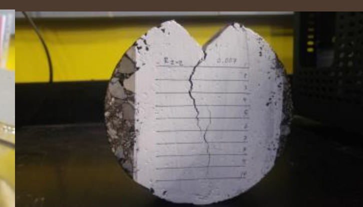
Laboratory and Field Evaluation of Asphalt Mixtures Containing RAP in Phoenix, Arizona



Ali Zalghout

Staff Engineer, GMU Geotechnical Inc.

Arizona Pavement and Materials Conference

November 21, 2019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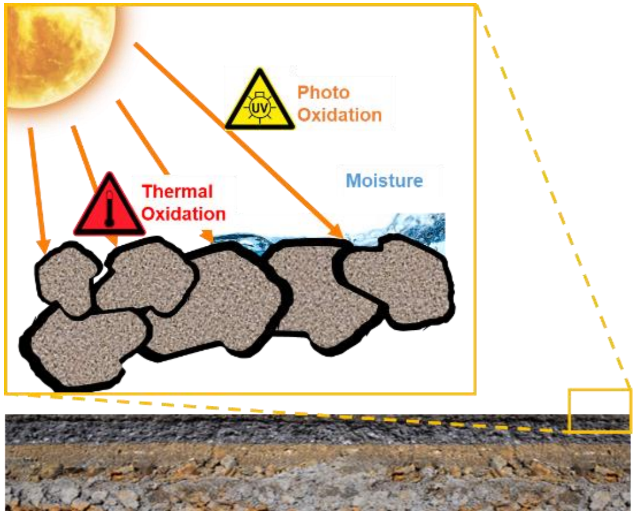

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Overview

- With the High Temperatures in Phoenix, how pavements with RAP contents are going to perform in practice?

- Is RAP going to affect the Mechanical Properties of RAP mixtures in terms of cracking? Permanent Deformation? Moisture Damage?

Presentation Outline

- Introduction
- Plan of Work and Objective
- Materials and Field Sections Construction
- Mixture Level Testing and Analysis
- Field Evaluation and Cores Testing
- Conclusion

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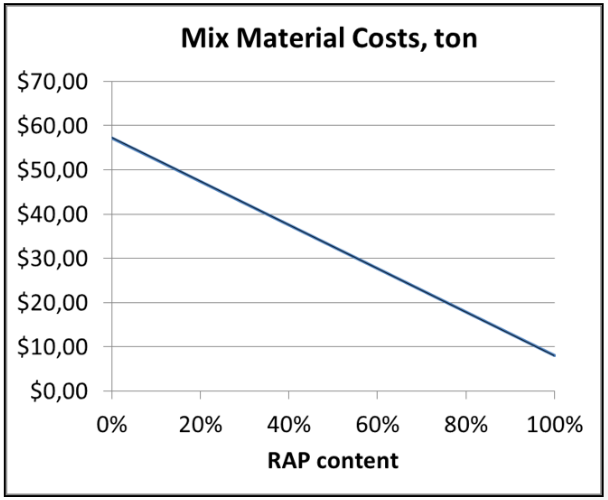
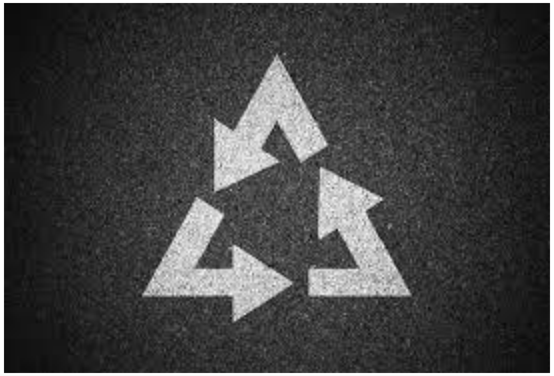
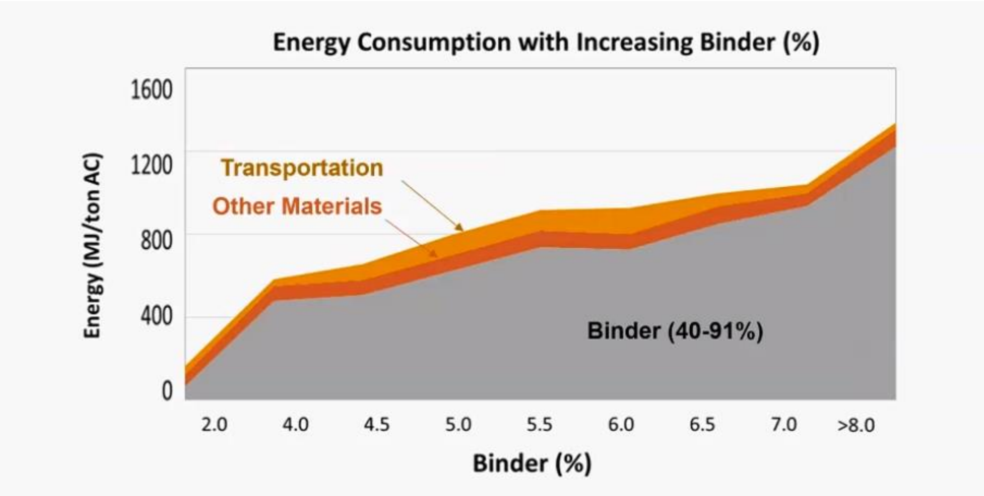
Introduction

RAP is a potential solution



Zaumanis, 2013





Al-Qadi et al, 2018

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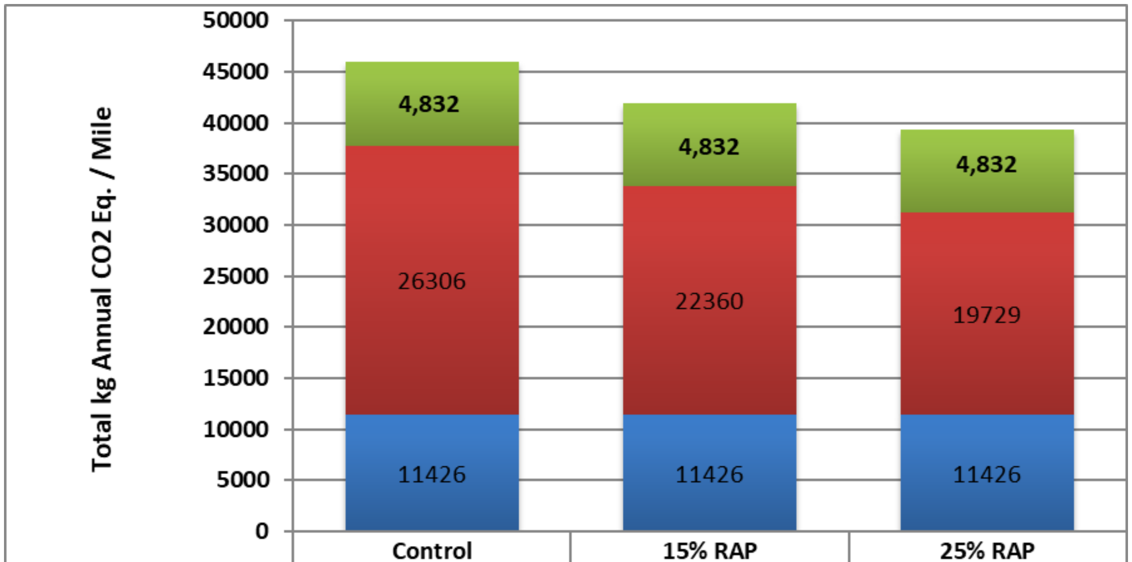
Introduction

CO2 Savings



	Control	15% RAP	25% RAP
Transportation	8176	8176	8176
Manufacturing	26306	22360	19729
Production	11426	11426	11426

Kaloush (2018)

Introduction

Asphalt Aging

- Thermal Degradation

- Chemical Degradation
  - Photo-Oxidation (UV 300-400 nm provide the needed energy)
  - Thermal Oxidation
  - Hydrolytic Degradation

- Asphalt Aging is a complex phenomenon

→ Oxidation occurs, Asphalt stiffens and become more brittle

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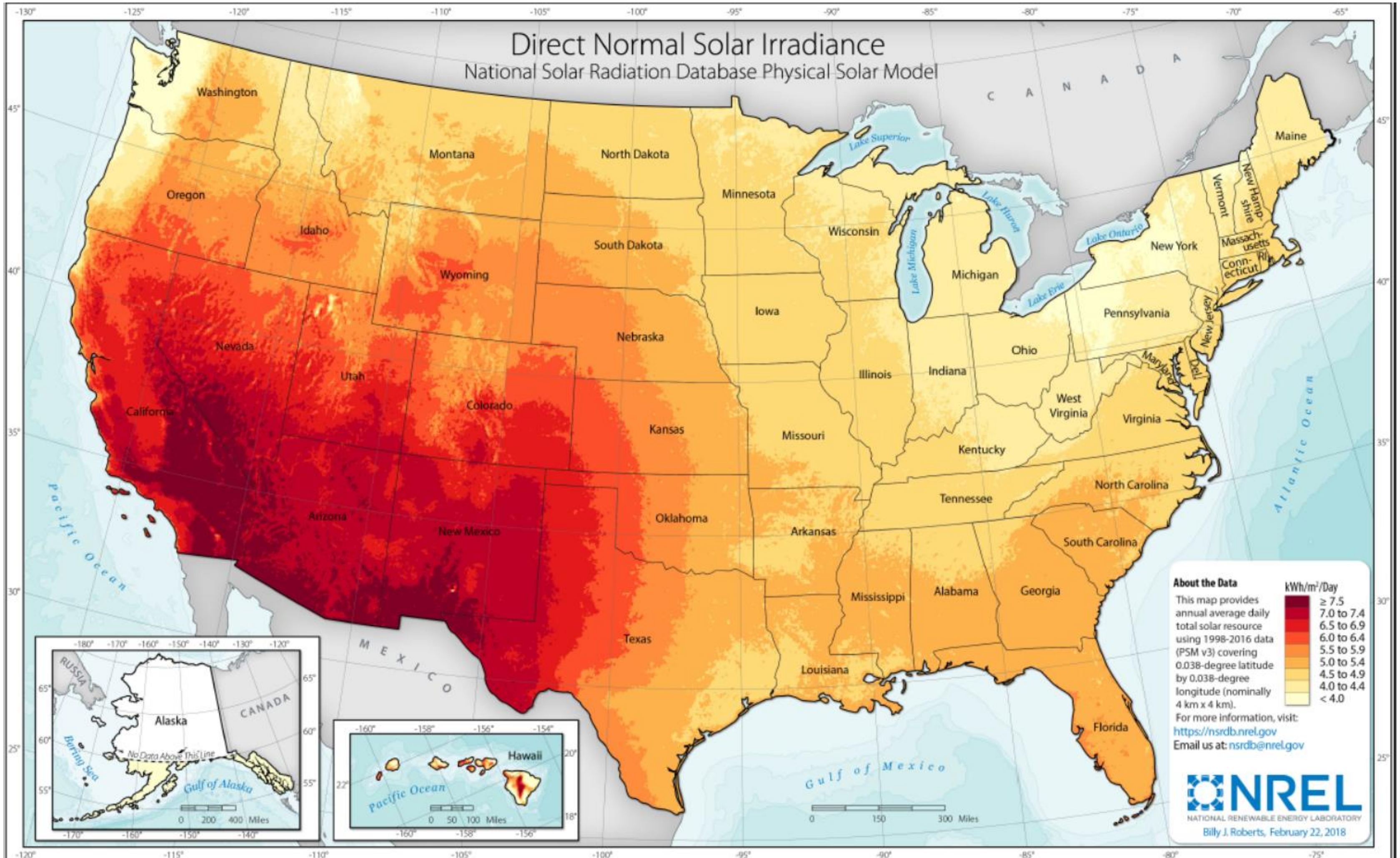

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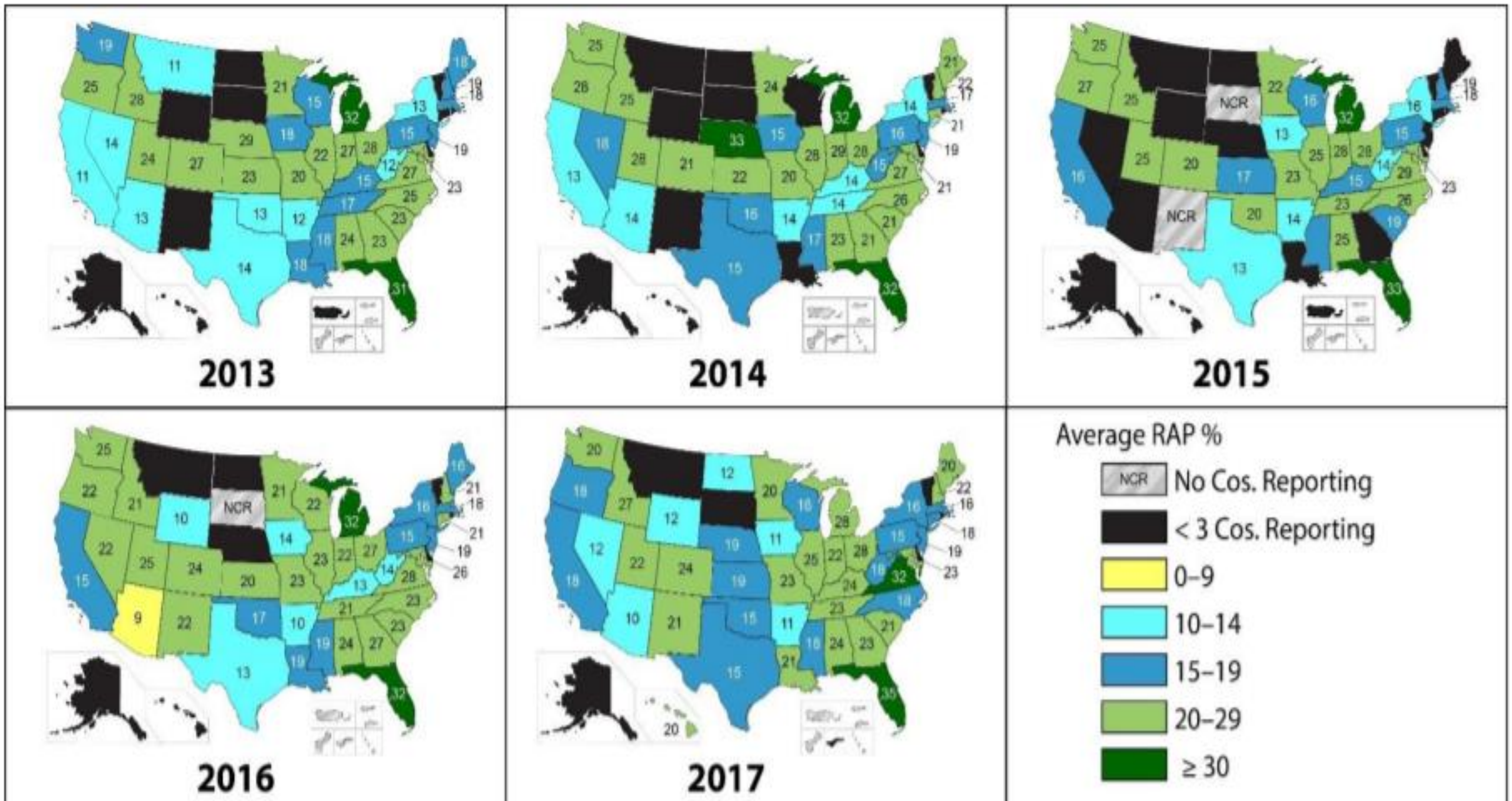
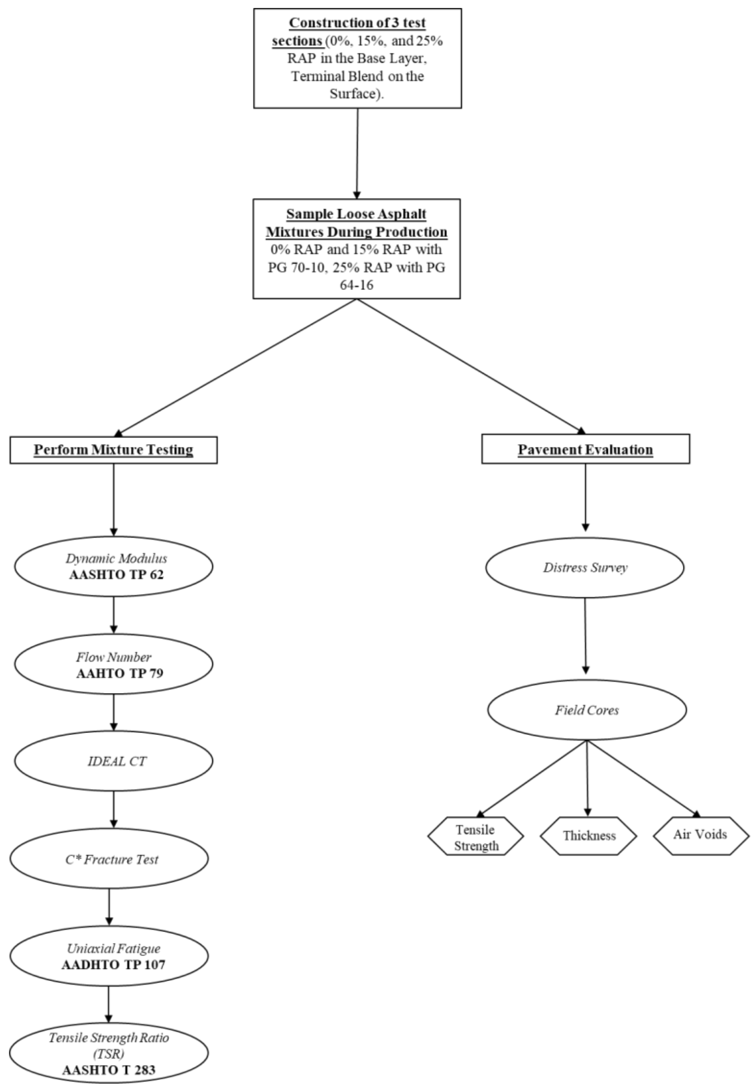


NAPA. 2017

PG 58-34 → PG 82-16

In Phoenix PG 70-10 → PG 124+26

Plan of Work



Construction of 3 test sections (0%, 15%, and 25% RAP in the Base Layer, Terminal Blend on the Surface).
Sample Loose Asphalt Mixtures During Production 0% RAP and 15% RAP with PG 70-10, 25% RAP with PG 64-16
Perform Mixture Testing
Pavement Evaluation
Dynamic Modulus AASHTO TP 62
Flow Number AAHTO TP 79
IDEAL CT
C* Fracture Test
Uniaxial Fatigue AADHTO TP 107
Tensile Strength Ratio (TSR) AASHTO T 283
Distress Survey
Field Cores
Tensile Strength
Thickness
Air Voids

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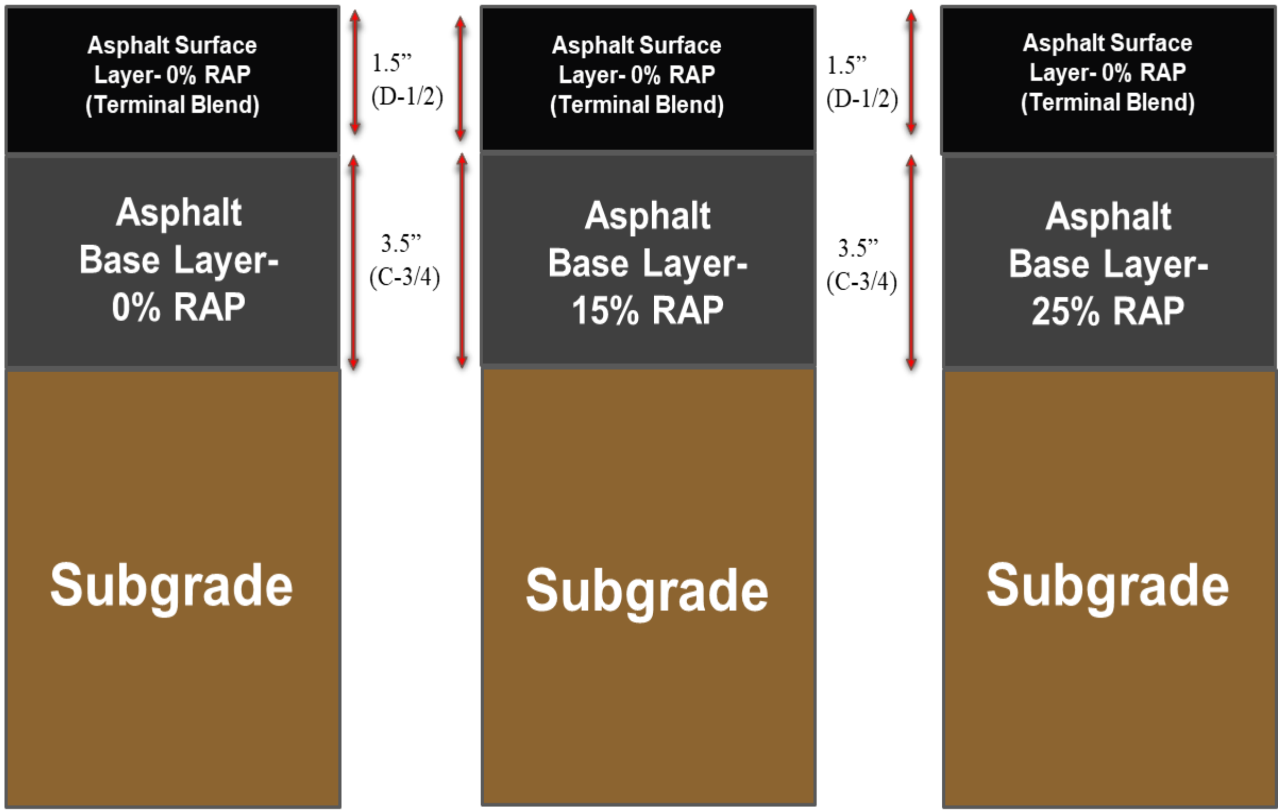
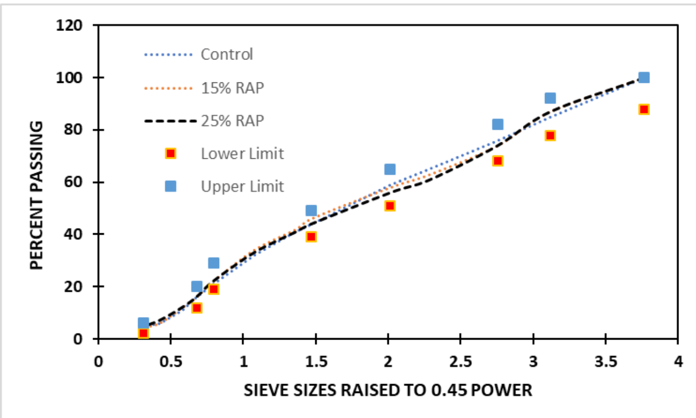
Materials and Sections Construction



Section 1 Section 2 Section 3

Materials and Sections Construction



Property	0% RAP (Control)	15% RAP	25% RAP
Total Binder Content (%)	5	5	5
Marshall Bulk Density (pcf)	148	148.7	149.2
Max. Theoretical Specific Gravity	2.478	2.481	2.486
Max. Theoretical Specific Density (pcf)	154.6	154.8	155.1
Stability	5010	5390	5210
Marshall Flow (in)	11	10	11
% Air Voids	4.3	3.9	3.8
% VMA	14.5	14.5	14.2
% Air Voids Filled	70.5	72.7	72.8
% Eff Asphalt Total Mix	4.39	4.52	4.41
Film Thickness (micro)	9	9	9
Dust/Bitumen Ratio	1.1	1	1.1

PG 70-10　PG 70-10　PG 64-16

75 Blows

Section 710.2.3, MAG Specifications, 2013

Hydrated Lime as Anti-stripping agent for base mixtures, and type II cement for surface TR mix.

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Materials and Sections Construction

- The base layers were constructed on December 3, 2018.

- The surface layer TR was constructed on the following day.

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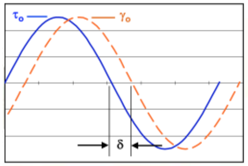
Materials and Sections Construction

Mixture Testing



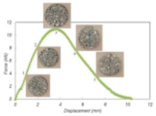

Dynamic Modulus: To determine the Stiffness of the material. Fundamental property for pavement design (temperature and frequency).


Flow Number: To determine the Rutting Potential of the RAP mixtures compared to that of the Control one.


Uniaxial Fatigue : To determine the Fatigue Cracking resistance of the three mixtures.

C* Fracture Test: To determine the crack propagation properties of the 3 mixtures.


Tensile Strength Ratio (TSR): To determine the Moisture Damage susceptibility of the 3 mixtures.

IDEAL CT: To determine the cracking properties of the 3 mixtures

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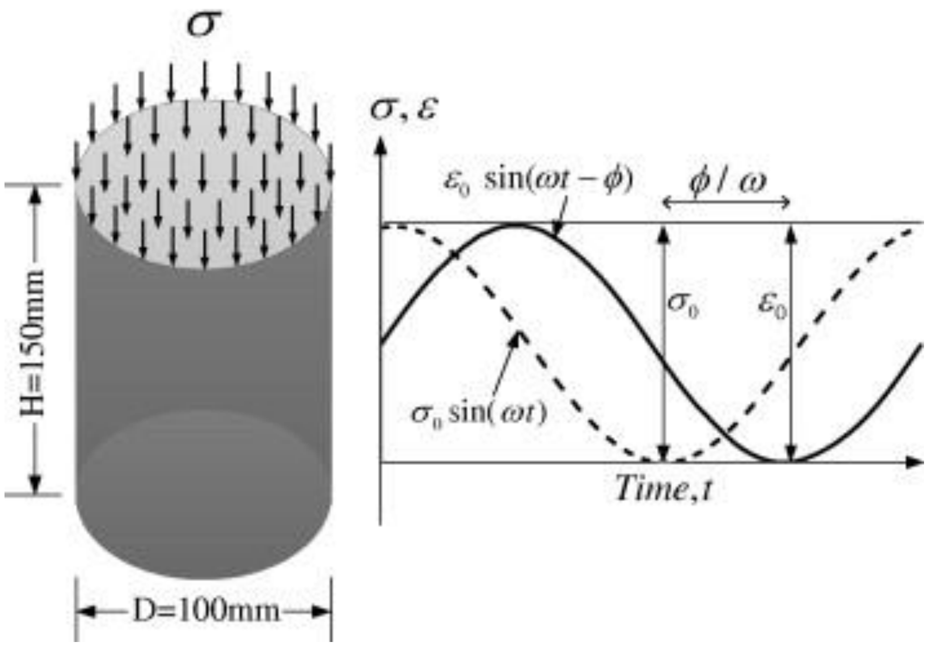
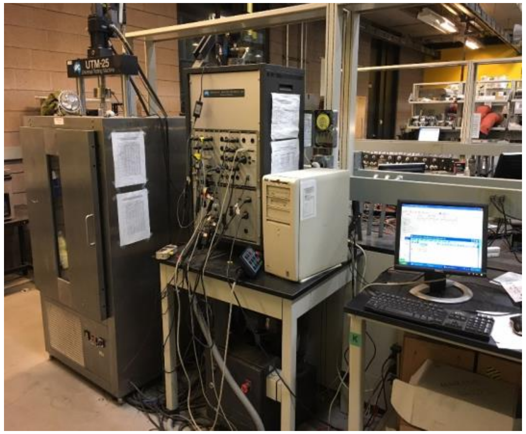
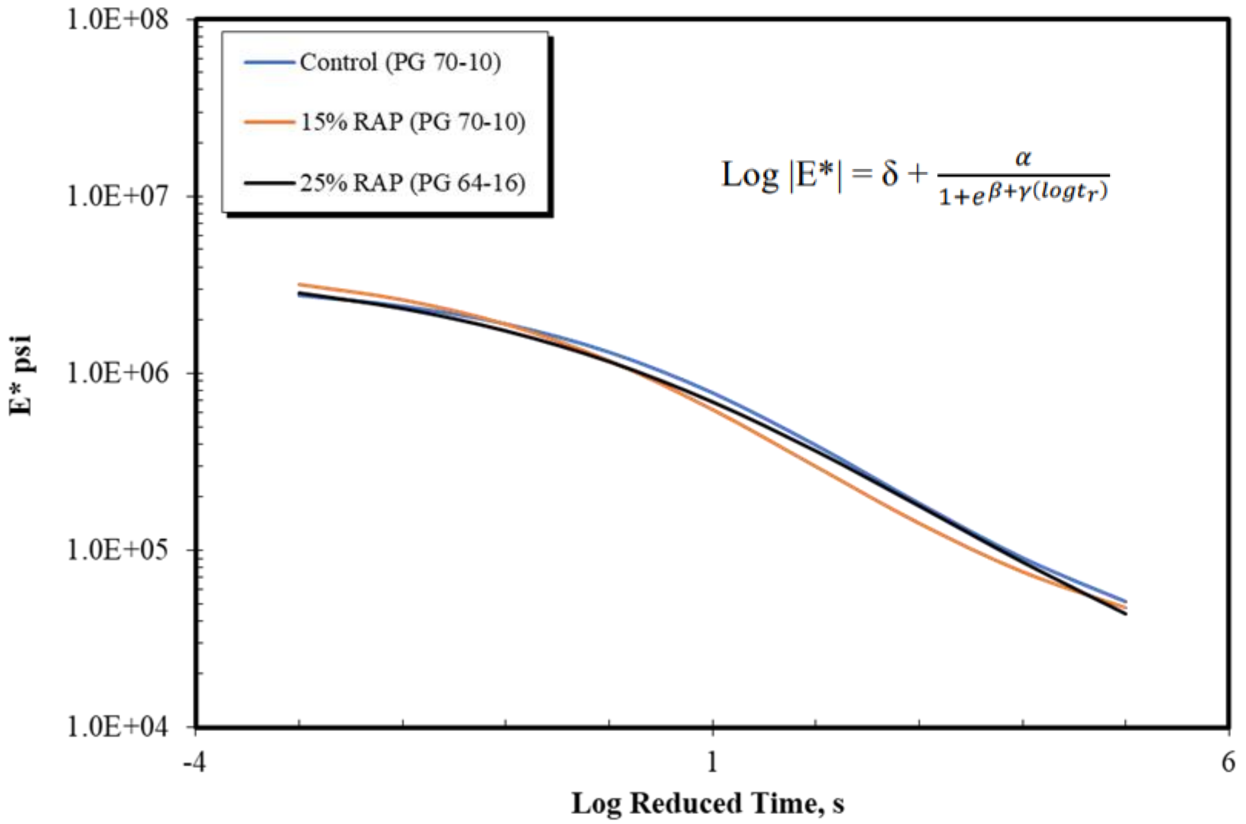
Dynamic Modulus
AASHTO TP 62





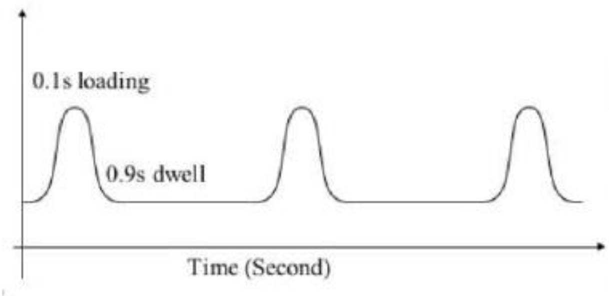
- Sinusoidal repetitive load
- 4 Temp. : **4.4, 21.1, 37.8 and 54.4°C**.
- For 6 frequencies: **25, 10, 5, 1, 0.5 and 0.1 Hz**.
- The dynamic modulus, |E*| & phase angle δ

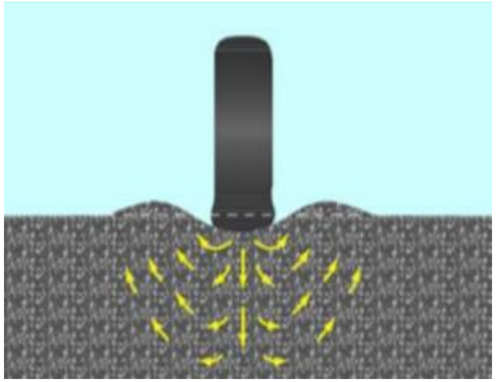
Dynamic Modulus Results

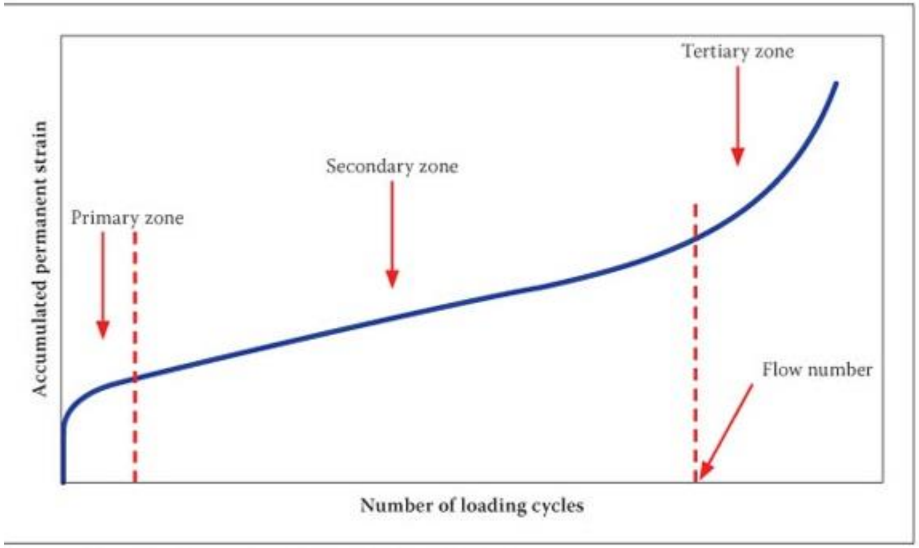


Dynamic Modulus	
0%	NS
15%	
25%	

Flow Number
AASHTO TP 79



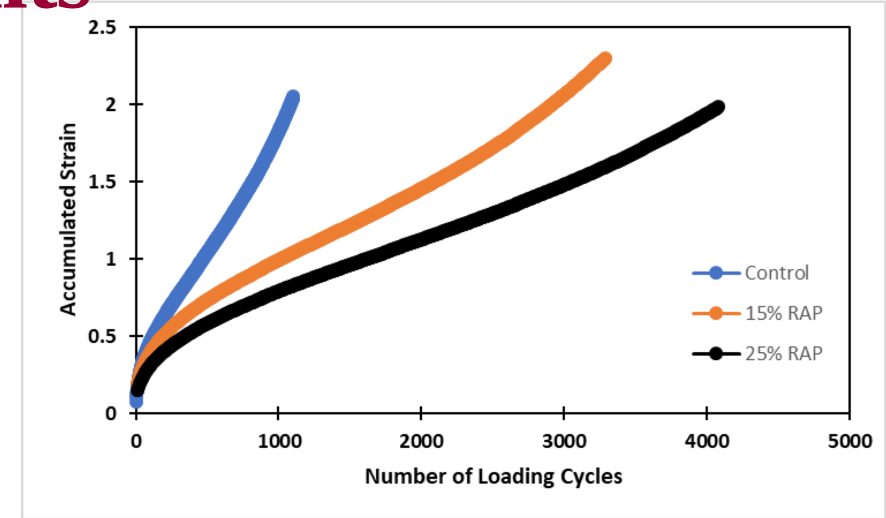


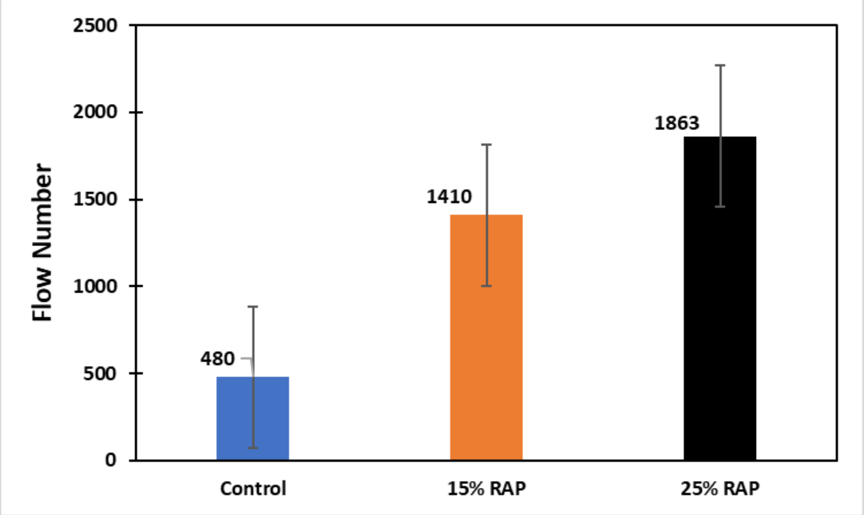


Flow Number Results

$$\varepsilon_p(N) = a \cdot N^b + c(e^{d \cdot N} - 1)$$

Flow Number	
0%	S
15%	
25%	





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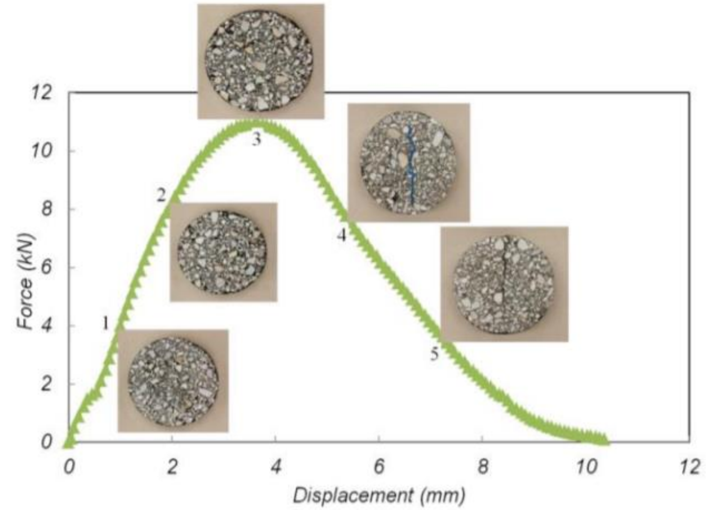
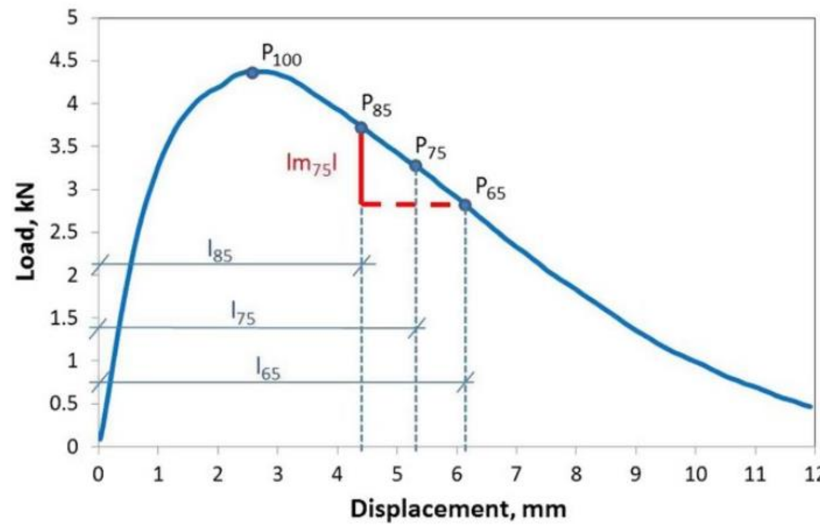
IDEAL CT





$$CTI = \frac{G_f}{|m_{75}|} \times \left(\frac{l_{75}}{D}\right) \quad (1)$$

where G_f = fracture energy (J/m^2); $G_f = W_f/(t \times D)$, where W_f = work of fracture (J), area under the load-displacement curve as shown in Fig. 1(b); t = specimen thickness (m), and D = specimen diameter (m); l_{75} = displacement corresponding to P_{75}, where $P_{75} = 0.75 \times P_{100}$, where P_{100} = peak load; and $|m_{75}|$ = postpeak slope corresponding to the P_{75} and l_{75} curve location

$$|m_{75}| = \frac{|P_{85} - P_{65}|}{|l_{85} - l_{65}|} \quad (2)$$

where $P_{85} = 0.85 \times P_{100}$; $P_{65} = 0.65 \times P_{100}$; l_{85} = displacement corresponding to P_{85}; and l_{65} = displacement corresponding to P_{65}.

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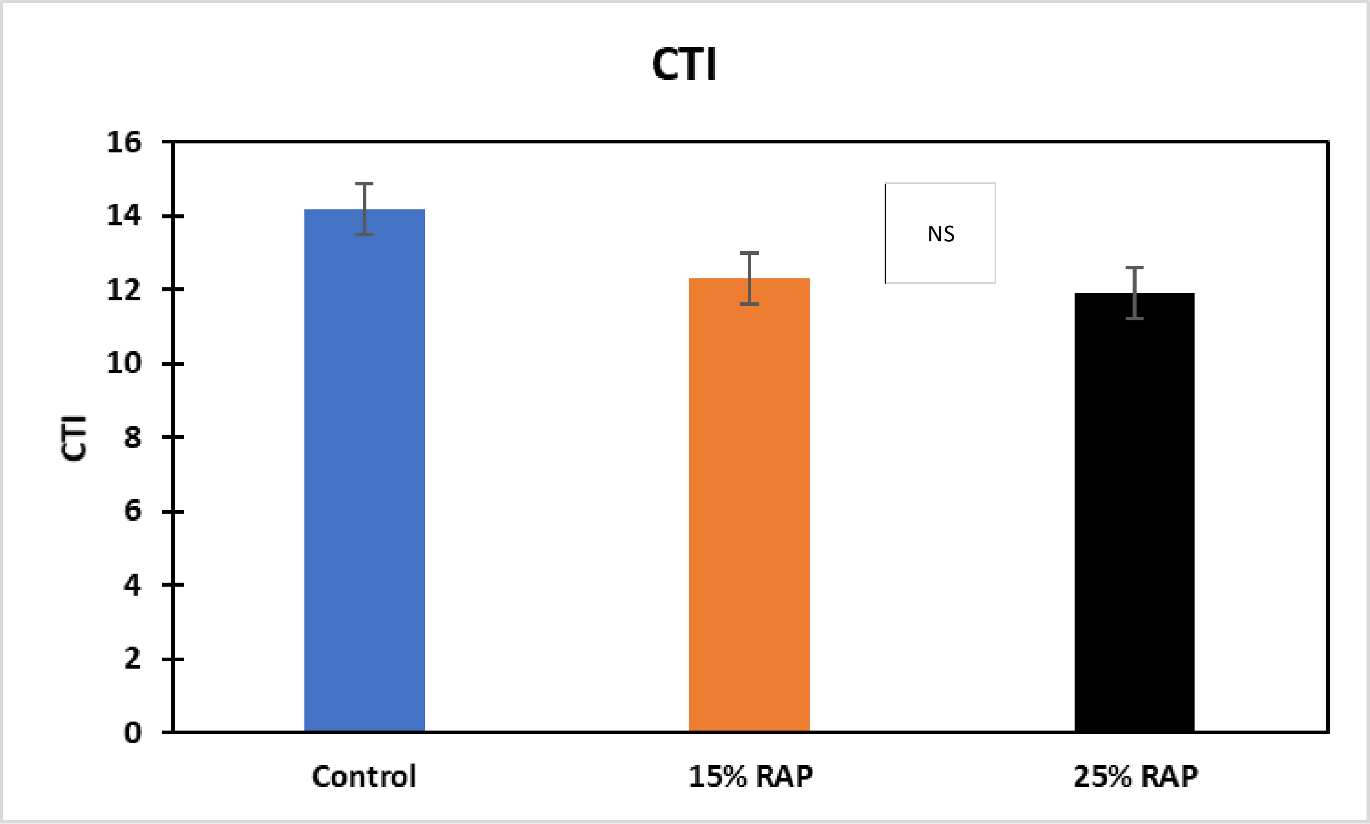
IDEAL CT Results



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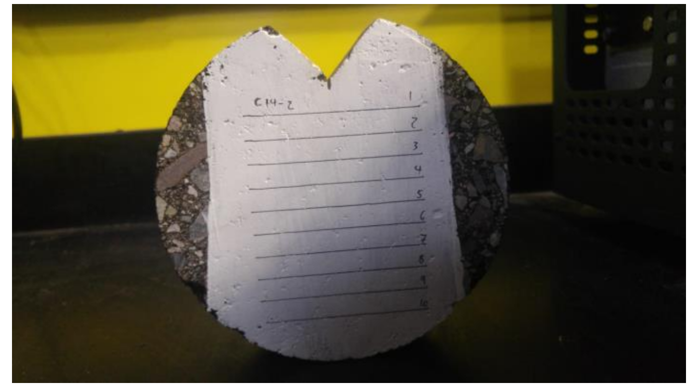
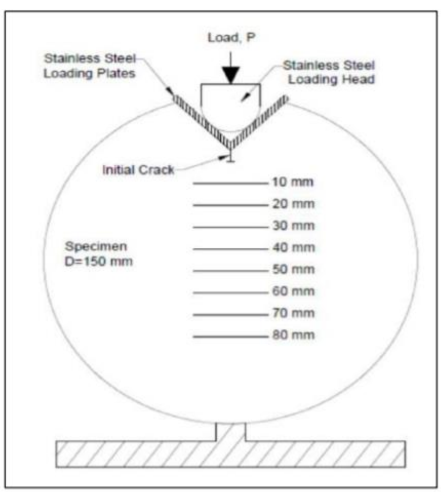
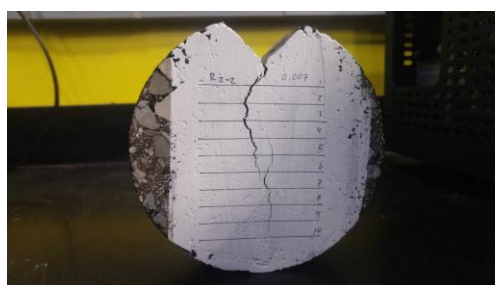
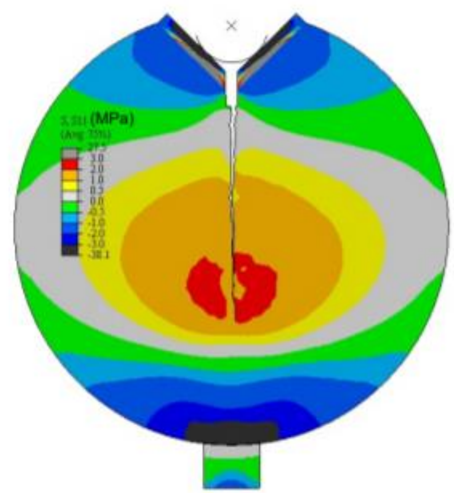
C* Fracture Test









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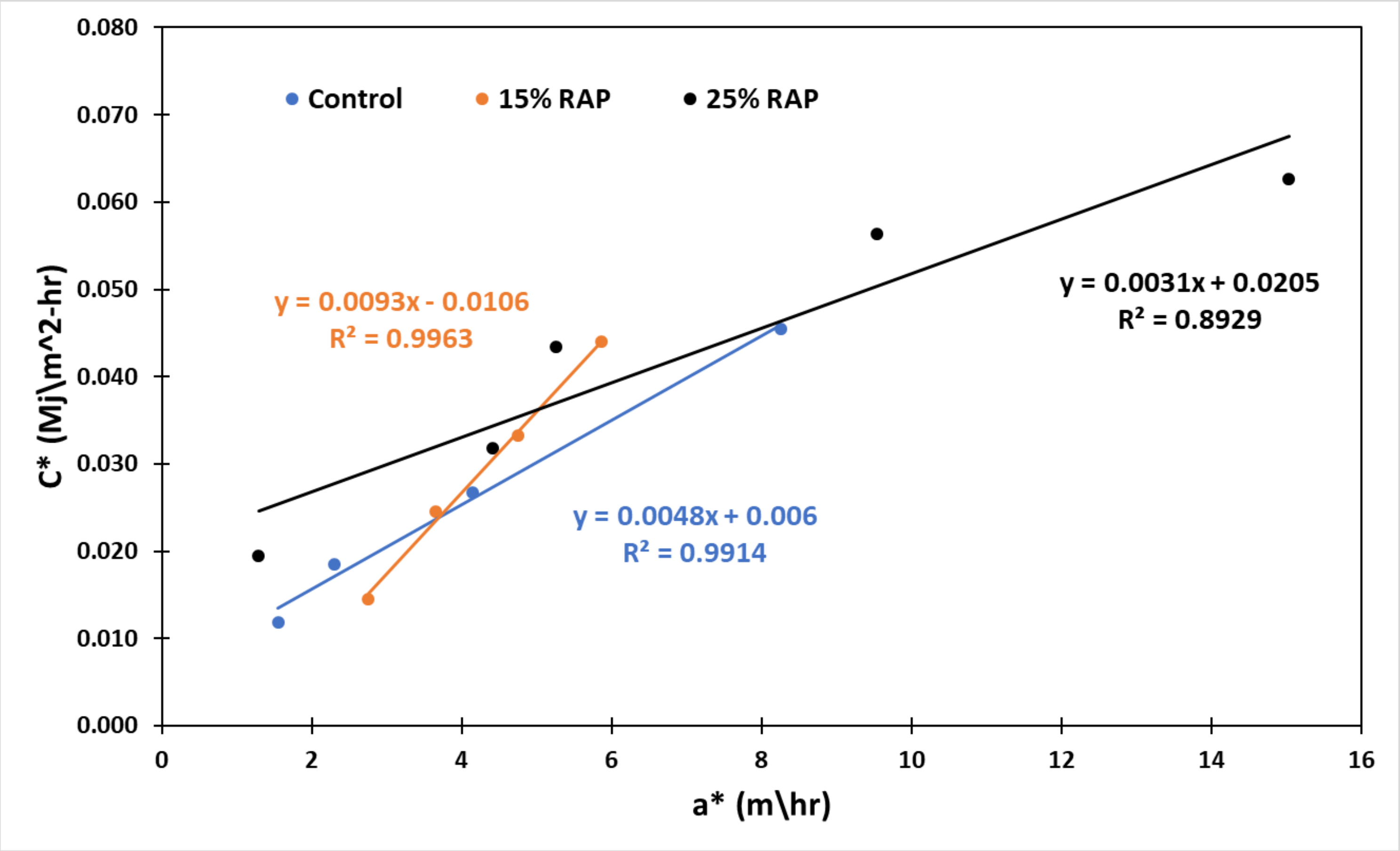
C* Fracture Test Results



Uniaxial Fatigue AASHTO TP 107

- To assess the resistance fatigue damage.
- The test was performed at an intermediate temperature of 18° C
- run at four strain levels.
- The strain levels were estimated such that the material fails in less than 10,000 cycles, between 10,000 - 50,000 cycles, between 50,000 – 100,000 cycles and greater than 100,000 cycles.
- The fatigue test data was analyzed using simplified viscoelastic continuum damage theory (S-VECD) formulation as
- The first step in this approach is to establish the damage characteristic (*C* vs. *S*) curve.
- The *C* vs. *S* curve is a unique relationship to a given asphalt concrete mixture and it is independent of test conditions.

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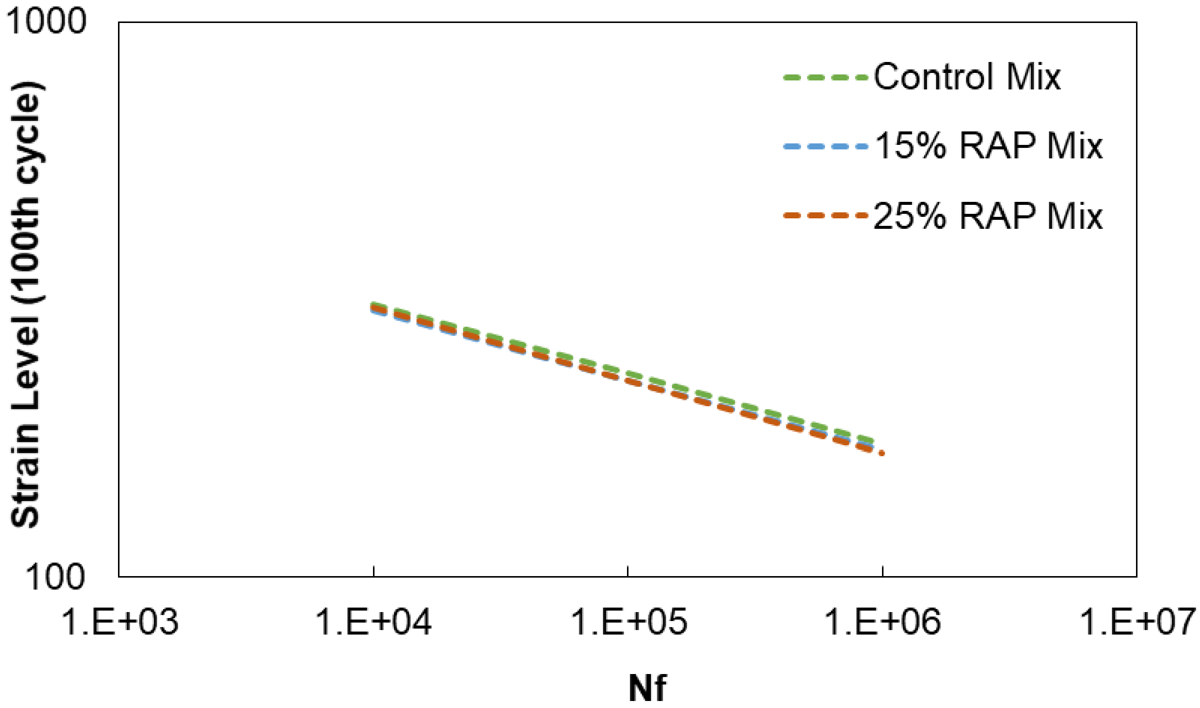
Uniaxial Fatigue Results



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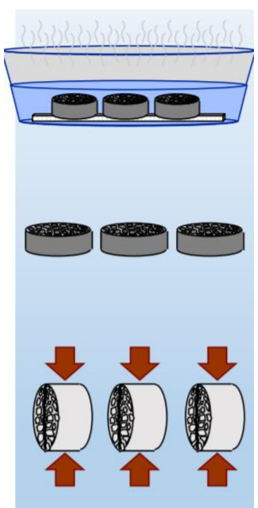
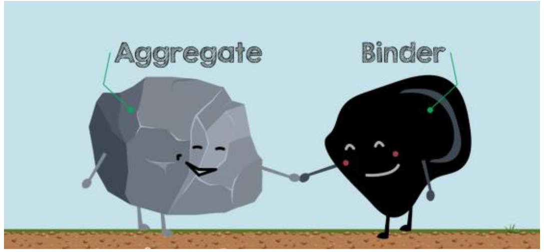
Tensile Strength Ratio
AASHTO T 283

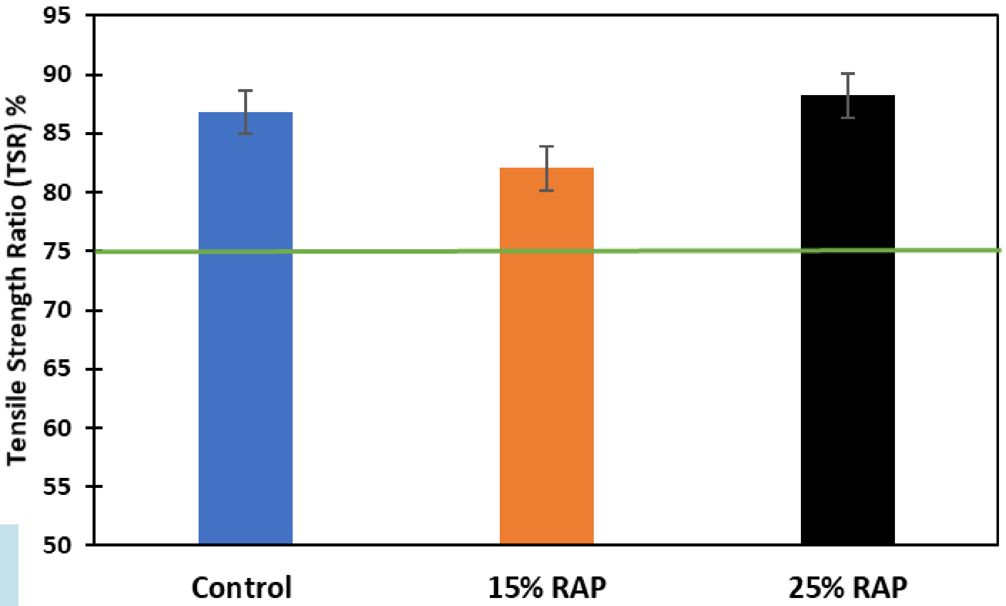
16 hours @ -16 °C ± 2 °C



24 hours @ 60 °C ± 2 °C

Tensile Strength Ratio Results





TSR	
0%	NS
15%	
25%	

Surface Evaluation (Distress Survey)

Photos Taken on April 24, 2019

Field Cores

Cores taken from 15% RAP Section

Cores taken from the Control Section

Cores taken from 25% RAP Section

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Field Cores

15% RAP Section | 25% RAP Section | 0% RAP Section

15% RAP Section
- Air Voids: 8.14%
- Thickness: 3.24”
- TS: 1012 kPa
- Laboratory TS: 1540 kPa

25% RAP Section
- Air Voids: 7%
- Thickness: 4.04”
- TS: 1203 kPa
- Laboratory TS: 1672 kPa

0% RAP Section
- Air Voids: 8.33%
- Thickness: 2.82”
- TS: 797 kPa
- Laboratory TS: 1242 kPa

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Conclusion

Property	Test	Support	Remarks
Stiffness	Dynamic Modulus (E*)	Yes	
Rutting Resistance	Flow Number	Yes	
Cracking	Initiation (IDEAL CT)	Yes	
	Propagation (C* Test)	Questionable	Could be arguable, yet the 25% RAP mix was comparable to the control one
	Fatigue (Uniaxial Fatigue)	Yes	
Moisture	Tensile Strength Ratio	Yes	

Final Recommendation: 15% RAP can be incorporated to the City mixtures while keeping the same grade (PG 70-10). 25% RAP can be incorporated while using a softer binder (PG 64-16)

Acknowledgments

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Trey Billingsley
Austin Bolze

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Thank you!

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Questions?