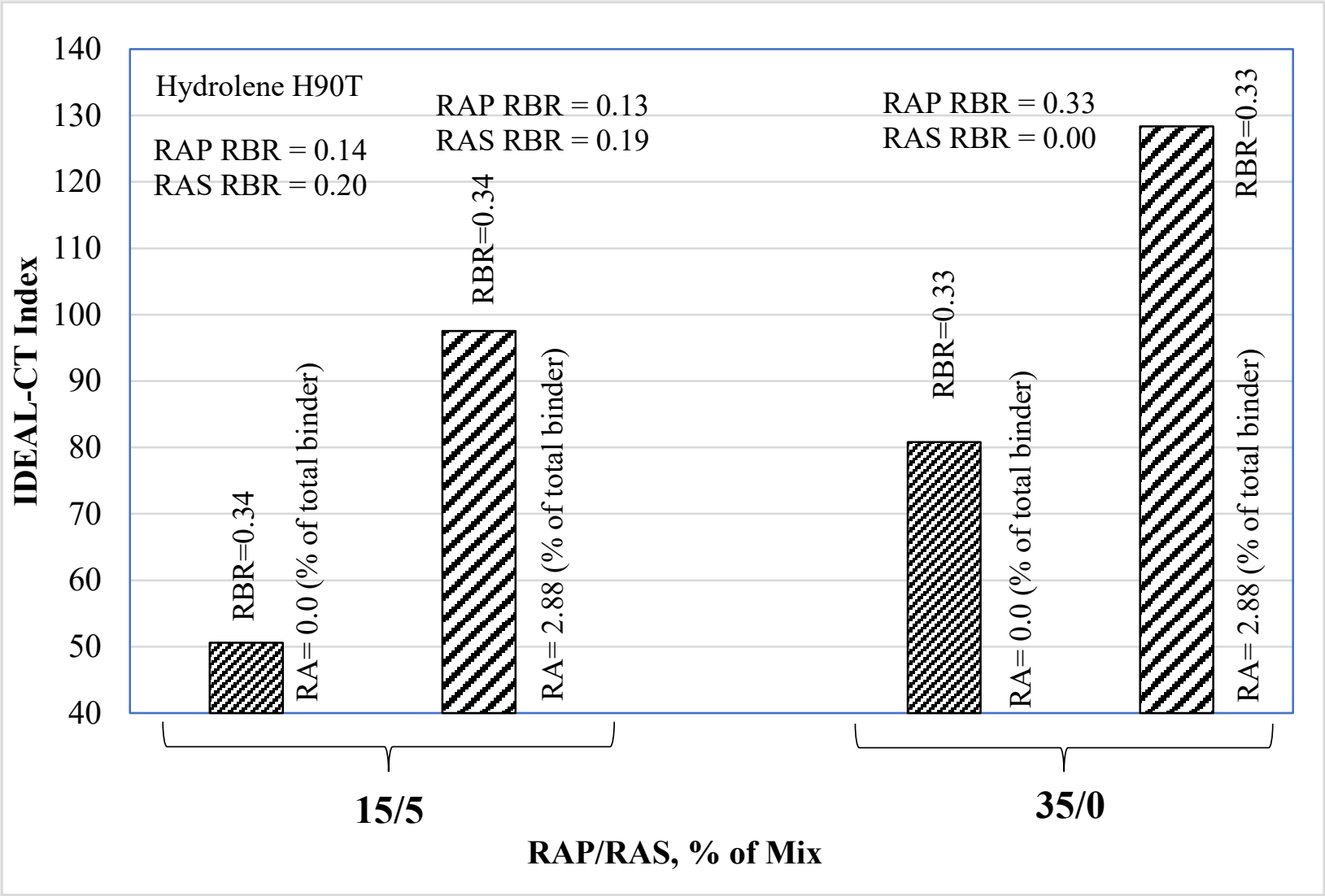

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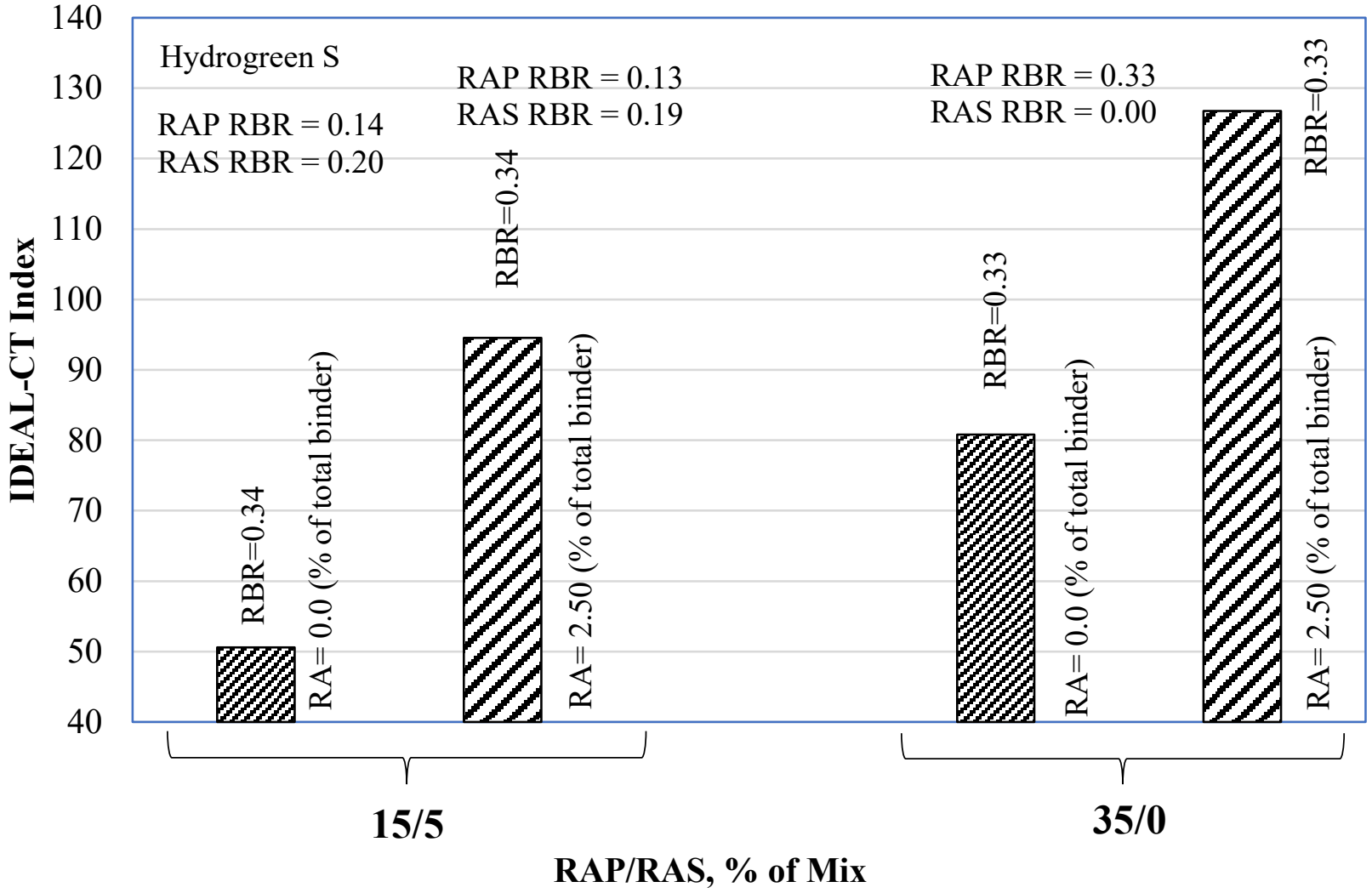

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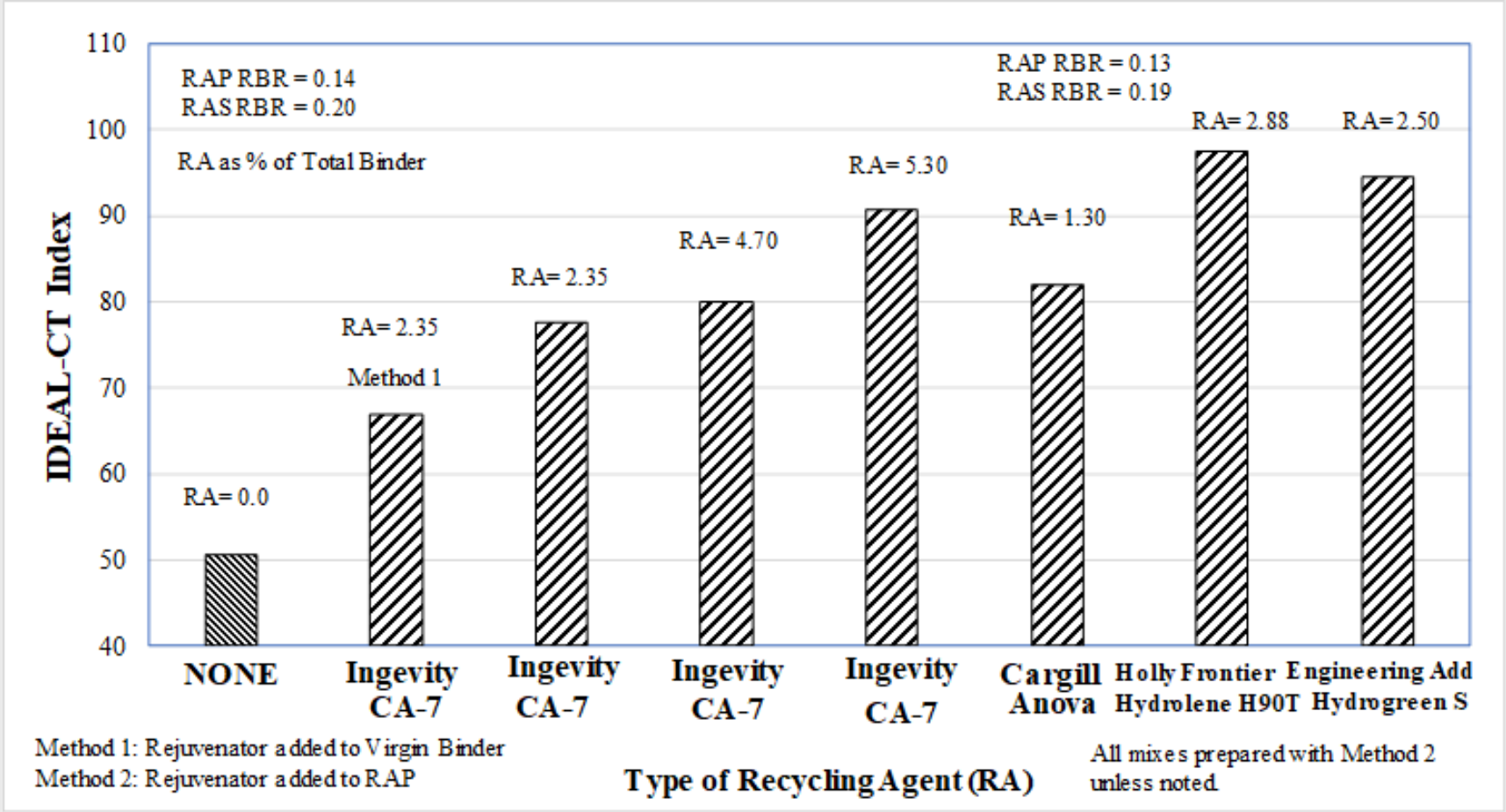
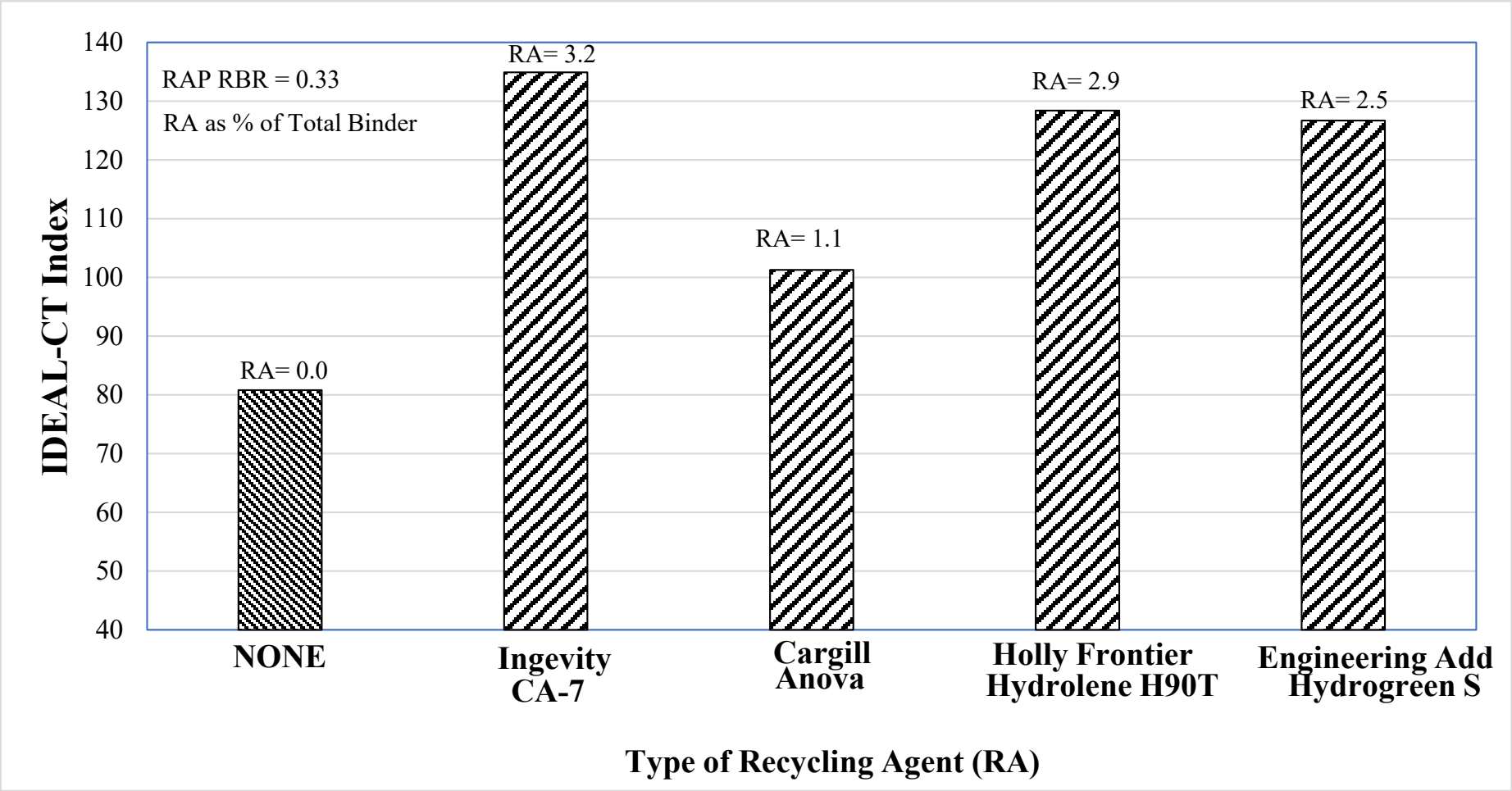


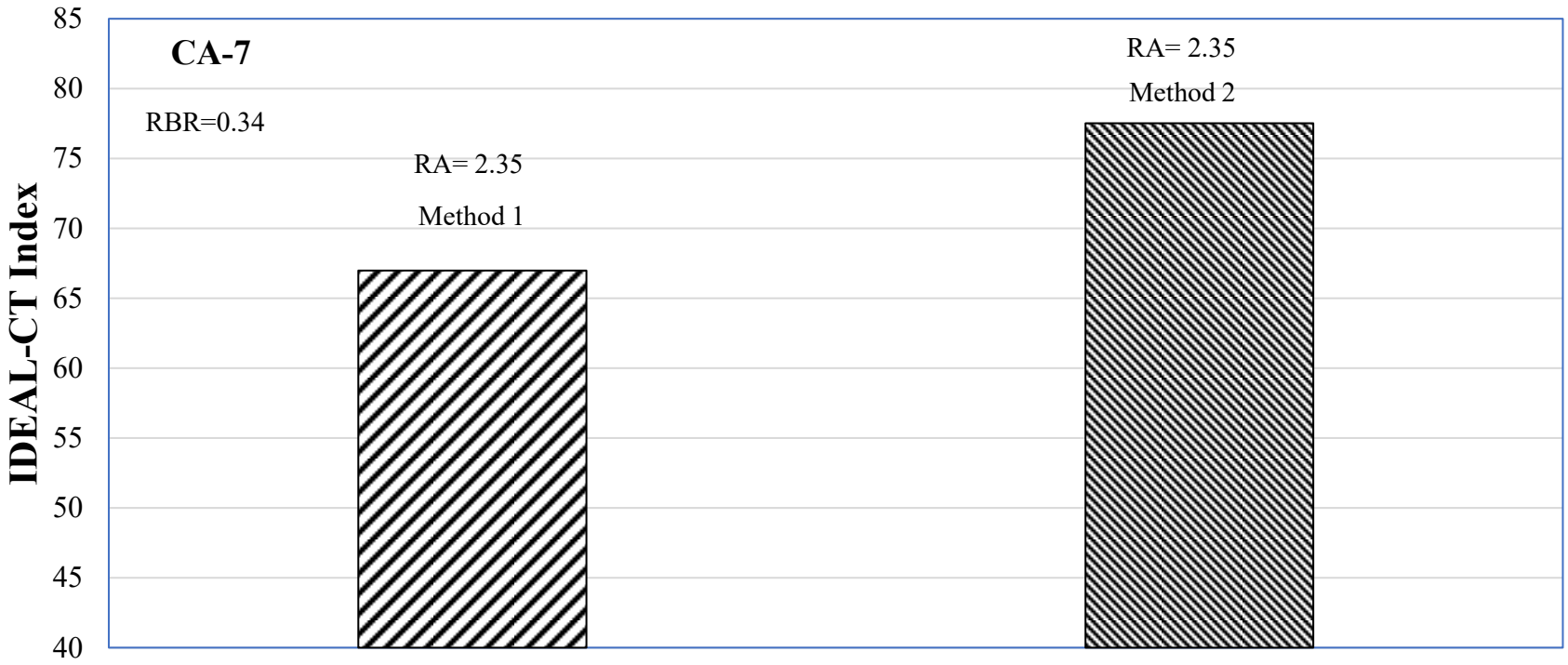
All Mixtures with 15%RAP/5%RAS

Results from IDEAL-CT Test

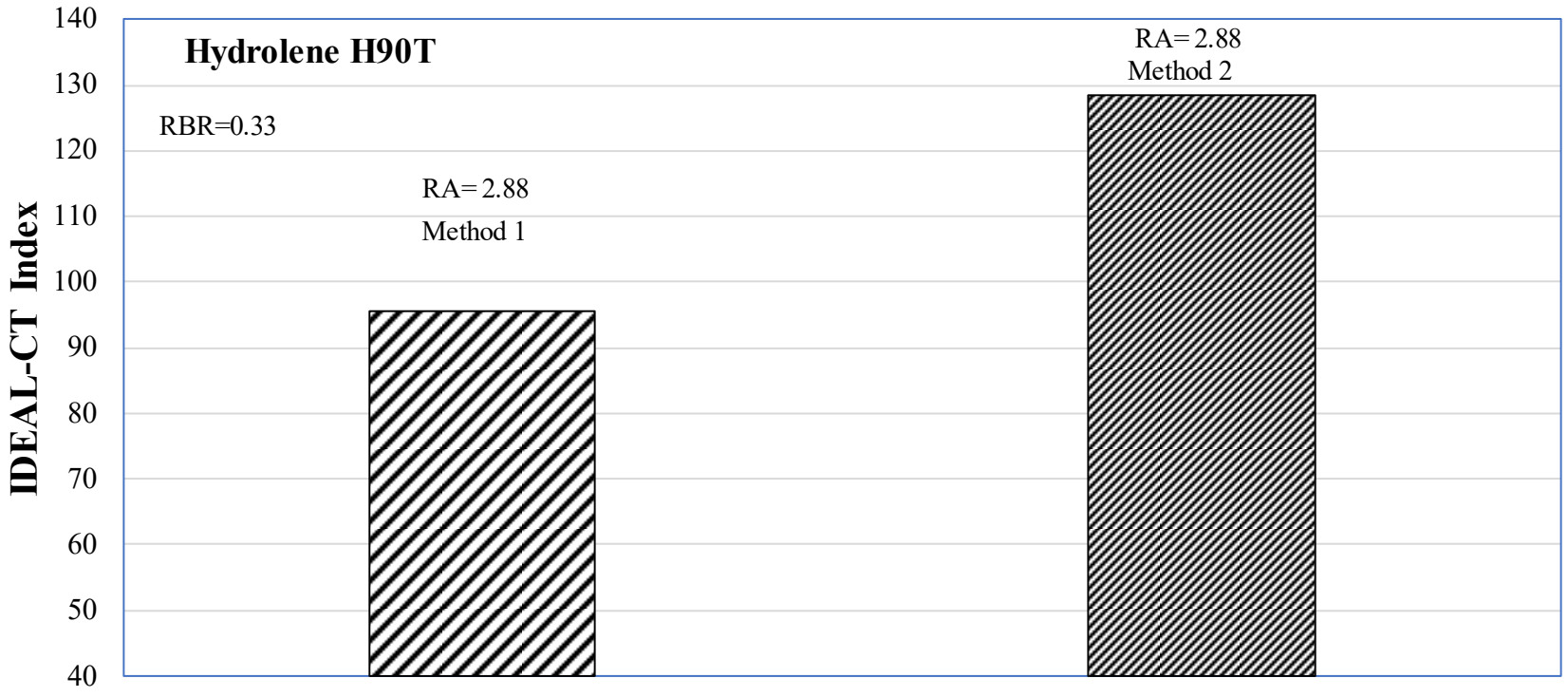


All Mixtures with 35%RAP

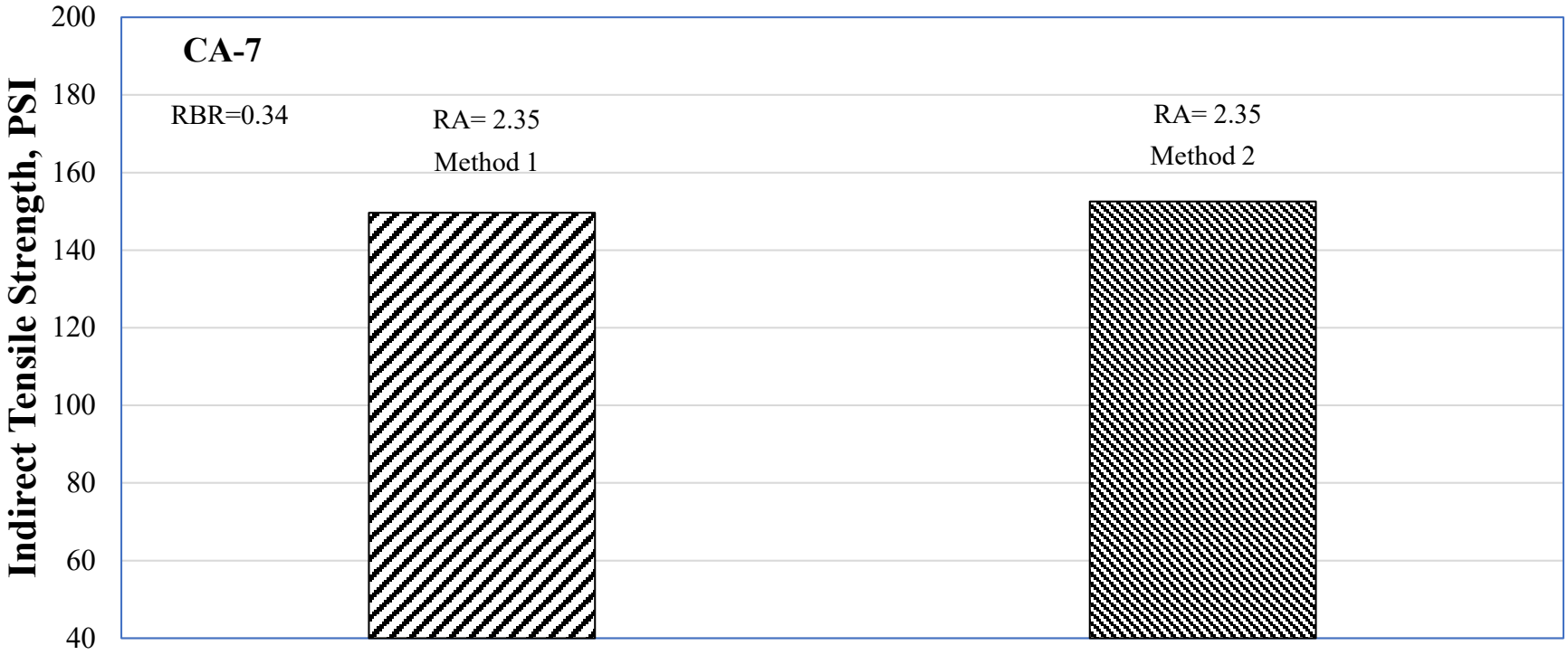
Effect of Blending Technique



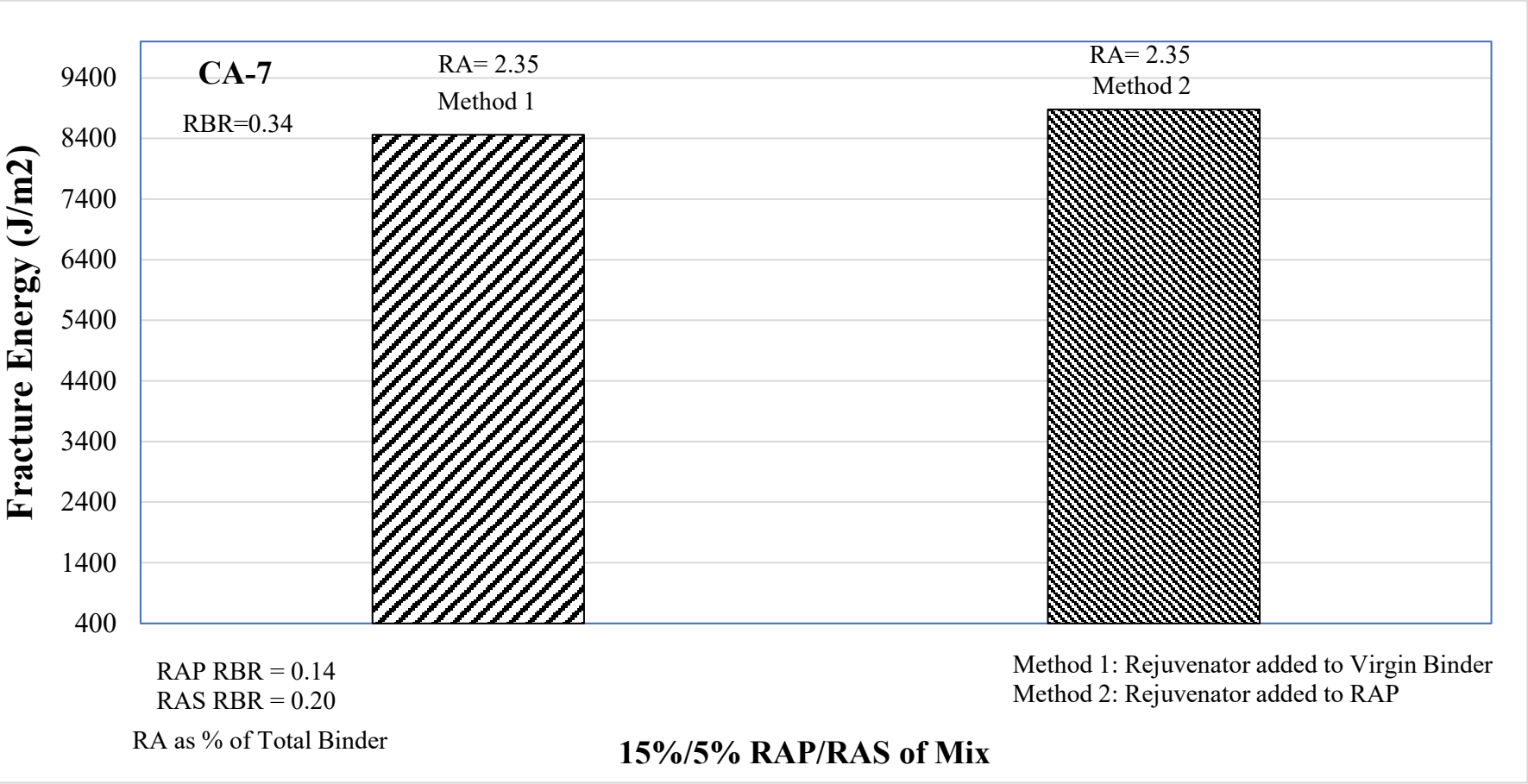
Effect of Blending Technique



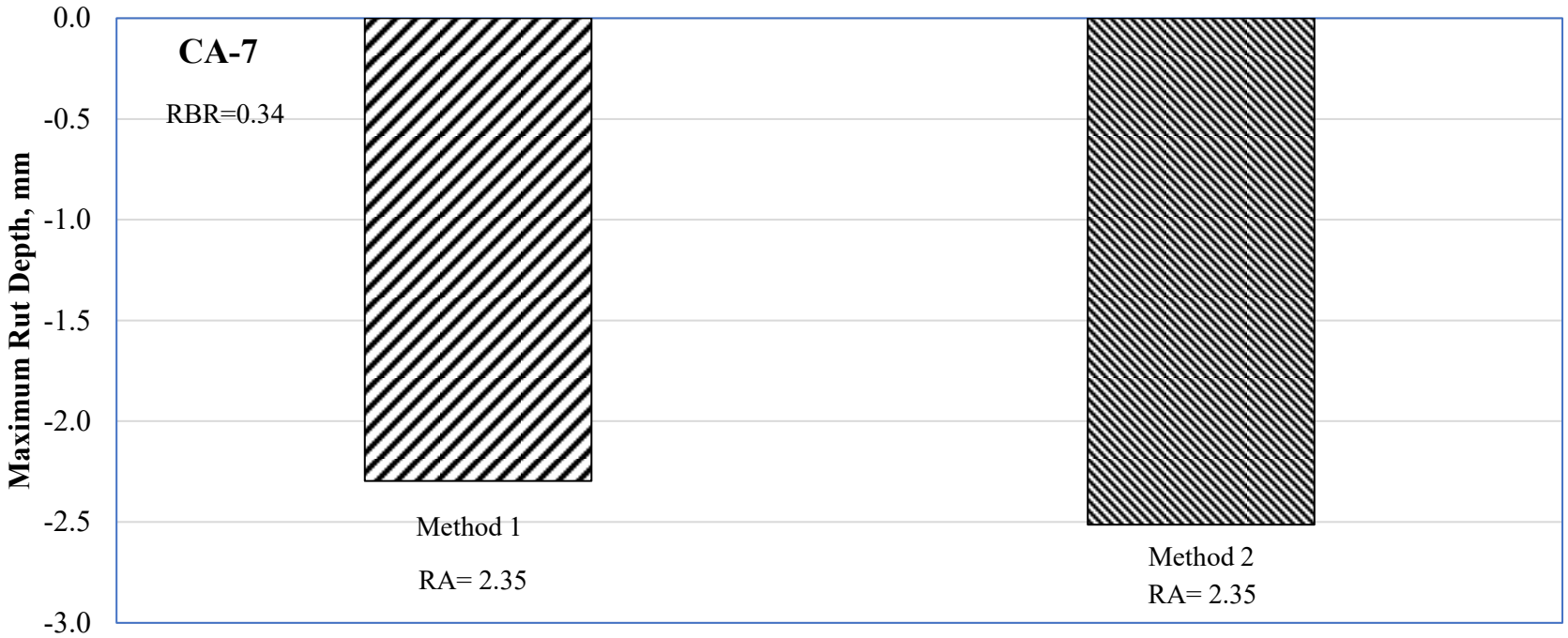
Effect of Blending Technique



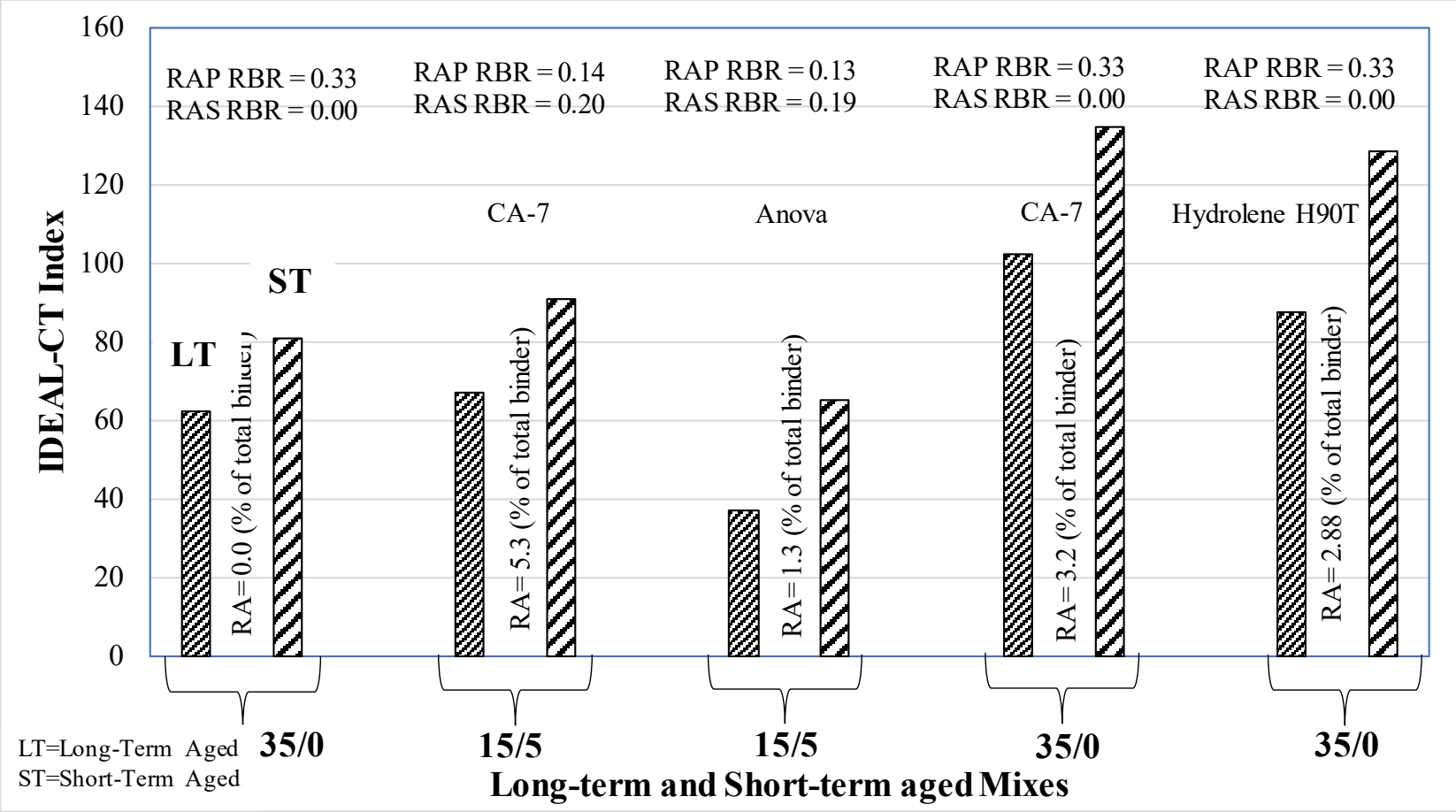
Effect of Blending Technique



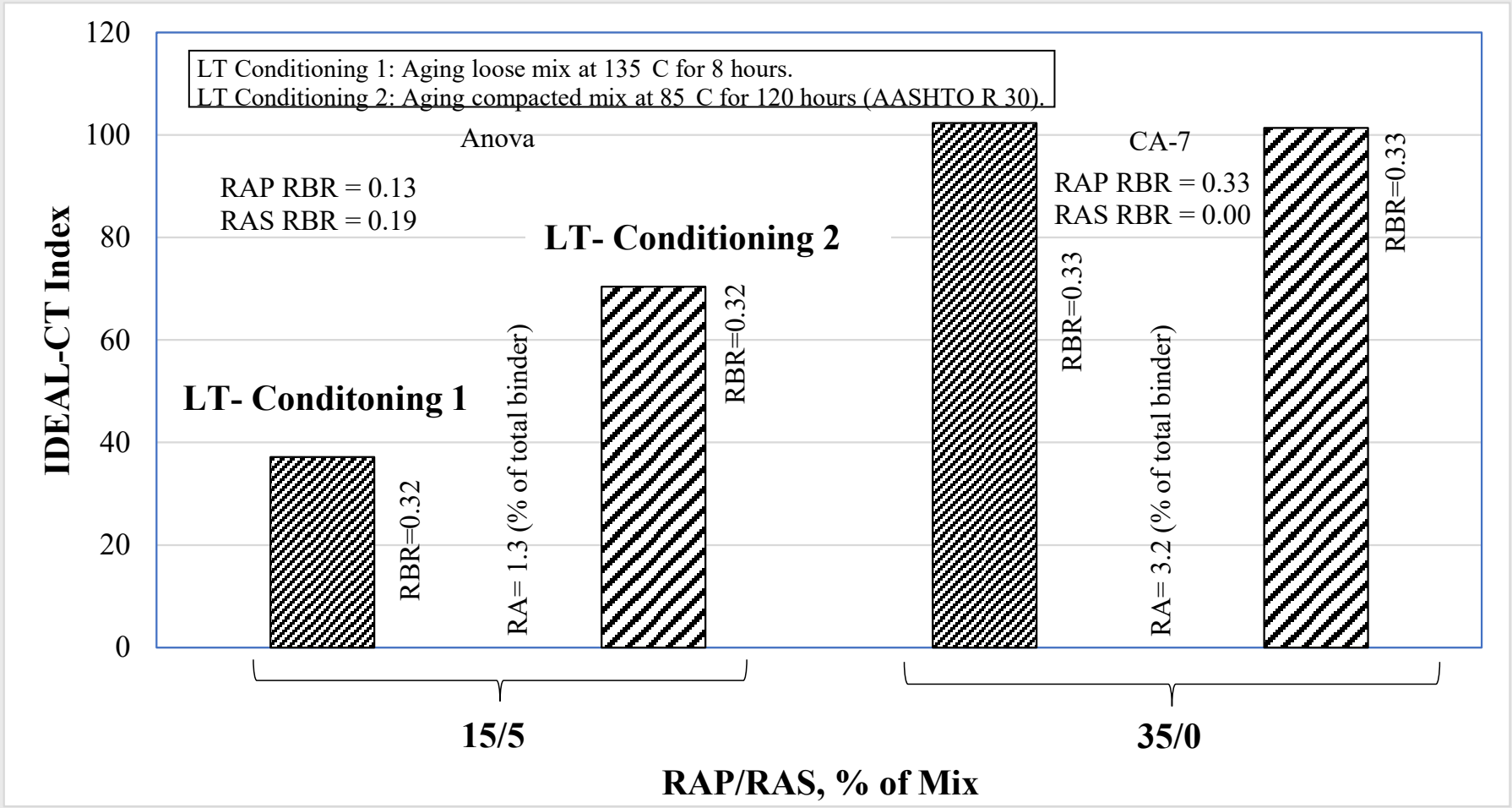
Effect of Blending Technique



Effect of Long-Term Conditioning



Comparison of Long-Term Conditioning Techniques



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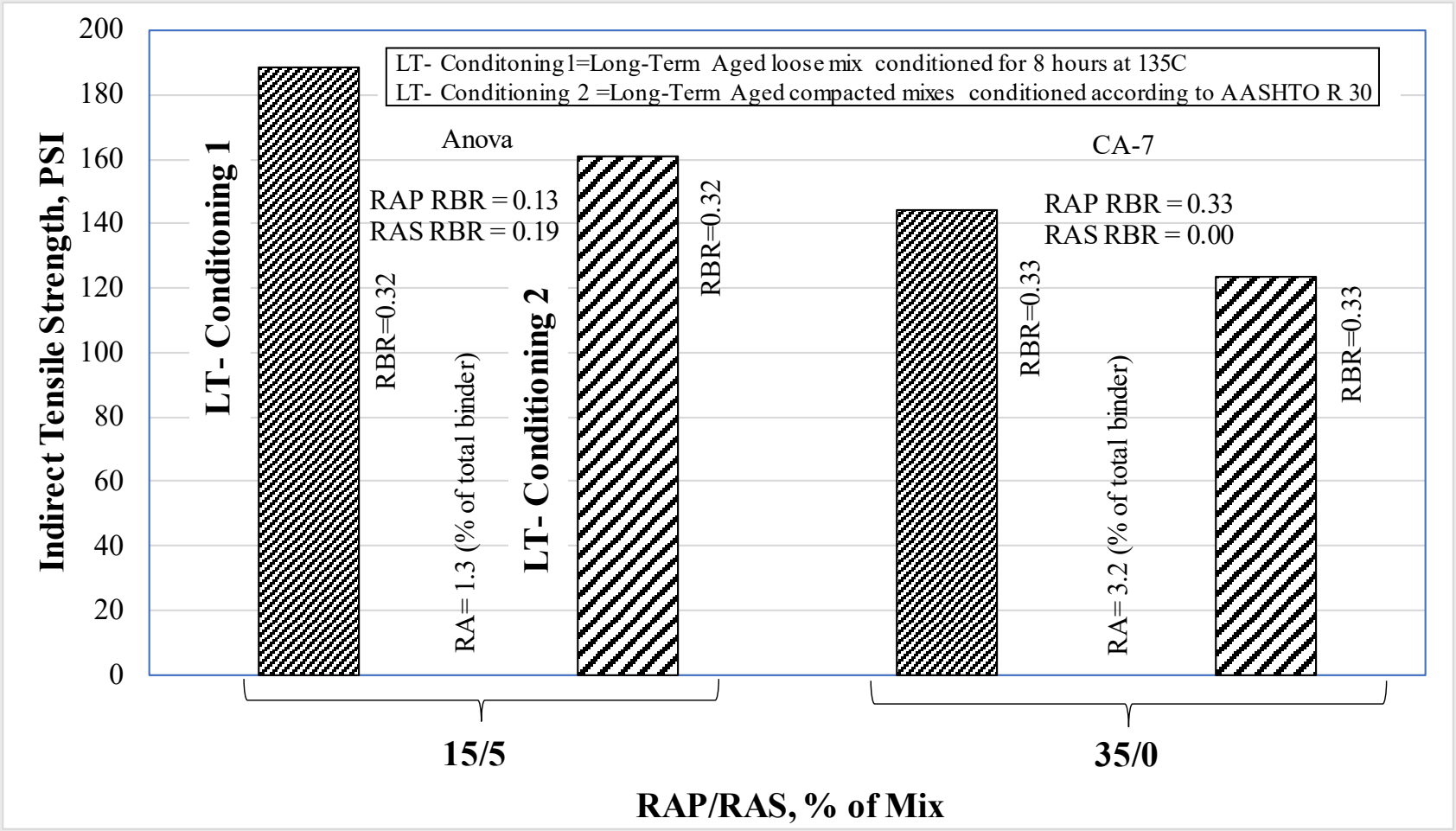

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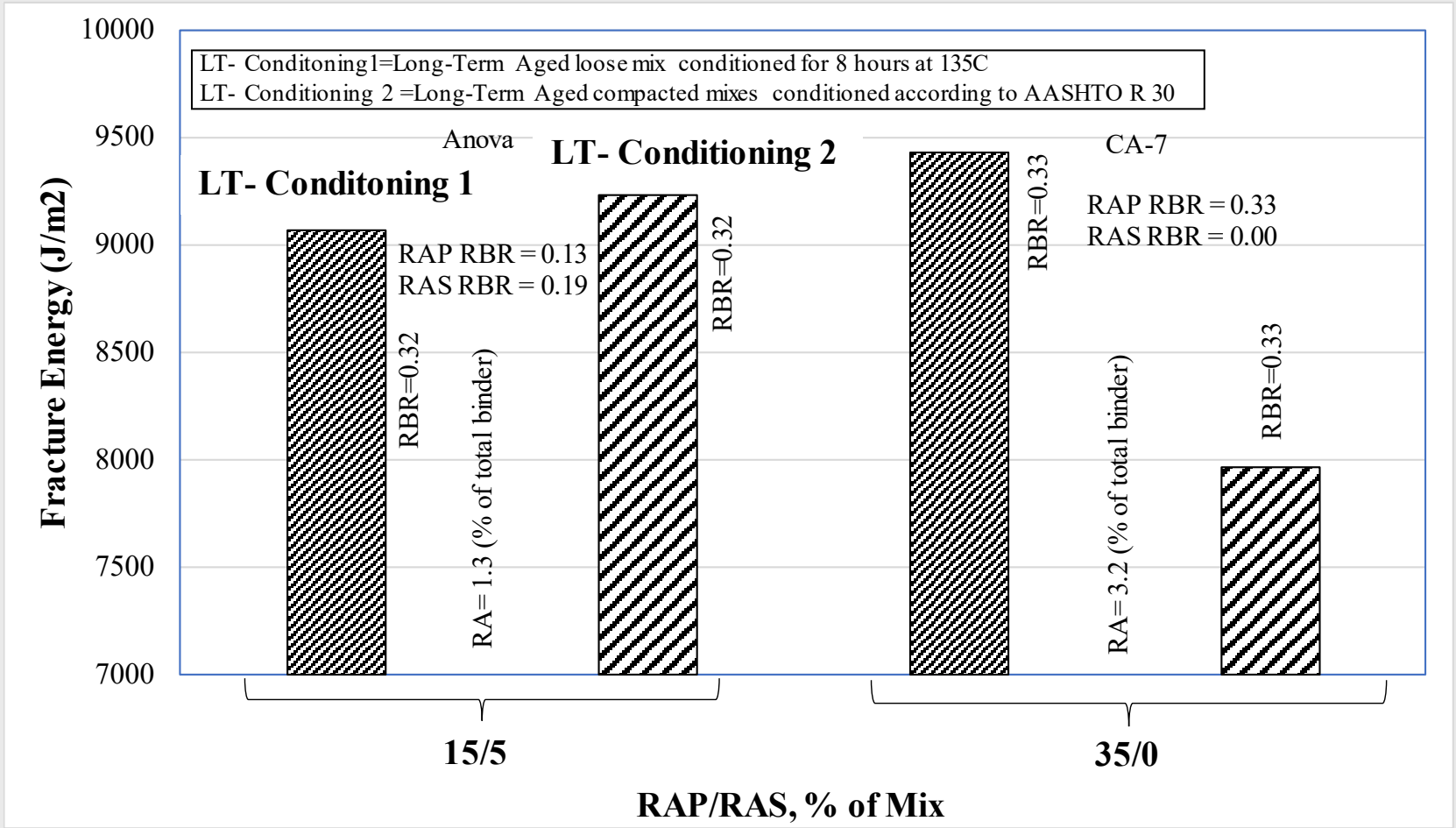
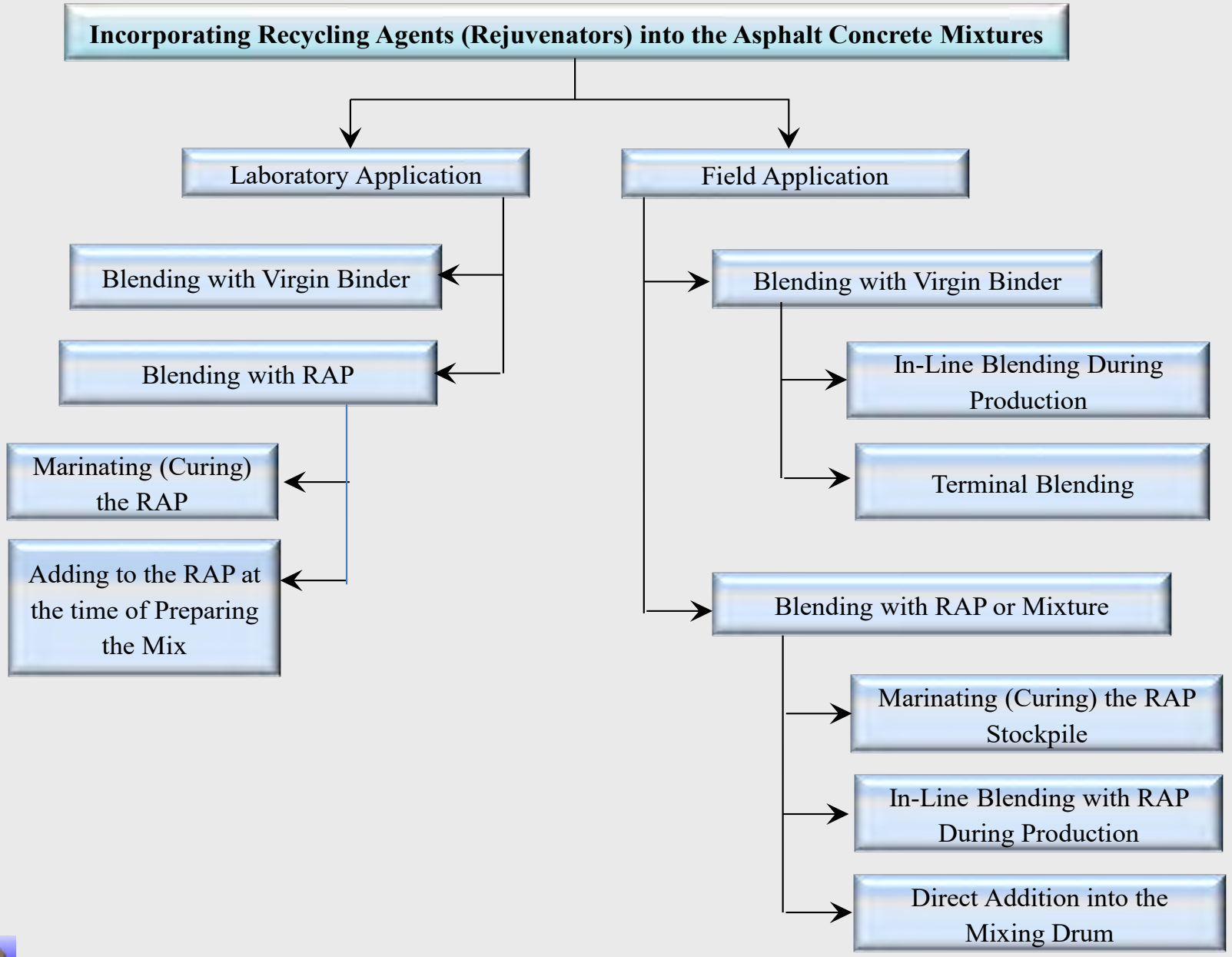


Usage Guide

- **The Usage Guide Covers the Following:**
  - **Terminology and References**
  - **Types of Rejuvenators**
  - **Blending Techniques**
  - **Dosage Rate Selection**
  - **Evaluation of Long-Term Effectiveness**

Blending Methods



Dosage Rate Selection

- 1. Manufacturer's Recommendation
- 2. Blending Chart
- 3. Performance Testing and BMD

Evaluation of Long-Term Effectiveness

❖ 1. Through Binder Testing

Parameter (measured on PAV aged binder)	Change after incorporation of the rejuvenator at the recommended dosage rate
G*.sinδ at intermediate test temperature	Decrease of at least 25% in G*.sinδ
Stiffness (S) at low temperature	<300 MPa, and decrease of at least 25% in S
Relaxation parameter (m-value) at low temperature	Increase of at least 25% in m
ΔTc at low temperature	>-5°C, and increase of at least 25% in ΔTc

❖ 2. Through Mixture Testing

Parameter (measured on long term aged mixture)*	Change after incorporation of the rejuvenator at the recommended dosage rate
IDEAL-CT Index	Increase of at least 30% in the calculated index compared to the mix with no rejuvenator

**** Long-term aging achieved through conditioning loose mixture through the NCAT protocol***

Summary and Conclusions

- Five RAs used in binder evaluations (one petroleum based)
- Four RAs used in mixture evaluation (one petroleum based)
- Binder evaluation through rheological tests
- Mixture evaluation through performance index tests
- RA Dosage Rates very in a wide range depending on RA type
- RAs proved to be effective both short term and long term
- Different methods were reviewed for determination of the RA dosage rate
- Different techniques were proposed for evaluating long-term effectiveness


Thank You!