

Evaluation of Asphalt Mixtures Containing RAP and/or RAS with Recycling Agents

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FHWA Asphalt Mixture Expert Task Group

Fall River, MA

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LSU

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The Story!

Part 1

- **Background**
- **Objective/Scope**
- **Methodology**
 - **Mixture Design**
 - **Availability of RAS and/or RAP Binder**
 - **With and Without Recycling Agents**
 - **Laboratory Mechanical Tests**
- **Results**
- **Summary**

Part 2

Pool Fund Study TPF 5(294)

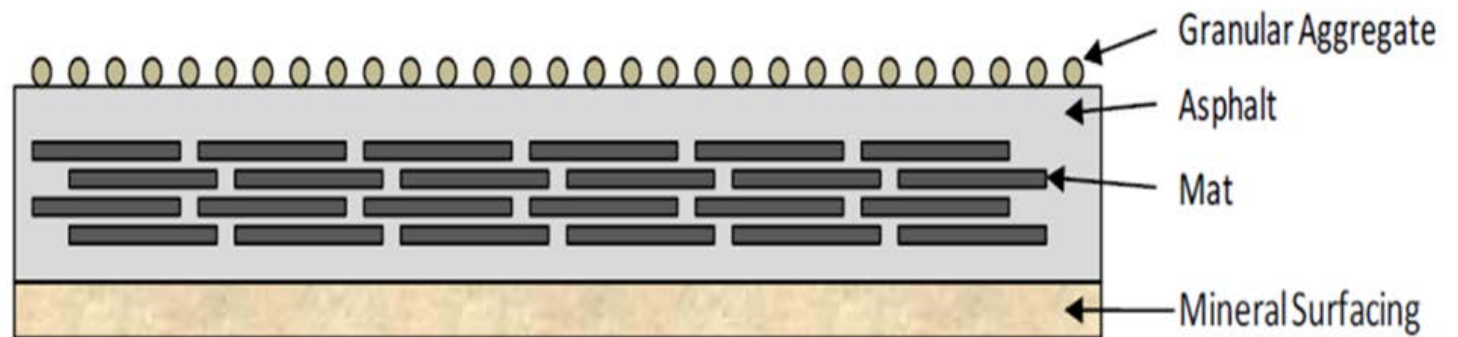


Background

- **Practice of utilizing RAP and/or RAS in new asphalt mixtures has increased in recent years**
 - **economic and environmental benefits**
- **RAP has most widely used materials**
 - **Wearing Course: 15%**
 - **Binder Course: 20%**
 - **Base Course: 30%**
- **RAS has emerged as a material of interest to the paving community**
- **RAP and/or RAS valuable components in asphalt mixtures**
 - **With increased demand and limited supply of aggregate and binder**
- **Potential benefits are high on use high percentages of RAP and RAS**
 - **state agencies have not proceeded to use high percentages of RAP on their roadways**
 - **non-uniformity of RAP materials**
 - **agency's lack of confidence in the long term performance data and specifications.**
 - **problem is further augmented when RAS is used in conjunction with RAP**

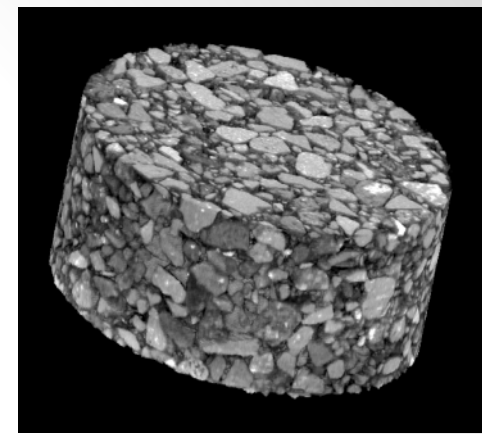
Recycles Asphalt Shingles

- **Asphalt binder**
 - 18 to 30%
- **Mineral matter**
 - 40 to 60%
 - granules and fillers
- **Fibers**
 - 8 to 12%



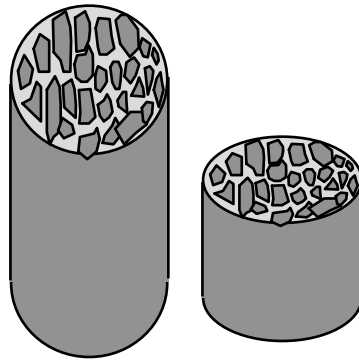
Asphalt Mixture Design

- Optimum asphalt cement content
 - Asphalt Binder from RAS and/or RAP
 - Availability
 - Quality



VOLUME

MASS




**Total
Volume**



**Total
Mass**




Use of RAS in Asphalt Mixtures

- AASHTO MP 15-09  AASHTO MP 23-14
 - *Use of RAS as an Additive in Hot Mix Asphalt (Asphalt)*
- Provides Standard definitions for RAS
- Process RAS
 - 100% passing 12.5-mm sieve
 - Allows blending of RAS with fine aggregate
 - Prevent agglomeration
 - Addresses deleterious materials

**Standard Specification for
Reclaimed Asphalt Shingles
for Use in Asphalt Mixtures**

AASHTO Designation: MP 23-14¹

How to incorporate RAS in Asphalt Mixtures

- AASHTO PP53  AASHTO PP 78-14
 - *Standard Practice for Design Considerations When Using RAS in Asphalt Mixtures*
- Design Considerations When Using RAS in Asphalt Mixtures
- Determining the Shingle Aggregate Gradation and Specific Gravity
- Determining Adjustment to the New Asphalt Binder Grade

Note 6—The RAS asphalt binder availability factor is assumed to range from 0.70 to 0.85 for this practice. Additional research is required to define the interaction of asphalt binder from RAS.

Standard Practice for

**Design Considerations When Using
Reclaimed Asphalt Shingles (RAS)
in Asphalt Mixtures**

AASHTO Designation: PP 78-14¹

Objective

- Laboratory Performance at **high, intermediate, and low temperature**
 - mixtures containing RAS and/or RAP
 - Effect of recycling agents (RAs)

Thermal
Cracking



Fatigue
Cracking



Permanent
Deformation



Scope

- 12.5 mm Asphalt Mixture
- RAS: Post-Consumer
- Binder: PG 70-22M

Mix ID	Mix Code	RAP	RAS	Recycling Agent
Mix 1	70CO	0	0	None
Mix 2	70PG5P	0	5	None
Mix 3	52PG5P-RA 1	0	5	PG 52-28
Mix 4	70PG5P-RA 2	0	5	5% V. D. O.
Mix 5	70PG5P-RA 3	0	5	12% N.O.
Mix 6	70PG5P-RA 4	0	5	20% S.A.
Mix 7	70PG5P15RAP-RA 2	15	5	(0.75% + 5%) V. D. O.
Mix 8	70PG5P_B-RA 5	0	5	15% REOB

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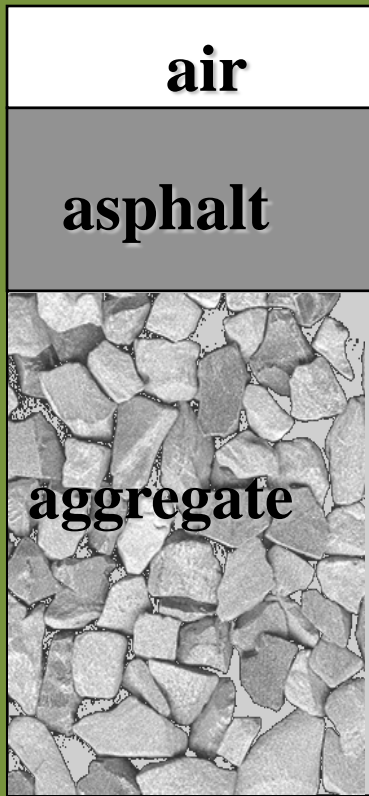
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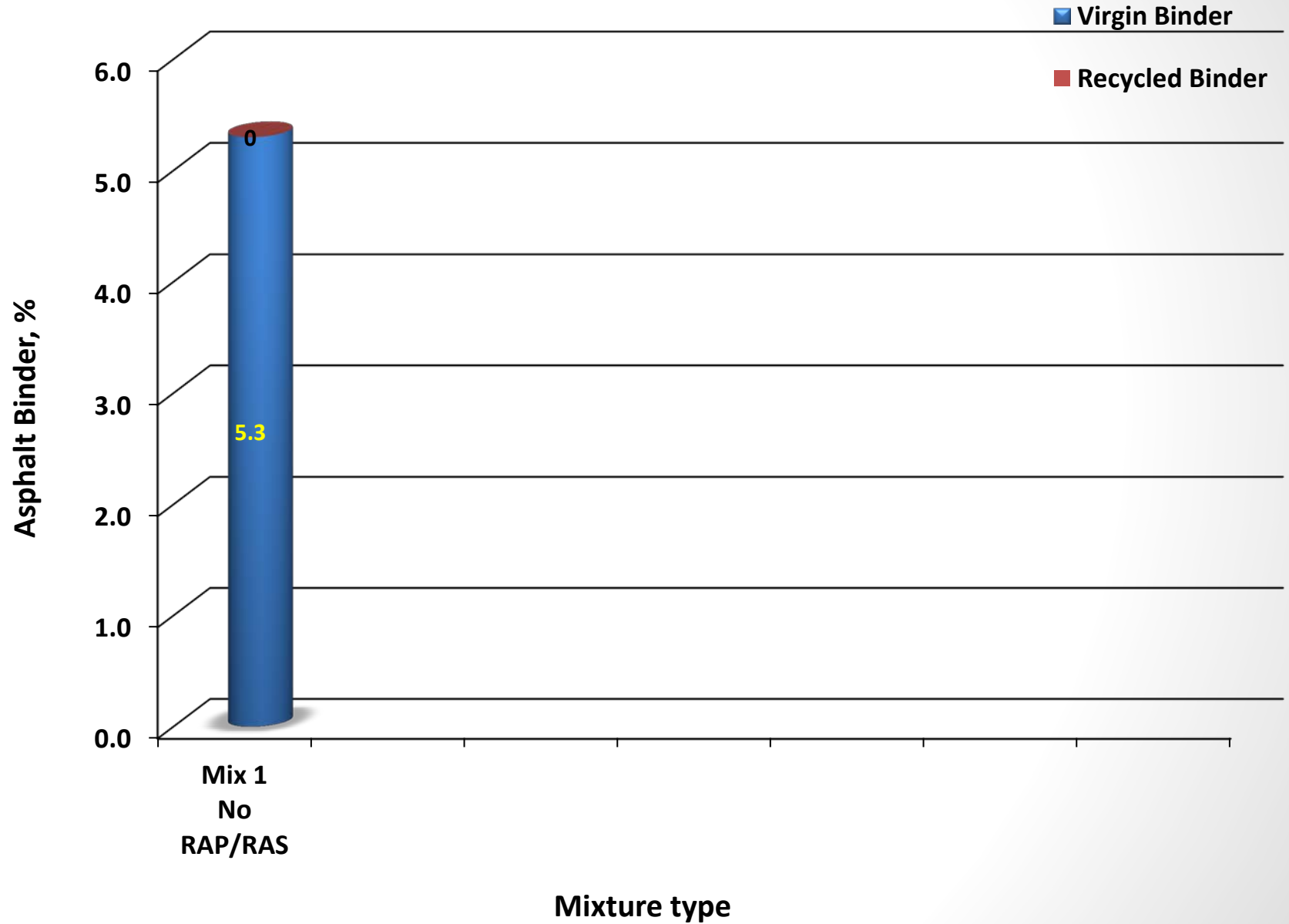
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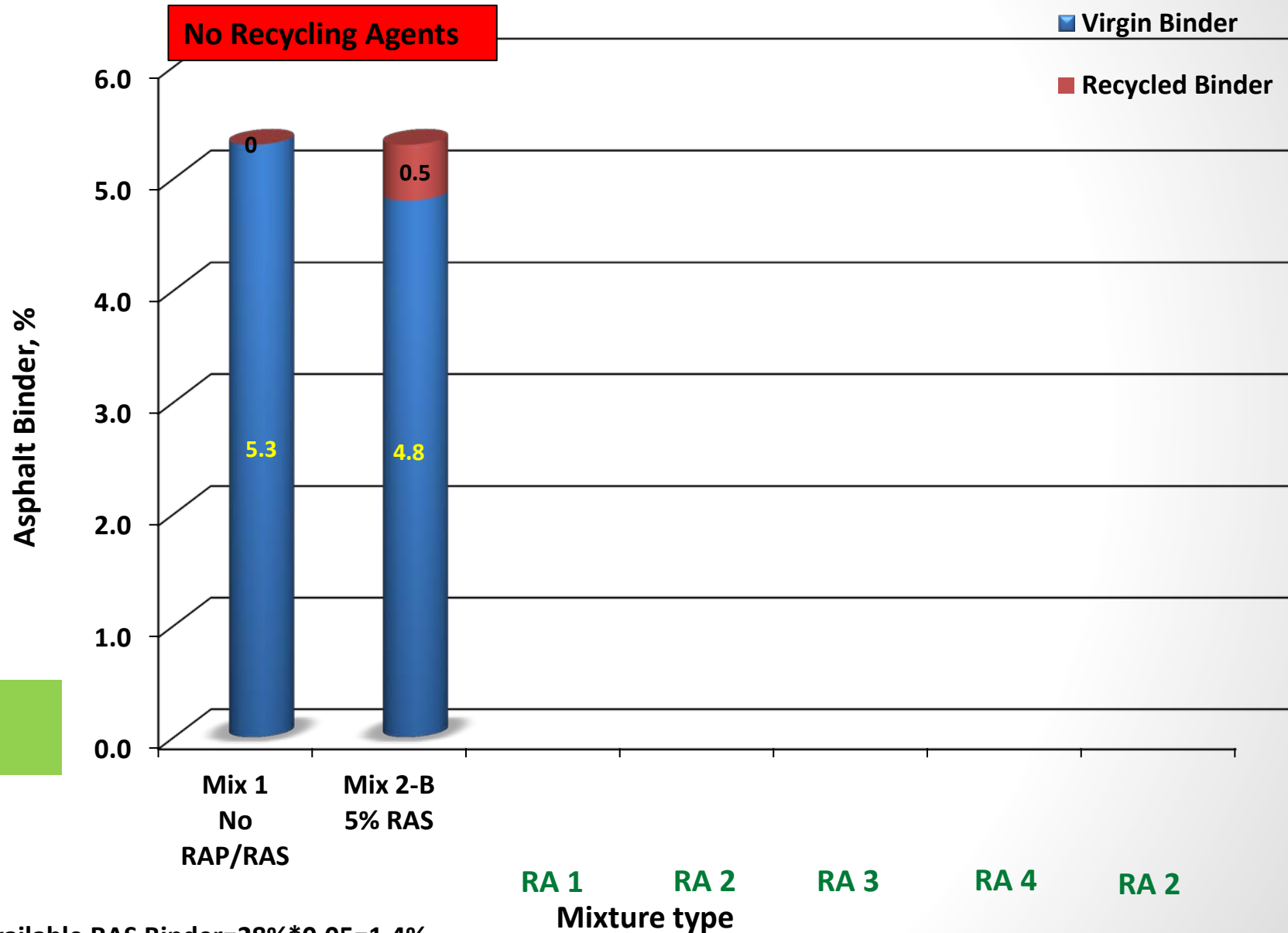
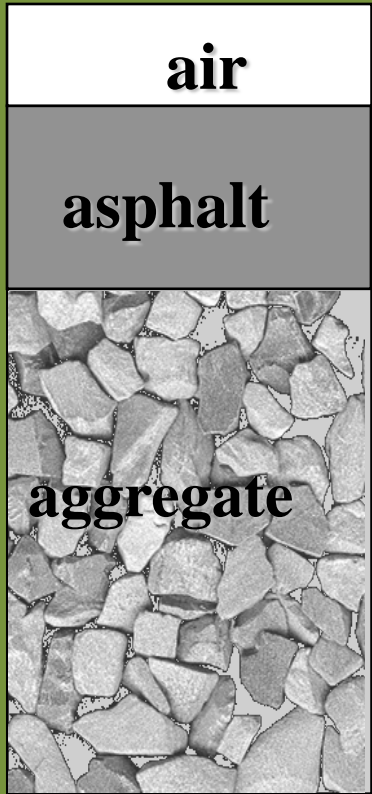
Design Consideration – OAC=5.3%



Mix 1 = 70CO



Design Consideration – OAC=5.3%



Mix 1 = 70CO
Mix 2 = 70PG5P

Available RAS Binder=28%*0.05=1.4%

Mixture Design Concerns

RAS Type	%RAS Total AC Content	%RAS in Mix Design	%RAS AC Binder Available
PCWS	28.6	5.0	1.4

• Classes of Recycling Agents

REJUVENATING AGENTS	SOFTENING AGENTS
Lube Extracts	Lube Stock
Extender Oils (aromatic oils)	Lubricating or Crankcase Oil
Anti-Stripping Agent	REOB (RA-5)
Naphthenic Oil (RA-3)	Asphalt Flux Oils
Vegetable Derived Oils (RA-2)	Soft Asphalt Binders (RA-1)

• Purpose of Recycling Agents

– Softening Agents

- lower the viscosity of the aged binder

– Rejuvenators

- help restore physical and chemical properties of aged binder
- contain a high proportion of maltene constituents

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REJUVENATING AGENTS	SOFTENING AGENTS
Lube Extracts	Lube Stock
Extender Oils (aromatic oils)	Lubricating or Crankcase Oil
Anti-Stripping Agent	REOB – RA 5
Naphthenic Oil (NO) – RA 3	Asphalt Flux Oils – RA 4
Vegetable Derived Oils (VDO) – RA 2	Soft Asphalt Binders – RA 1

• Purpose of Recycling Agents

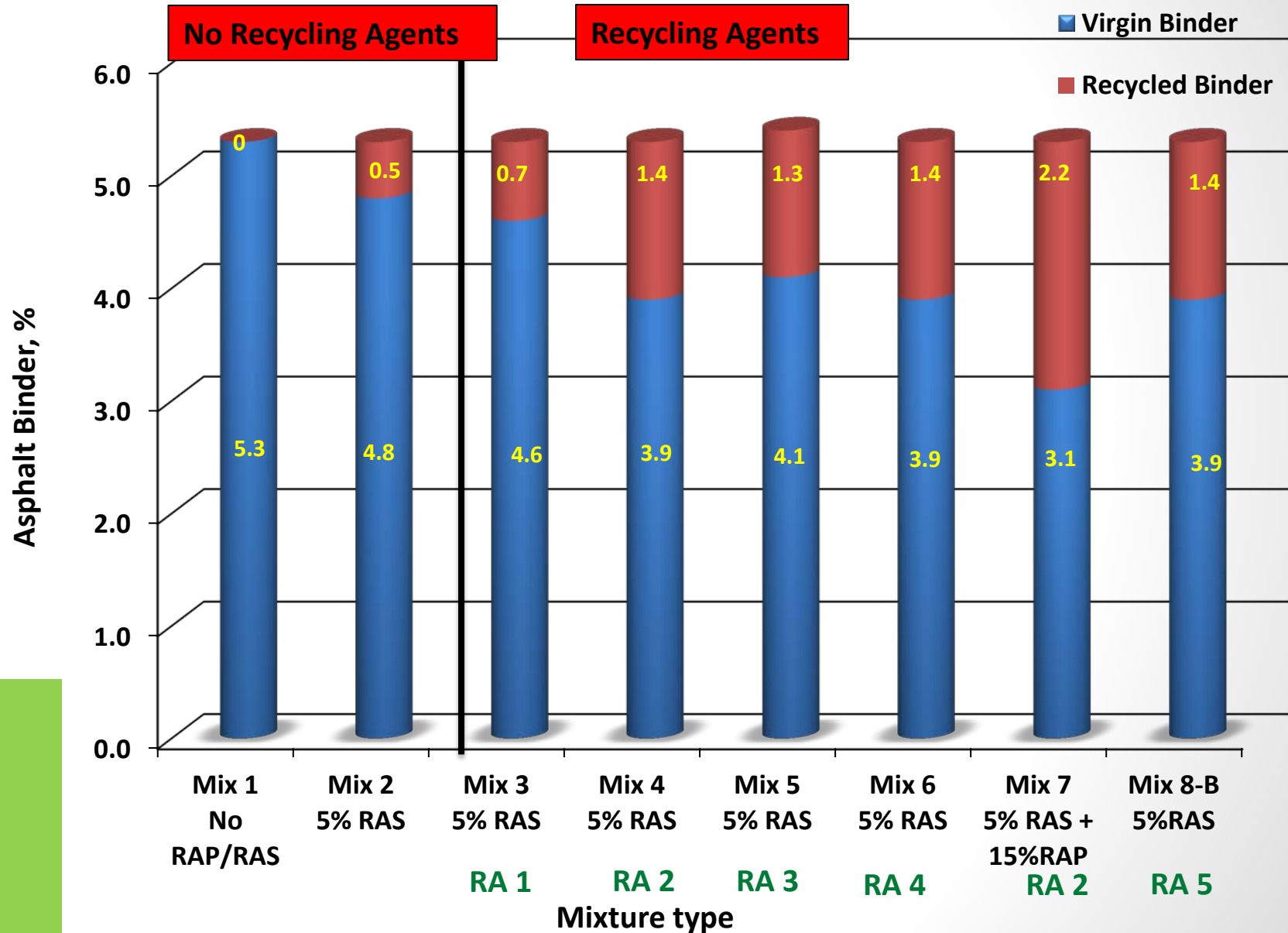
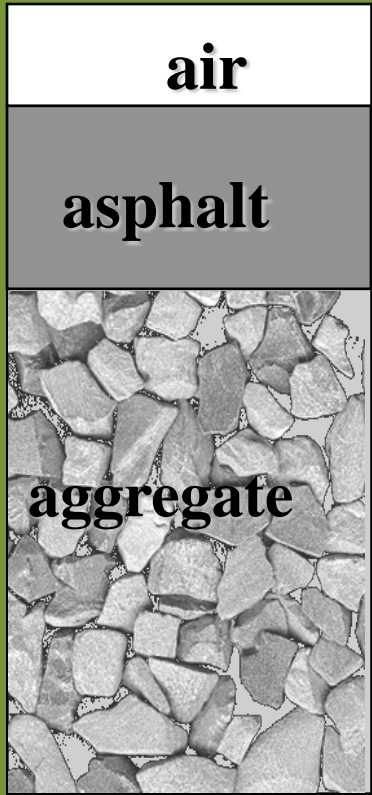
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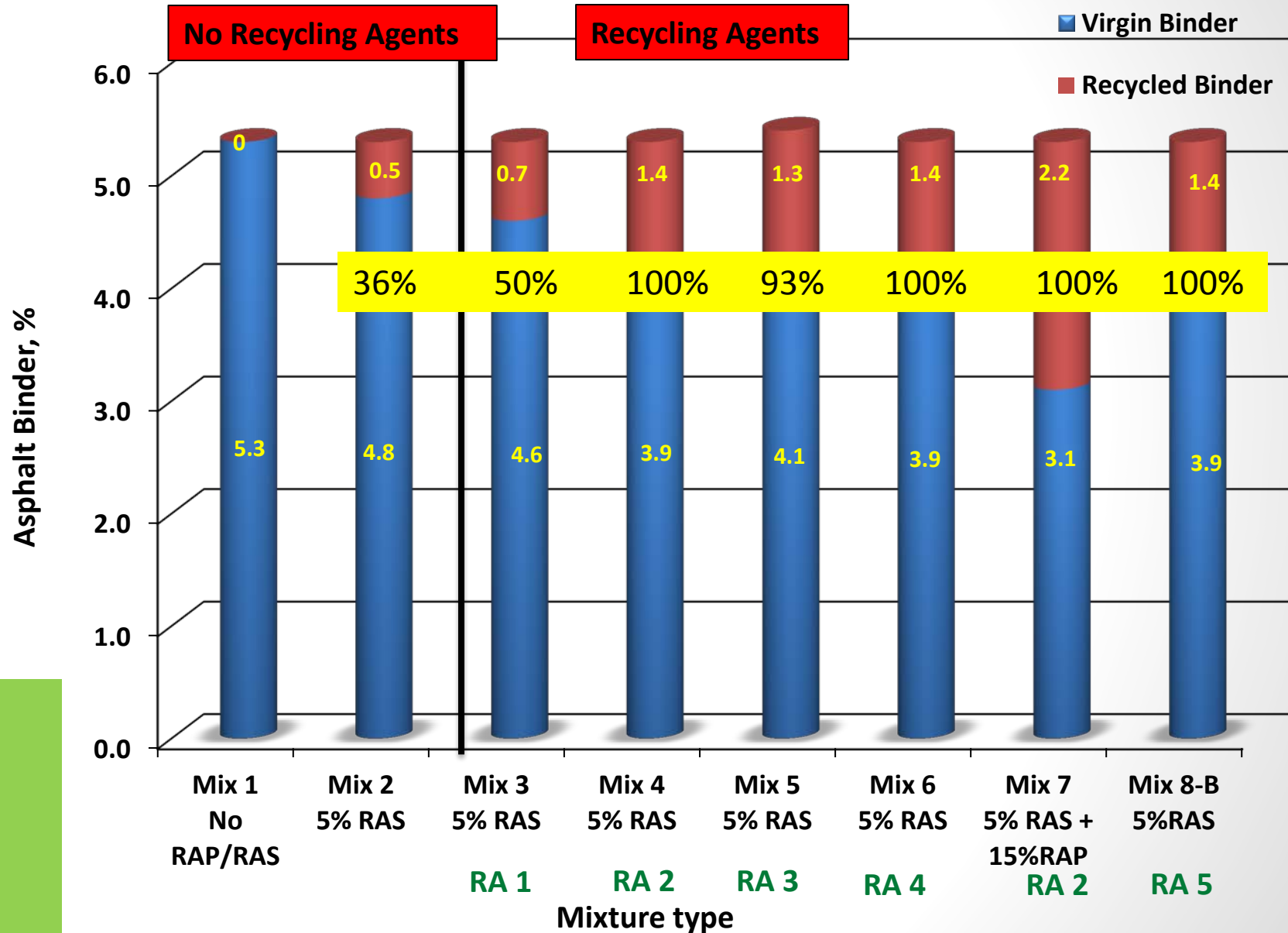
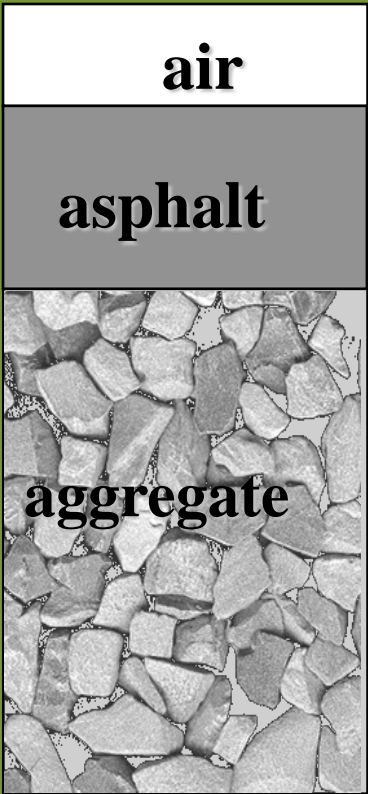
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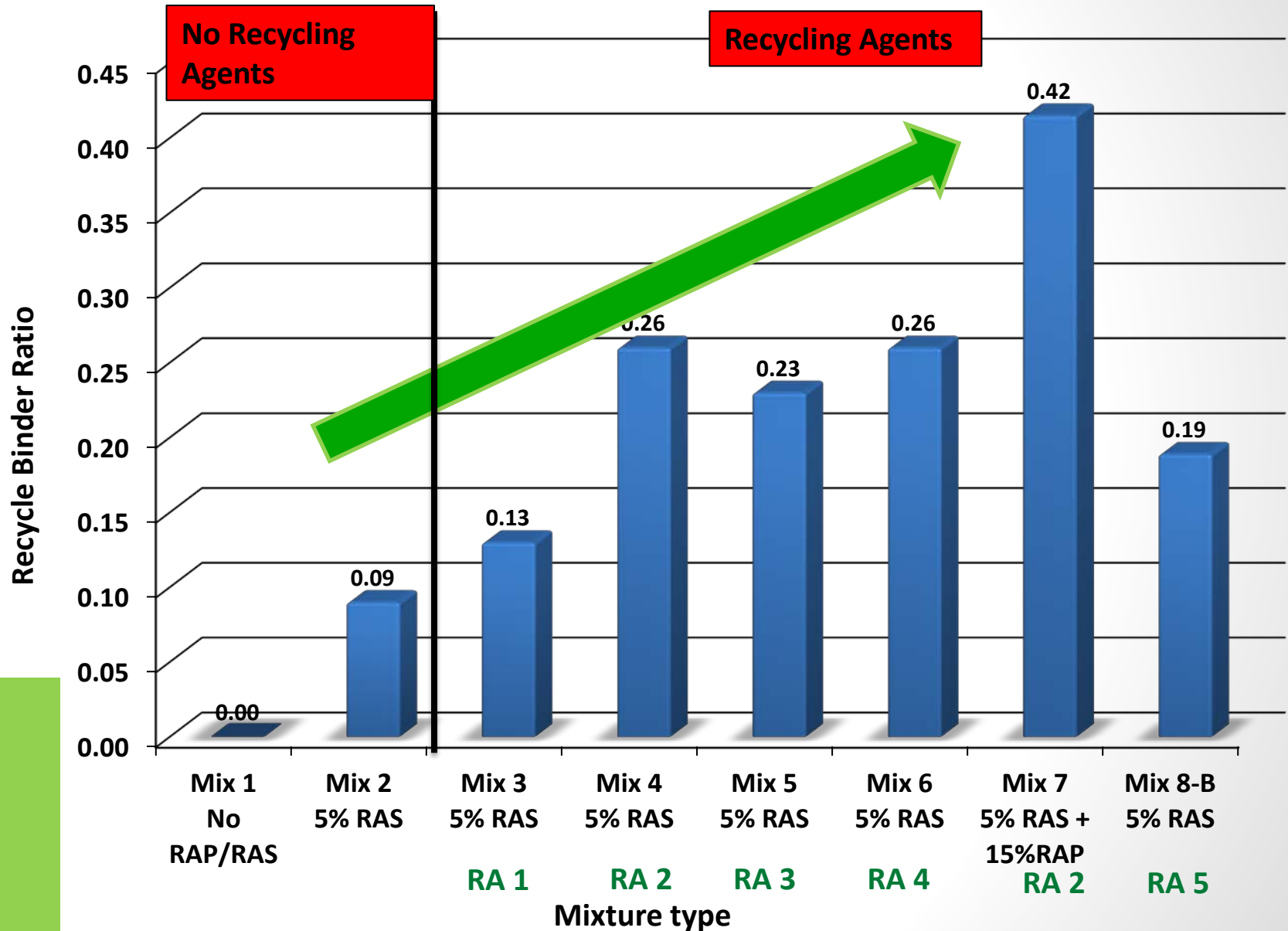
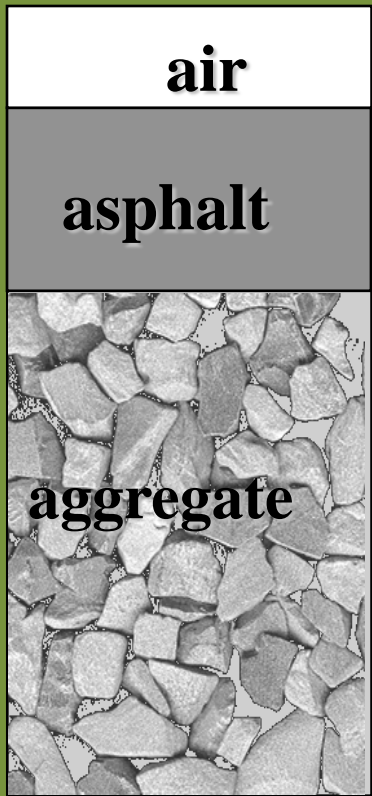
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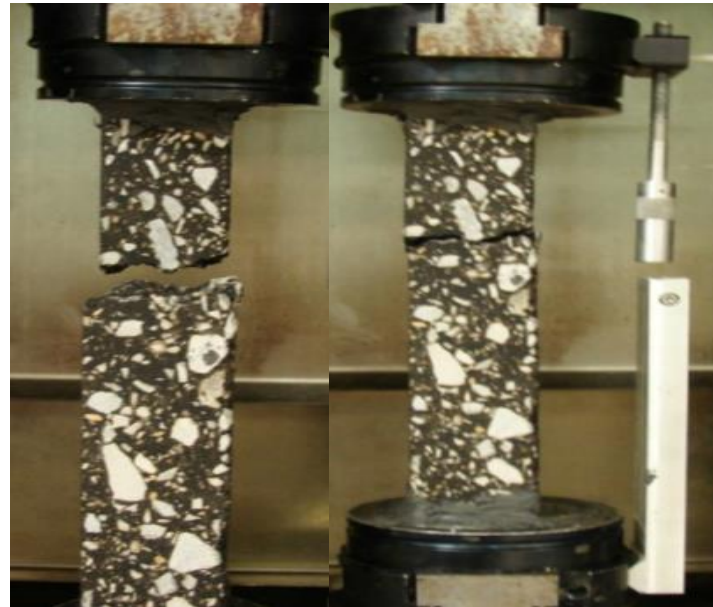
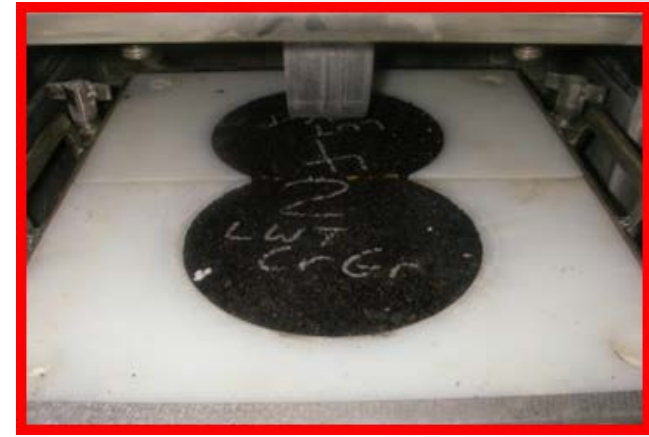
Effect of RAs on Recycled Binder Ratio



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Laboratory Performance Tests

- **High temperature Performance**
 - Loaded Wheel Tracking Test
- **Intermediate temperature Performance**
 - Semi-Circular Bending Test
- **Low temperature performance**
 - Thermal Stress Restrained Specimen Test
- **Triplicates**
 - VTM: $7 \pm 0.5\%$



Thermal
Cracking



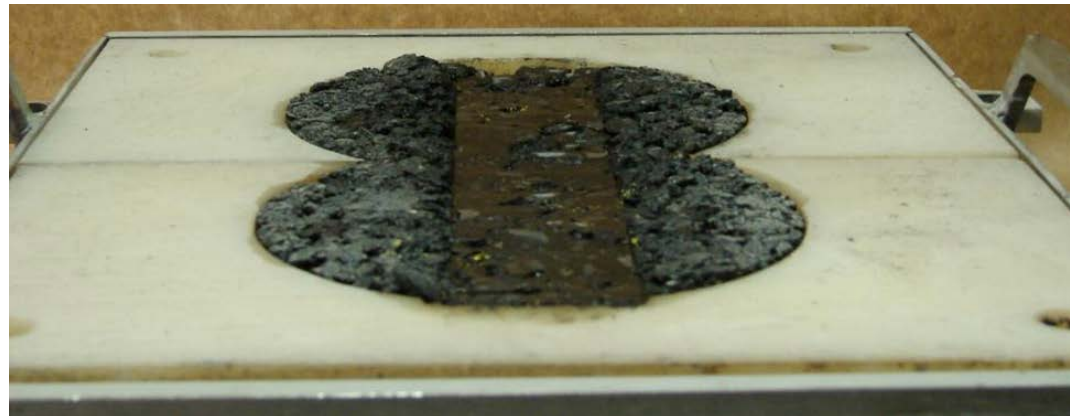
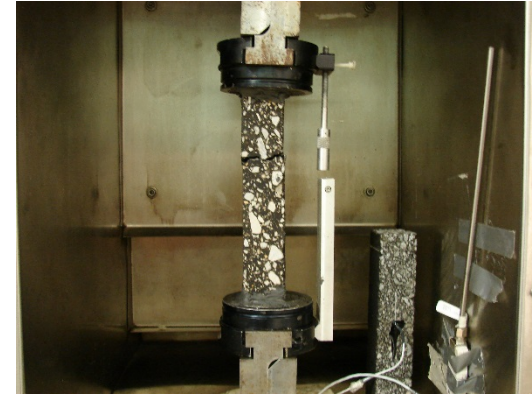
Fatigue
Cracking



Permanent
Deformation

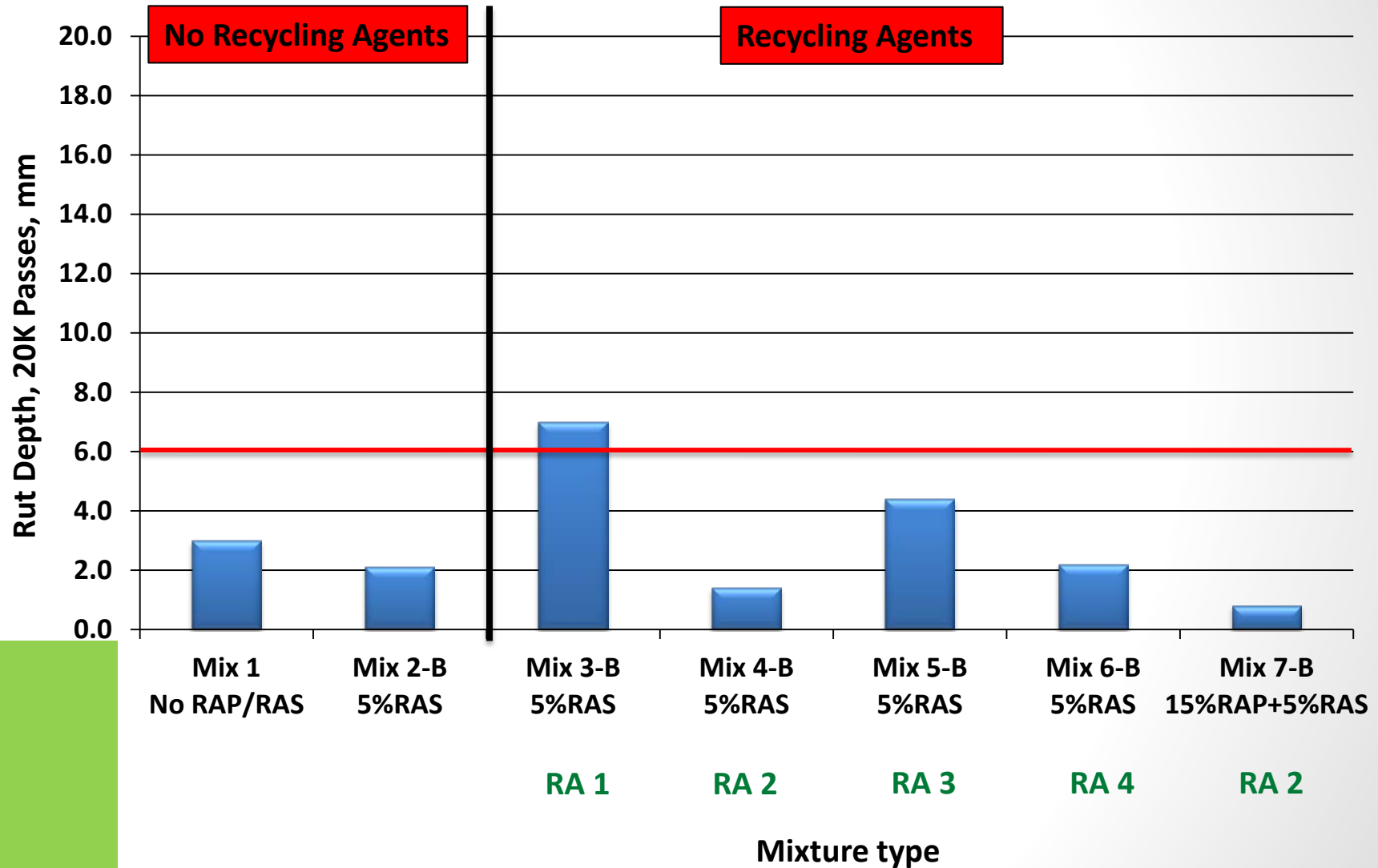


Results



Loaded Wheel Tracking Test Results, 50°C

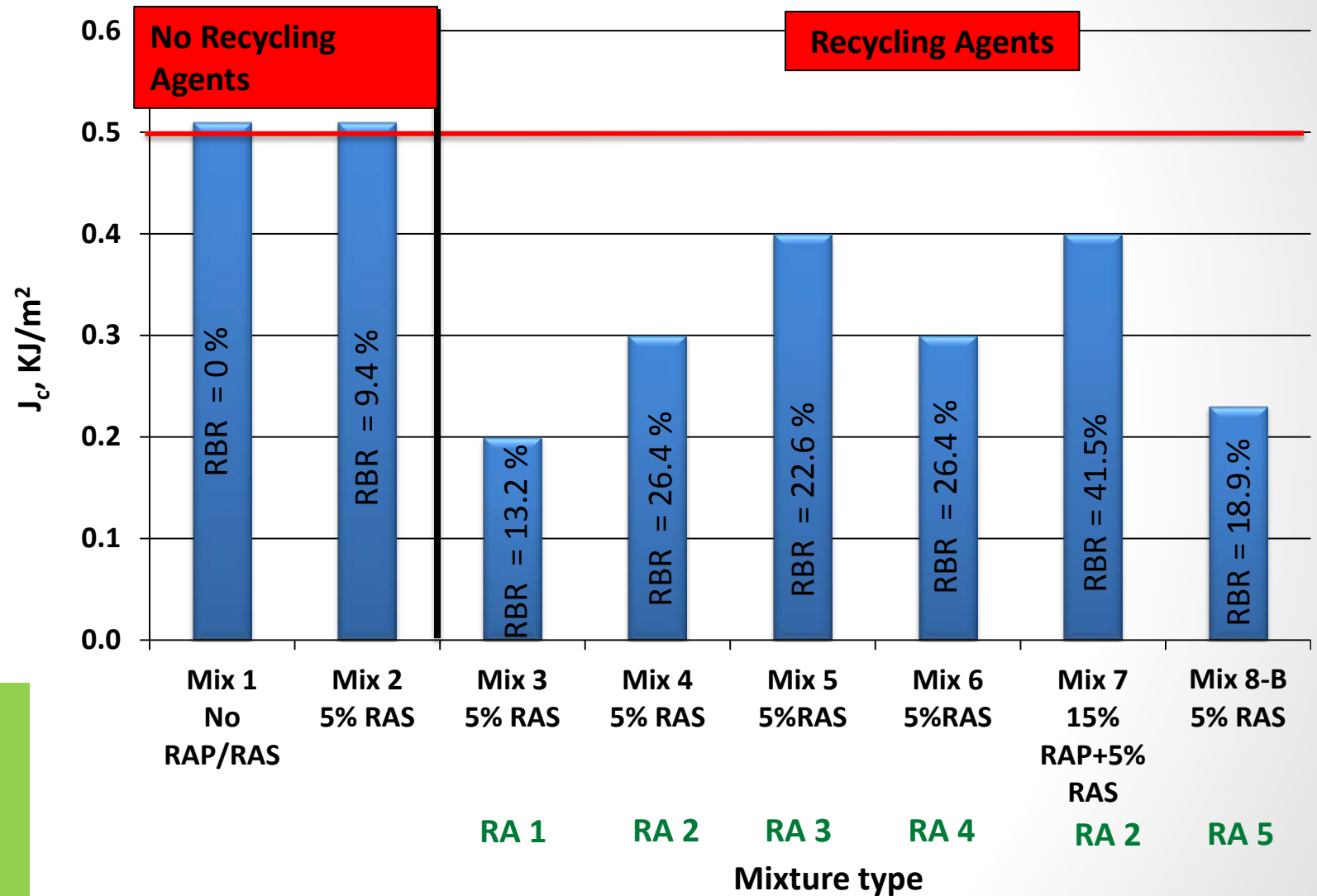
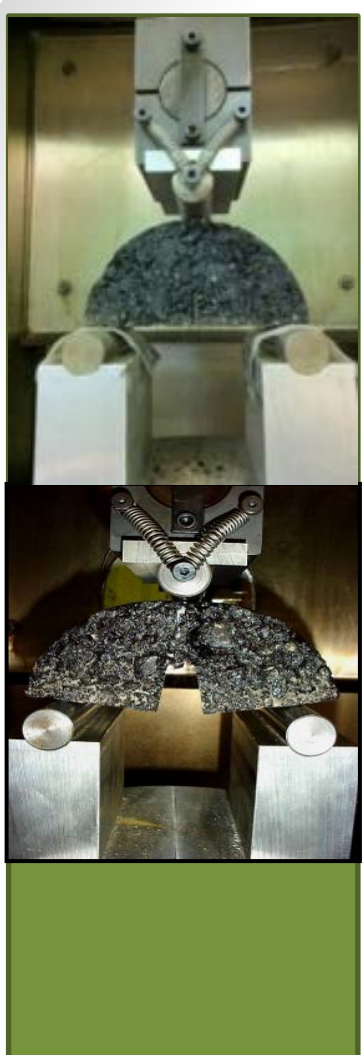
RAP and/or RAS



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Semi-Circular Bend Test Results, 25°C

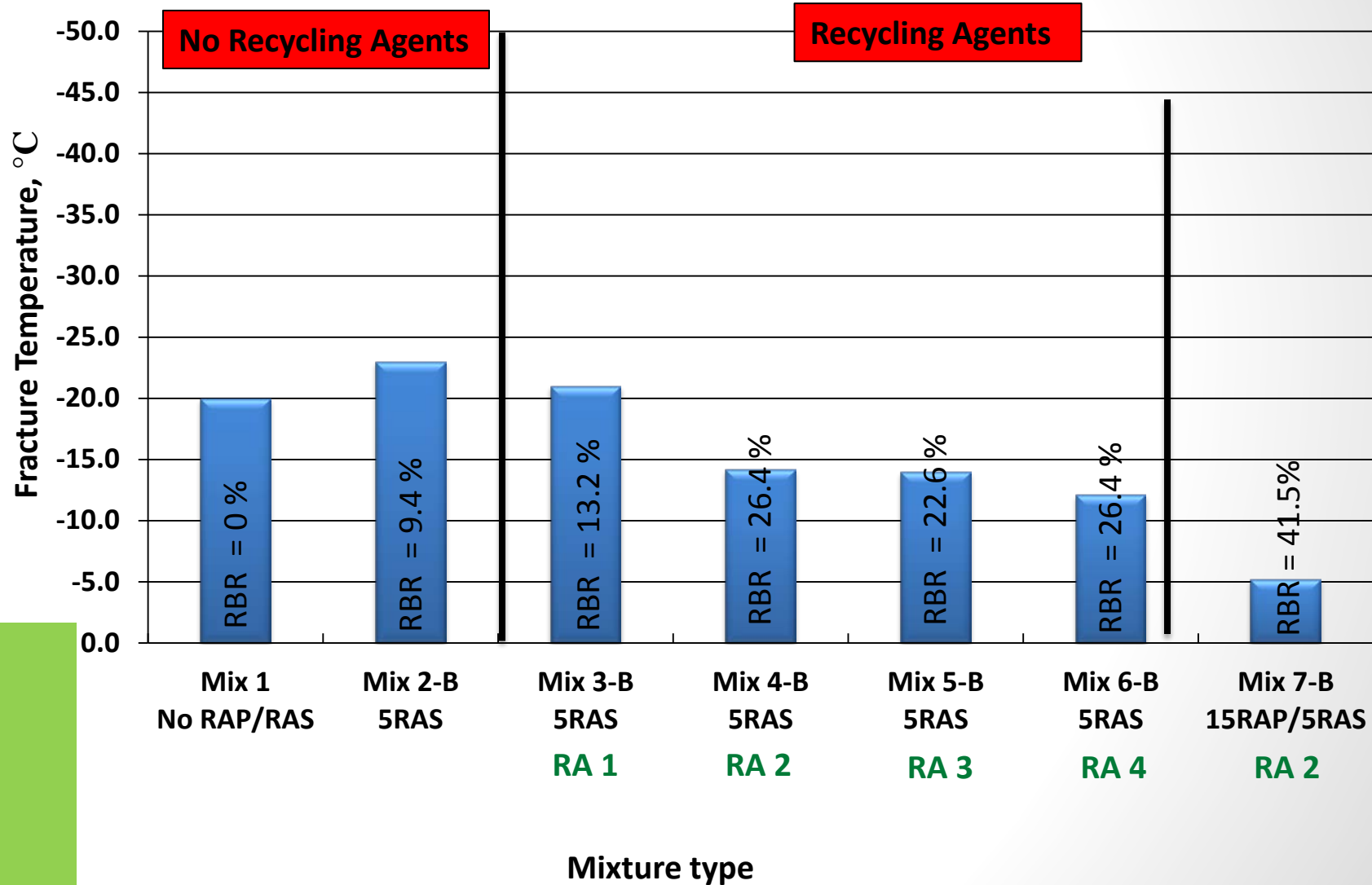
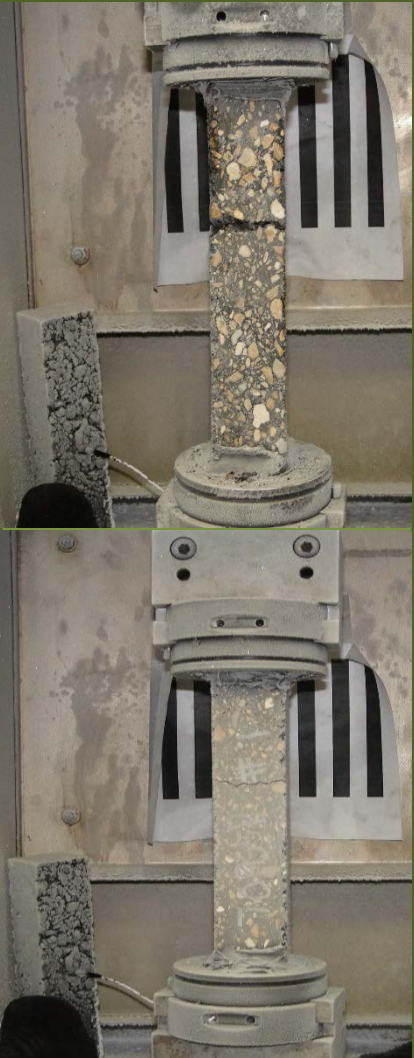
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Thermal Stress Restrained Specimen Test

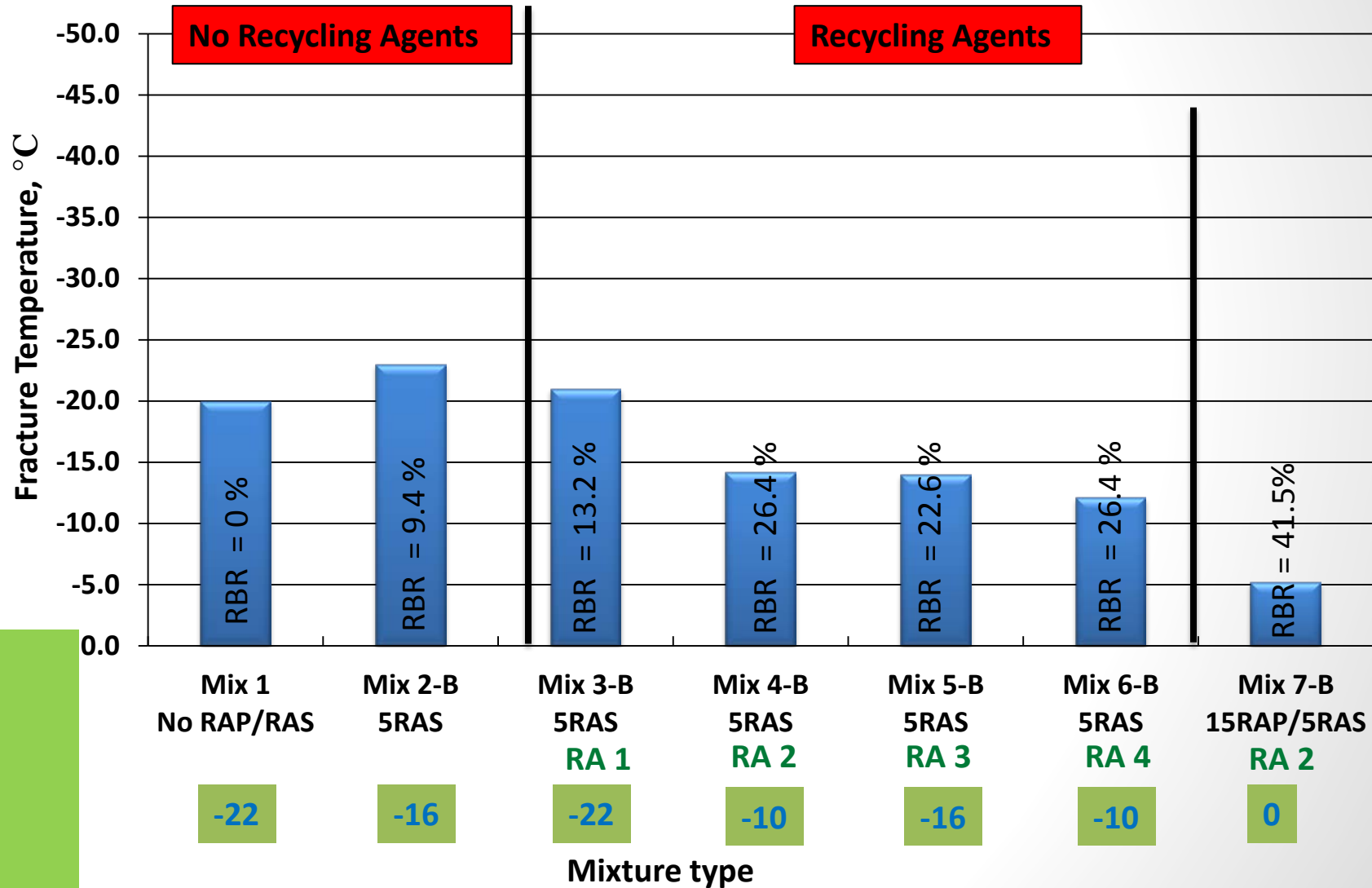
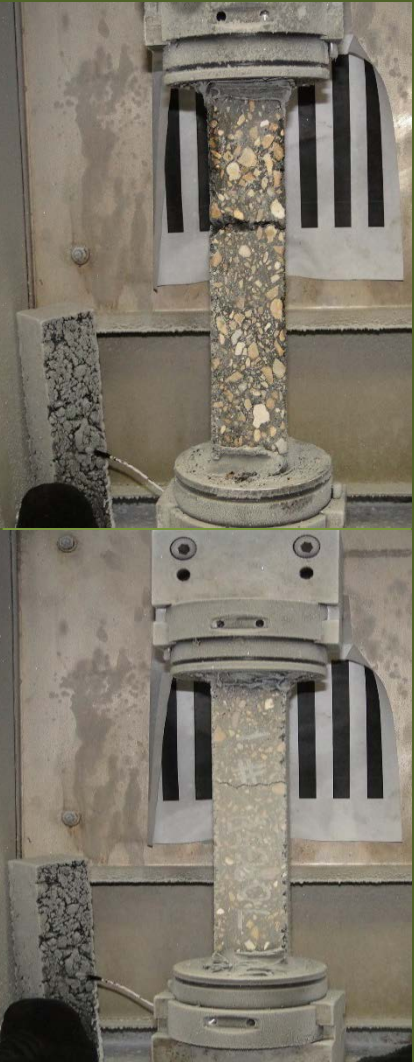
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Thermal Stress Restrained Specimen Test

RAP and/or RAS





















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Summary of Performance *Mixes Containing RAS and/or RAP as Compared to Control Mixture*

Mixture	High Temp (LWT)	Intermediate Temp (SCB)	Low Temp (TSRST)
70PG5P			
52PG5P-RA 1			
70PG5P-RA 2			
70PG5P-RA 3			
70PG5P-RA 4			
70PG5P15RAP-RA 2			

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Mixture	High Temp (LWT)	Intermediate Temp (SCB)	Low Temp (TSRST)
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70PG5P-RA 2			
70PG5P-RA 3			
70PG5P-RA 4			
70PG5P15RAP-RA 2			

Summary

- **Asphalt mixture design**
 - Availability of asphalt binder from RAS and/or RAS
 - **With and Without RAs**
 - **0.36 – 1.0**
- **Quality of the Asphalt binder**
 - **Laboratory test**
 - **Criteria**
- **Effect of Recycling Agents**
 - Use of RAs did enhance the extraction of RAS binder
- **High Temperature Performance, LWT**
 - All mixtures performed well
 - Addition of RAS and/or RAP increased mixtures resistance to rutting



Summary

- **Intermediate Temperature Performance, SCB**
 - Mixes with NRAs
 - No adverse effects
 - Design approach considered
 - Mixes with RAs
 - Lower Jc values
 - Varied with type of RA
- **Low Temperature Performance, TSRST**
 - Mixes with NRAs
 - No adverse effects
 - Mixes with RAs
 - Reduction in Fracture temperature
 - Fracture temperature did track the low temp PG grade of binder



Develop Mix Design and Analysis Procedures for Asphalt Mixtures Containing High-RAP Contents – TPF 5(294)



Transportation Pool Fund Program

<http://www.pooledfund.org/Details/Study/536>



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Study Detail View

Design and Analysis Procedures for Asphalt Mixtures Containing High-RAP Contents and/or RAS

General Information

Study Number: TPF-5(294)

Lead Agency: Louisiana Department of Transportation and Development

Contract Start Date:

Partners: CO , FL , LA

Status: Cleared by FHWA

Est. Completion Date:

Contract/Other Number:

Last Updated: Oct 30, 2013

Contract End Date:

Contact Information:

Lead Agency Contact(s):

Harold Paul
harold.paul@la.gov
Phone: ☎ 225-767-9101

FHWA Technical Liaison(s):

Jack Youtcheff
Jack.Youtcheff@fhwa.dot.gov
Phone: ☎ 202-493-3000

Financial Summary:

Contract Amount:

Total Commitments Received: \$196,000.00

100% SP&R Approval: Approved

Commitments by Organization:

Agency	Year	Commitments
Colorado Department of Transportation	2013	\$28,000.00
Florida Department of Transportation	2012	\$28,000.00
Florida Department of Transportation	2013	\$28,000.00
Florida Department of Transportation	2014	\$28,000.00
Louisiana Department of Transportation and Development	2012	\$28,000.00
Louisiana Department of Transportation and Development	2013	\$28,000.00
Louisiana Department of Transportation and Development	2014	\$28,000.00



Objective

- Evaluate mechanical (fatigue/fracture) tests that can be conducted on plant mixtures (lab or field compacted) from participating states into establish guidelines for use when ranking the quality of RAP and or RAP/RAS mixtures as compared to virgin mixtures.
- Criteria



Approach

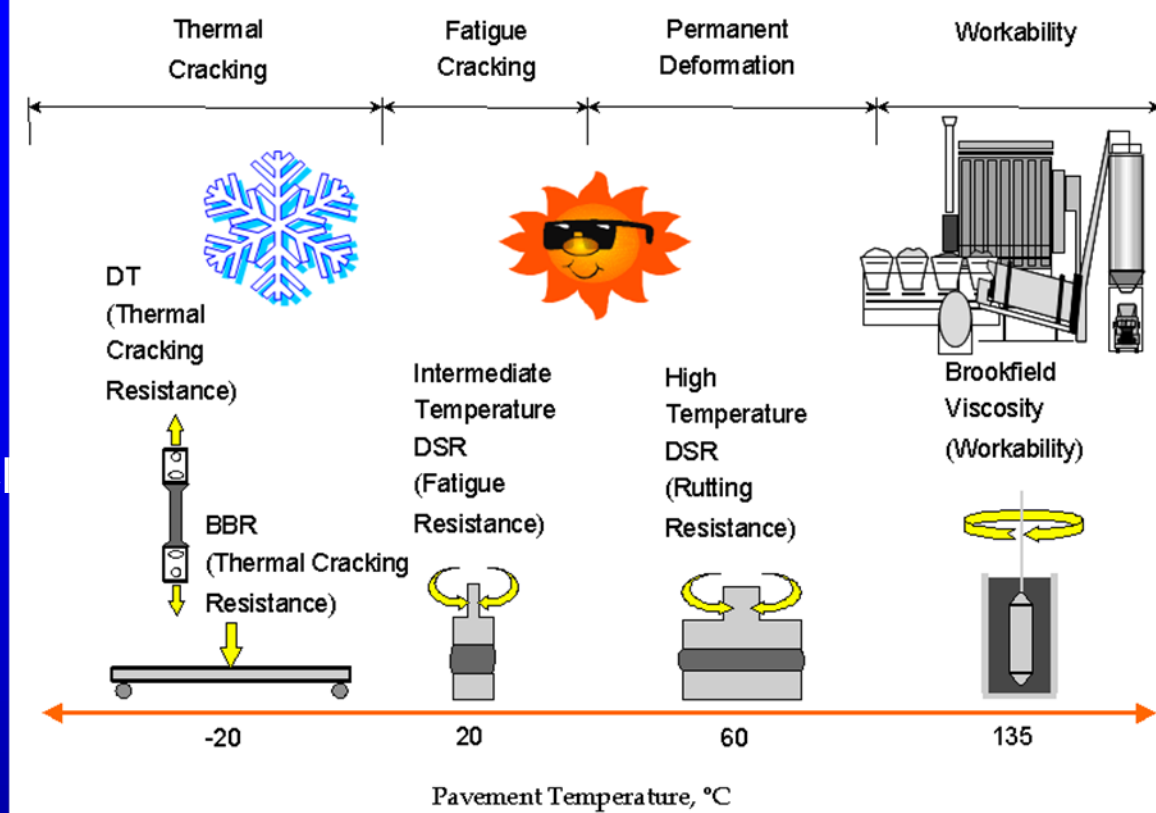
- **Two field projects**
 - Each field project
 - » Two mixtures: Conventional, RAP and/or RAS
 - Conventional may include 15% RAP
 - Four mixtures
- **Collect Mix Design / Pavement Design Record**
 - JMF
 - Loose mixtures
 - Cores
 - » Challenging
- **Standard Materials Characterization**
 - Binder
 - » Solvent Extraction
 - Aggregate properties
 - Mixture



Binder Experiment

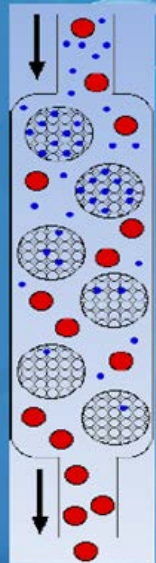
● Binder Rheology

- PG grading
- MSCR
- GPC (Gel permeation chromatography)
- LAS
- Others



GPC

- GPC separates molecules on the basis of size (like sieving!).
- When a mixture of molecules dissolved in a solvent is applied to the top of the column, the smaller molecules are distributed through a larger volume of gel than is available to the large molecules. Consequently, the large molecules move more rapidly through the column, and in this way the mixture can be separated (fractionated) into its components.



AGILENT 1100 GPC SYSTEM



Mixture Experiment

- **Specimen Types**

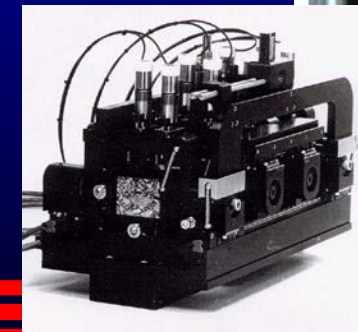
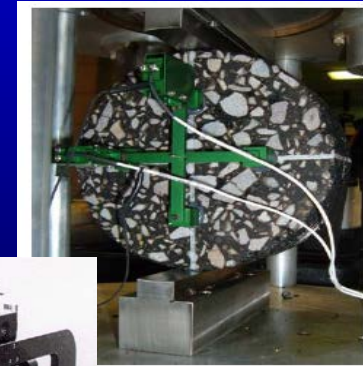
- Laboratory mixed laboratory compacted (LL)
- Plant produced laboratory compacted (PL)
- Plant Produced Field Compacted (Cores)
 - » Challenging
- Triplicates

- **Fracture/fatigue testing**

- Semi-circular bend test, SCB
- Overlay tester test, OT
- Energy Ratio Test
- Beam Fatigue Test
- pseudo visco-elastic continuum damage, SVECD
 - » Pull/Push test

- **Per mixture and Specimen**

- 5 tests x 3 = 15 mixes



Data Analysis

- **Each test will be ranked**
 - Standard test method
 - Field verification/Criteria
 - Cost of Equipment
 - Time required
 - » Sample preparation
 - » Testing
 - » Analysis
 - Level of difficulties
 - » requiring highly-trained personnel
- **Develop a score card**





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LSU
LOUISIANA STATE UNIVERSITY
Photo: Jim Zietz, Office of Public Affairs