Determining the Correct Mixing and Compaction Temperatures for Using High RAP Content in HMA

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2017 Idaho Asphalt Conference

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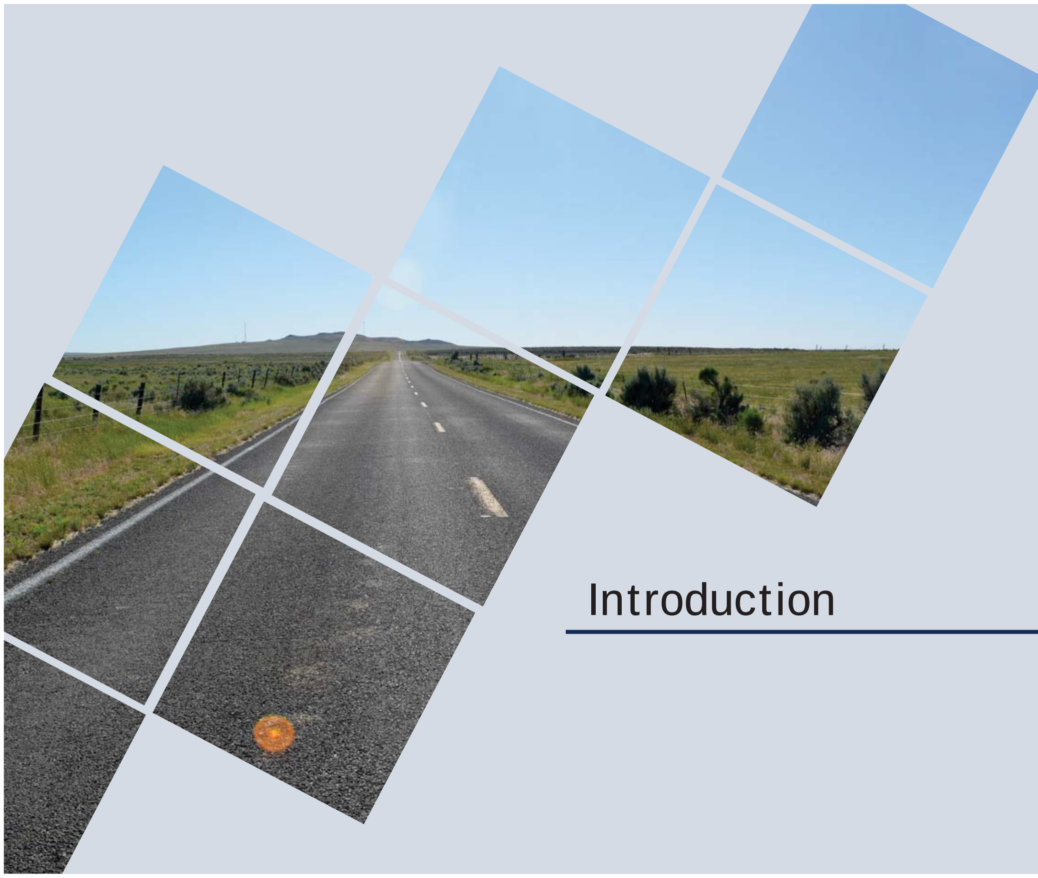

Introduction

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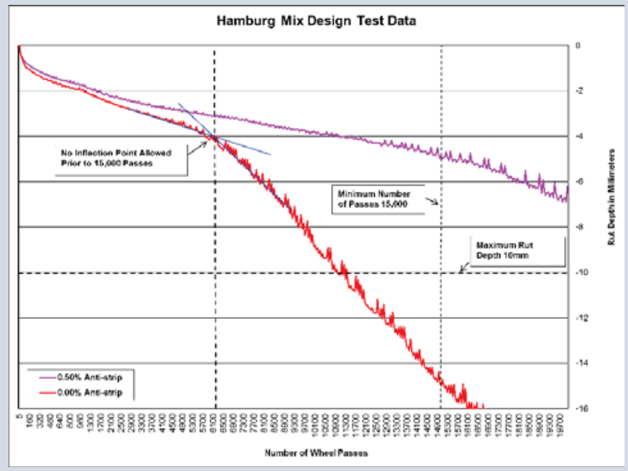
Introduction

- Significant increase in RAP% in HMA designs in Northwest region
  - Washington: Less than 20% in 2014 to amount allowed to meet the target PG grade (Based on Blending Chart)
    - Target PG 70-28, RAP grade PG 88.7-16.5
    - 20% RAP: PG 65.8-30.8; 40% RAP: PG 59.8-35.7
  - Idaho: Open the 20% limit in 2014 to basically 100% → Cap at 30% currently
    - Based on Blending Chart to the designed grade
  - ODOT: 20% RAP and RAS Combined. Pushing for up to 40%.

Introduction

- Problems
  - Too many different low temperature grades
    - PG 52-34, PG 52-40, PG 58-40, PG 64-40, PG 70-34, PG 76-34, etc
  - Mix Design Failures (Repeatability)
    - Hamburg (Washington)
      - **Stripping Inflection Point**
        - **No stripping at 15,000 passes**
      - **Rut Depth**
        - **10 mm at 15,000 passes**
    - Immersion-Compression Test (Idaho)
      - **85% Retained Strength**



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Introduction

- Current Solutions (**<u>It is always the oil</u>**):
  - Adding antistrip (up to 1.5%)
  - Changing grade
  - Changing formulation
  - Changing Supplier
- Possible Causes: **<u>(It is not always the oil)</u>**
  - RAP quality (Source/Grade/Gradation)
  - Interaction between RAP and Virgin Oil (Coating)

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Introduction

- Coating of the Agg/RAP
  - Not enough binder → Need more virgin binder
  - Mixing and Compaction (Temperatures too low)
- The mixing and compaction temperatures
  - The virgin binder (Low) **NCHRP 452**
  - The blended virgin/RAP binder (Medium)
  - The RAP binder (High)

Objectives

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Objectives

- Will higher mixing and compaction temperatures affect the OAC for HMA using RAP ?
  - NCHRP 9-36: SGC compaction process is insensitive to binder stiffness
  - FHWA/TX-11/0-6092-2: Increasing the mixing and compaction temperatures significantly lowers the OAC
- Will higher mixing and compaction temperatures affect the mechanical properties for HMA using RAP ?
  - NCHRP 9-36: Mechanical tests on HMA are affected by mixing and compaction temperatures
  - FHWA/TX-11/0-6092-2: Lower temperature → higher OAC → More Durable Mixes

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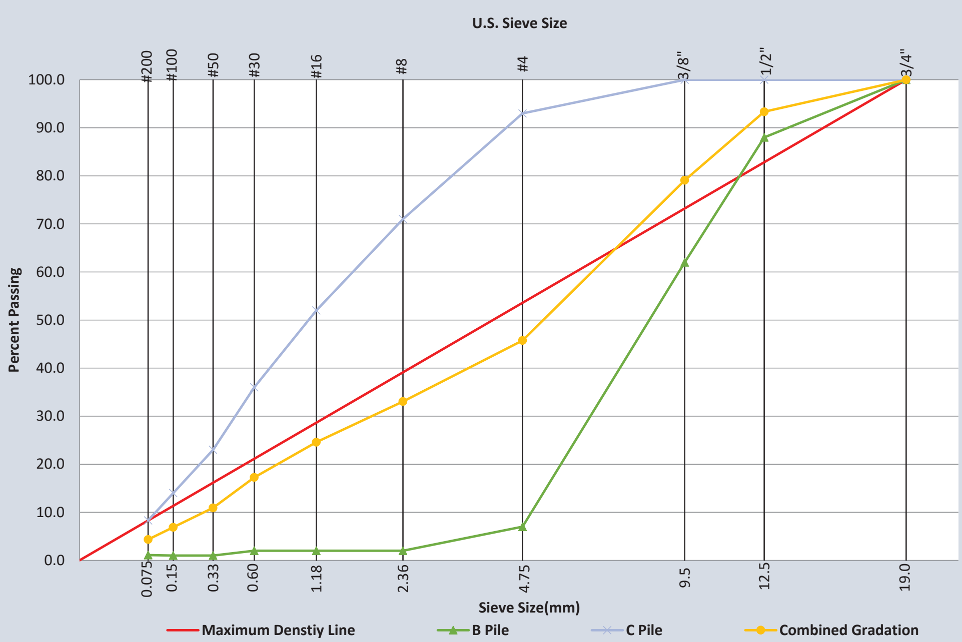
Materials and Test Methods

Materials and Test Methods

- Materials
  - Aggregate:

Sieve Size		B Pile (45%)	C Pile (55%)	Combined
Mesh	(mm)	45.0%	55.0%	100.0%
1-1/2"	37.5	100%	100%	100%
1"	25.0	100%	100%	100%
3/4"	19.0	100%	100%	100%
1/2"	12.5	88%	100%	95%
3/8	9.5	62%	100%	83%
#4	4.75	7%	93%	54%
#8	2.36	2%	71%	40%
#16	1.18	2%	52%	30%
#30	0.6	2%	36%	21%
#50	0.33	1%	23%	13%
#100	0.15	1%	14%	8%
#200	0.075	1.1%	8.3%	5.1%

Materials and Test Methods



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Materials and Test Methods

- RAP :
  - RAP was made by blending 4.5% RAP Asphalt with the same aggregate
  - RAP Asphalt: PG64-22 after 40 hrs PAV
  - To eliminate the variances in RAP source and binders
  - RAP Contents: 0%, 15% and 30%

- Virgin Binders:
  - PG52-34 (Neat Asphalt)
  - PG64-28ER (SBS modified asphalt)

Neat Asphalt	15% RAP	30% RAP
4.0%	4.7%	5.4%
4.5%	5.2%	5.9%
5.0%	5.7%	6.4%
5.5%	6.2%	6.9%

Sieve Size		RAP
Mesh	(mm)	
1-1/2"	37.5	100%
1"	25.0	100%
3/4"	19.0	100%
1/2"	12.5	91%
3/8	9.5	74%
#4	4.75	43%
#8	2.36	21%
#16	1.18	6%
#30	0.6	1%
#50	0.33	0%
#100	0.15	0%
#200	0.075	0.1%

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Materials and Test Methods

	RAP	PG 52-34	PG 64-28ER
HT	90.7	54.0	68.8
LT	-22	-35.4	-30.7

	PG 52-34		PG 64-28ER	
	15% RAP	30% RAP	15% RAP	30% RAP
HT	59.5	65.01	72.0	75.4
LT	-33.3	-31.38	-29.3	-28.1
PG Grade	PG 58-28	PG 64-28	PG 70-28	PG 76-28*

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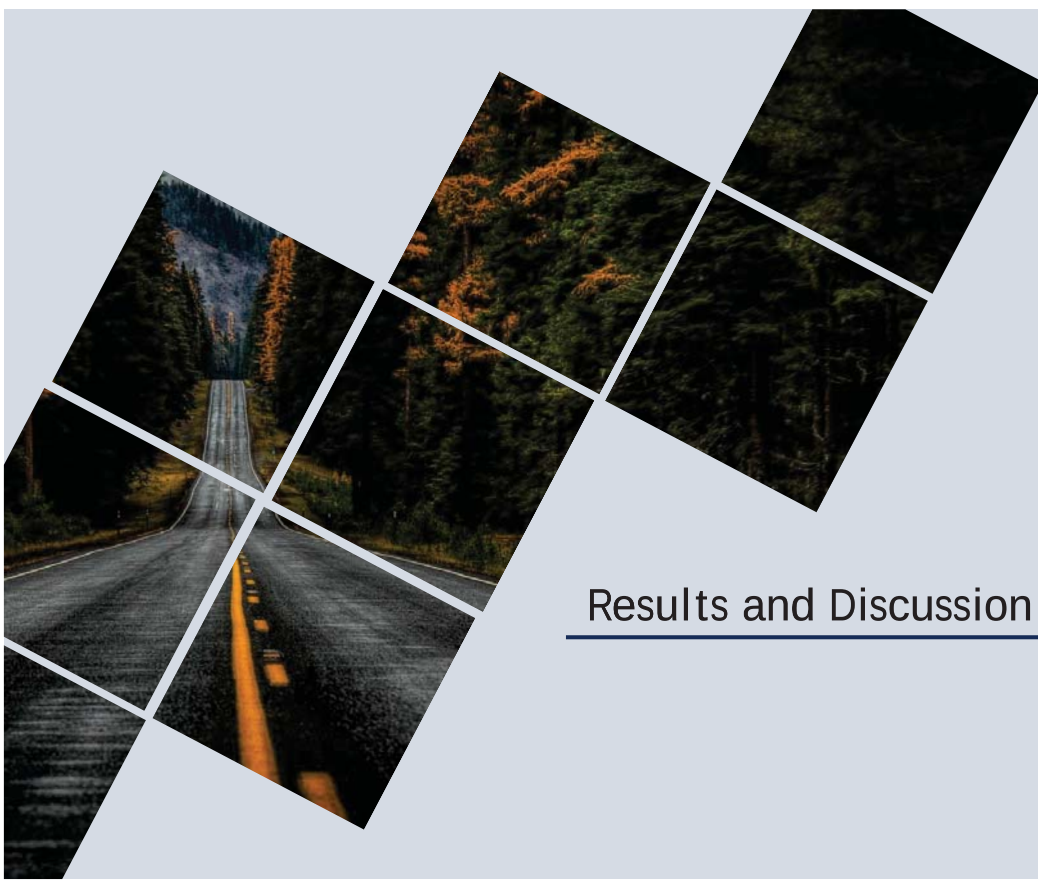
Materials and Test Methods

	Mixing Temp	Compaction Temp
PG 52-34	143°C (289°F)	132°C (270°F)
PG 64-28	160°C (320°F)	145°C (293°F)
PG 76-28	169°C (336°F)	153°C (307°F)
RAP	177°C (350°F)	169°C (337°F)



Results and Discussion

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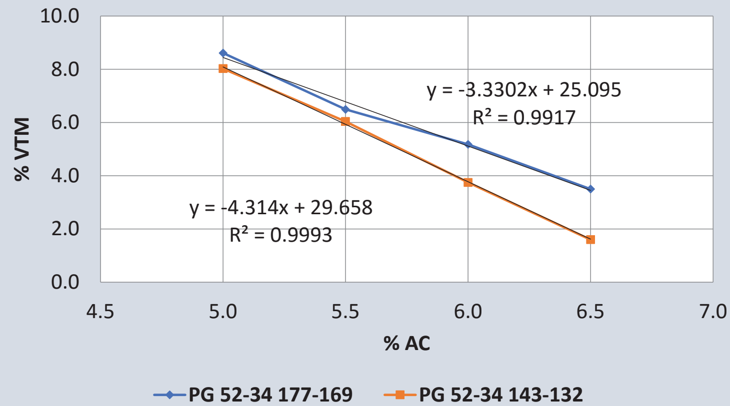
Results and Discussion

- Control (PG 52-34)

177-169	143-132
6.3%	5.9%



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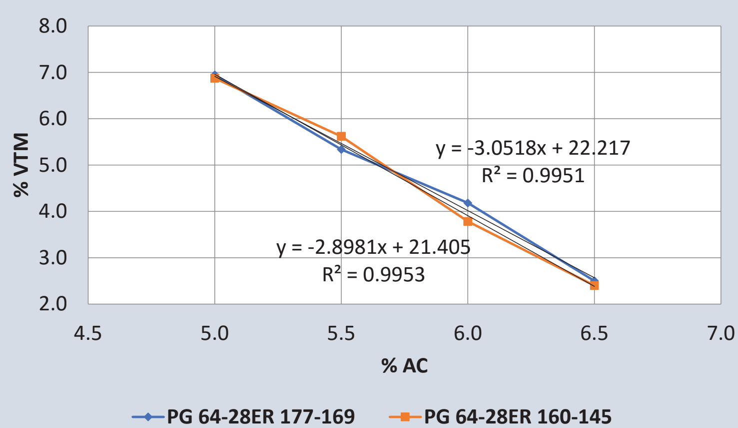
Results and Discussion

- Control (PG 64-28ER)

177-169	160-145
6.0%	6.0%



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Results and Discussion

	PG52-34	PG64-28ER
135°C	235 mPas	624 mPas
150°C	127 mPas	326 mPas
165°C	69 mPas	186 mPas

- Absorption:
  - At 177C, PG52-34 viscosity around 40 mPas; PG64-28ER, 123 mPas
  - Polymer network may limited the extend of absorption.

Results and Discussion

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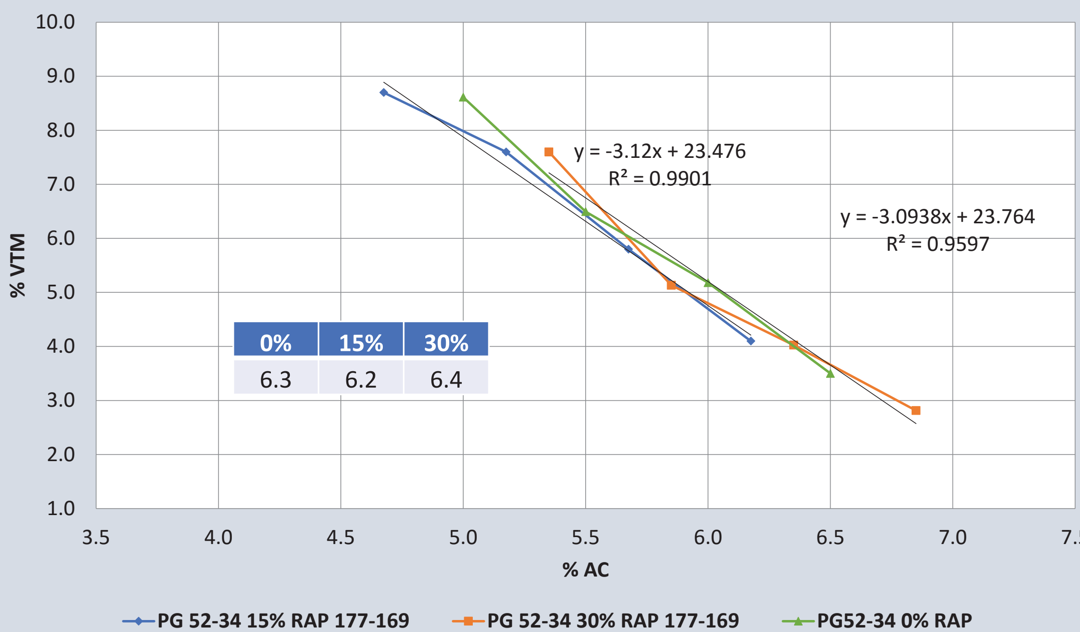

0%	15%	30%
6.3	6.2	6.4

Results and Discussion

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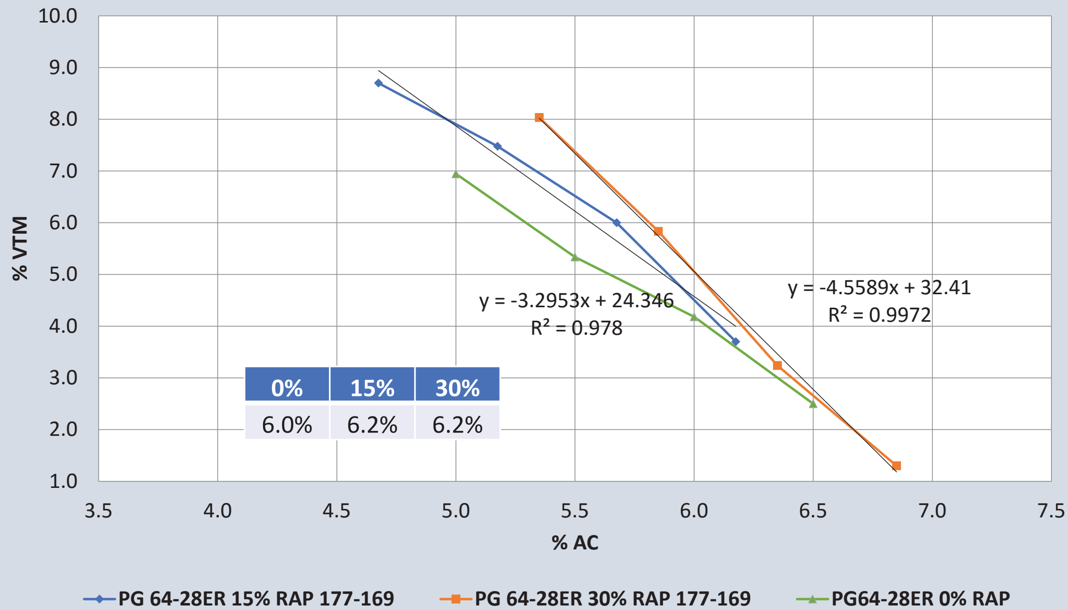

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Results and Discussion

RAP % has no effect on OAC (Total AC) at temperatures between Neat and target PG

	PG52-34				PG64-28ER		
Temp	0	15	30	Temp	0	15	30
177/169	6.3	6.2	6.4	177/169	6.0	6.2	6.2
160/145	N/A	5.8	5.9	169/153	N/A	6.1	6.3
143/132	5.9	5.9	6.0	160/145	6.0	6.1	6.1

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Results and Discussion

Number of Gyration to achieve 92% Gmm. Not much difference at different compaction temperatures, asphalt type or RAP%.

	PG52-34				PG64-28ER		
Temp	0%	15%	30%	Temp	0%	15%	30%
177/169	28	24	24	177/169	22	18	23
160/145	N/A	25	28	169/153	N/A	23	22
143/132	25	24	26	160/145	21	18	25

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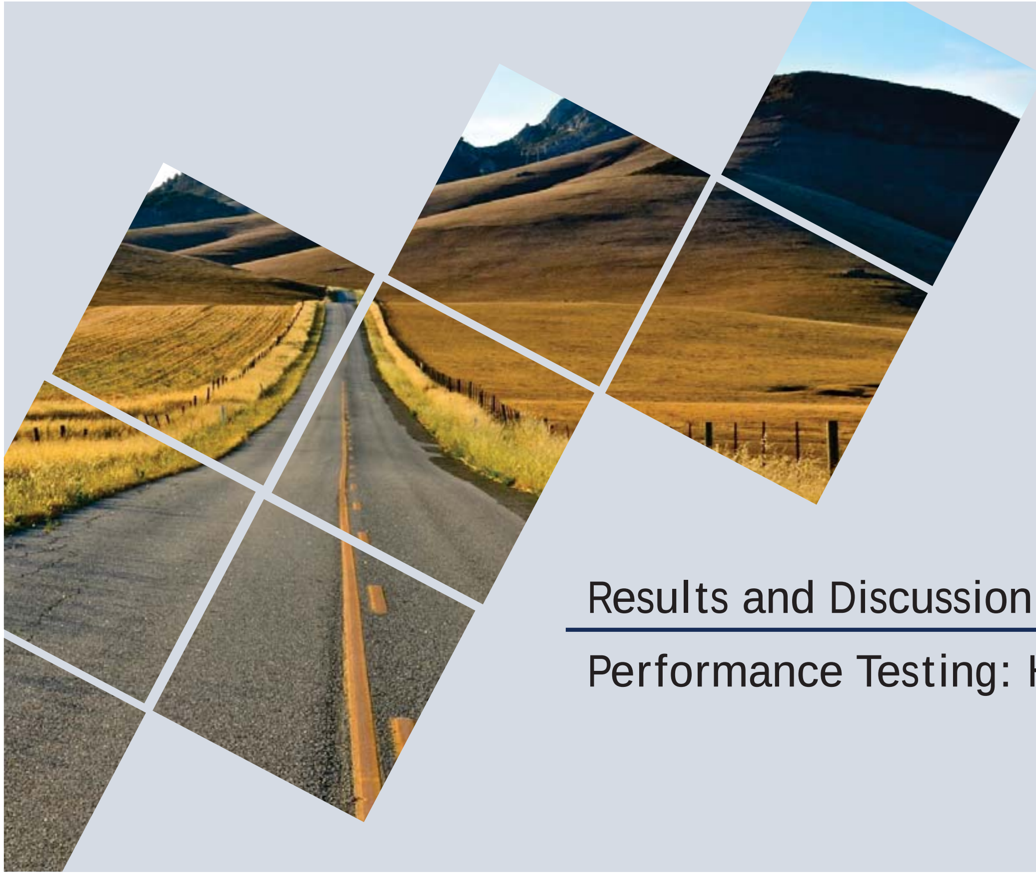
Results and Discussion

Summary:

- Will higher mixing and compaction temperatures affect the OAC for HMA using RAP ?
  - Depends on the grade of the virgin binder and how high the temperatures are.
  - For regular grade, we can consider that the OAC to be the same between Virgin Binder range to target PG grade range



Results and Discussion

Performance Testing: Hamburg

Performance Testing: Hamburg

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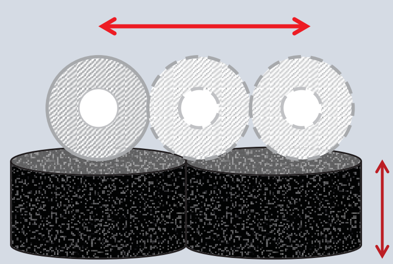

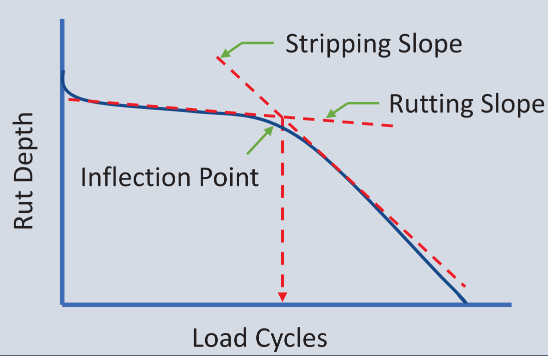

AASHTO T324

- 62.0 mm height
- 150 mm diameter
- 7.0%±1.0% air voids

- Minimum Criteria WSDOT
    - 50°C
    - 10 mm Rut Depth at 15,000 passes
    - No stripping at 15,000 passes

James Cox & Sons, Hamburg Wheel Tracker
Mike Anderson AI Presentation Spring 2002 Meeting, Houston, TX

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Performance Testing: Hamburg

PG 52-34

	177-169°C			143-132°C		
Passes	0% RAP	15% RAP	30% RAP	0% RAP	15% RAP	30% RAP
5000	-10.39	-4.46	-2.92	-12.06	-13.67	-13.67
10000	-12.47	-9.70	-3.66	-12.07	-13.68	-13.68
15000		-12.76	-4.36			
20000		-12.79	-5.22			

Performance Testing: Hamburg

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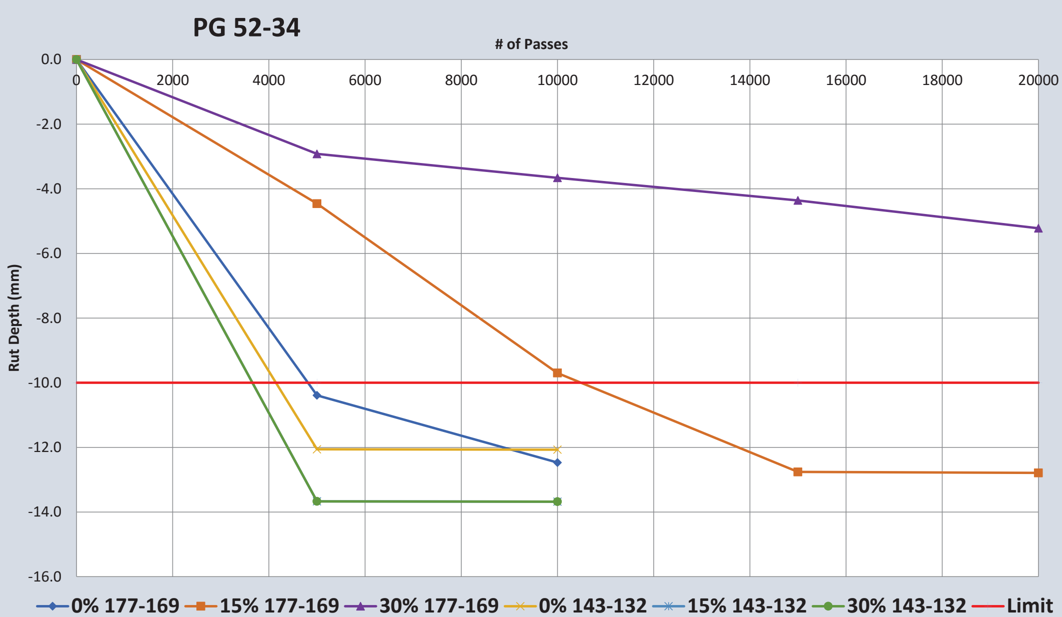

Performance Testing: Hamburg

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PG 52-34 0%RAP 143-132°C

PG 52-34 0%RAP 177-169°C

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Performance Testing: Hamburg

PG 64-28ER

	177-169°C			160-145°C		
Passes	0% RAP	15% RAP	30% RAP	0% RAP	15% RAP	30% RAP
5000	-3.10	-2.36	-2.49	-3.48	-3.26	-2.66
10000	-5.38	-2.90	-2.93	-4.76	-4.57	-3.42
15000	-7.53	-3.25	-3.22	-6.37	-6.36	-4.58
20000	-9.01	-3.54	-3.49	-9.40	-8.34	-5.95

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Performance Testing: Hamburg

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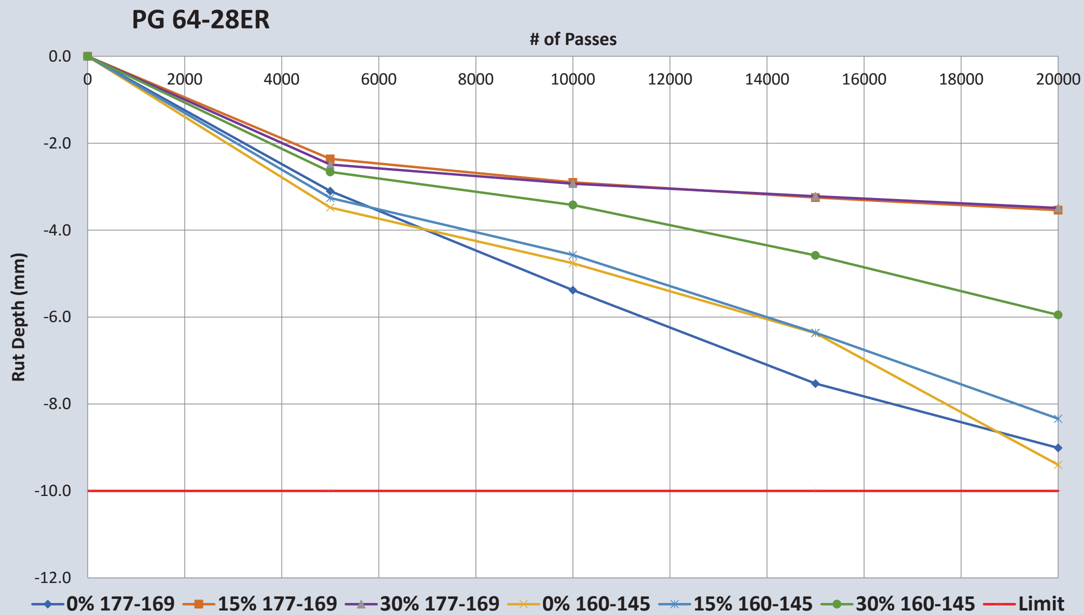

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Performance Testing: Hamburg

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PG 64-28ER 0%RAP 177-169°C

PG 64-28ER 15%RAP 177-169°C

PG 64-28ER 30%RAP 177-169°C

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Performance Testing: Hamburg

PG 64-28ER 0%RAP 160-145°C

PG 64-28ER 15%RAP 160-145°C

PG 64-28ER 30%RAP 160-145°C

Performance Testing: Hamburg

PG 64-28ER

	30% RAP		
	177-169°C	169-153°C	160-145°C
5000	-2.49	-2.50	-2.66
10000	-2.93	-2.97	-3.42
15000	-3.22	-3.29	-4.58
20000	-3.49	-3.59	-5.95

Performance Testing: Hamburg

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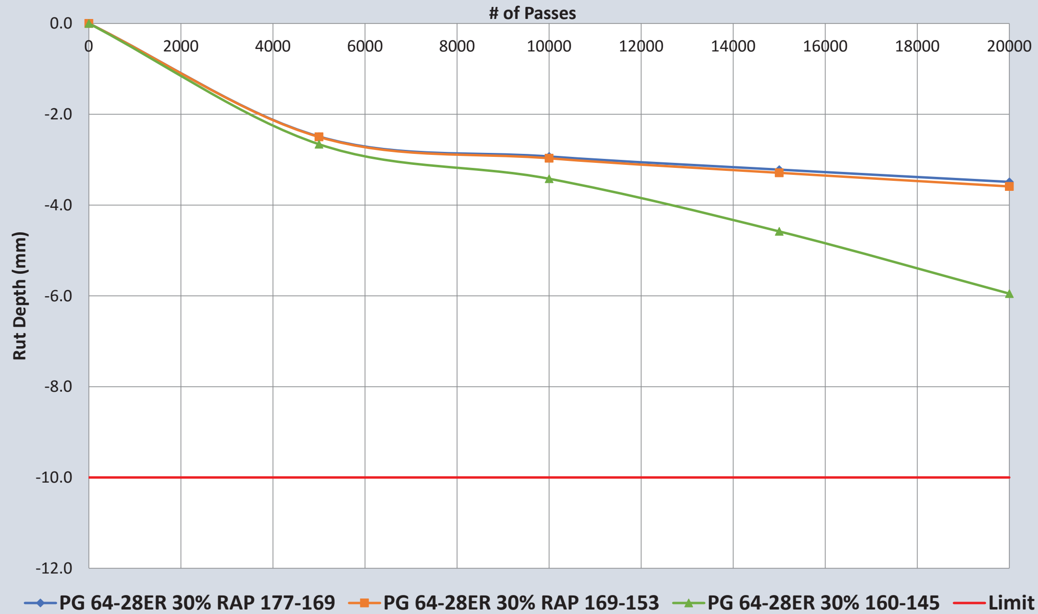

Performance Testing: Hamburg

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PG 64-28ER 30%RAP 160-145°C

PG 64-28ER 30%RAP 169-153°C

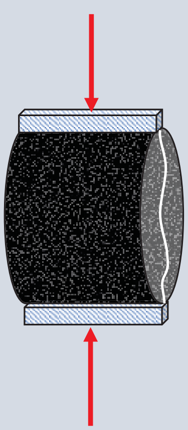
PG 64-28ER 30%RAP 177-169°C

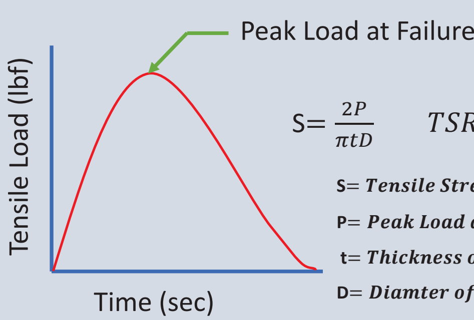
Results and Discussion

Performance Testing: Tensile Strength Ratio

Results and Discussion

Performance Testing: Tensile Strength Ratio





S= $\frac{2P}{\pi t D}$ $\quad TSR(\%) = \frac{S_{t,wet}}{S_{t,dry}}$

S= *Tensile Stress at Failure* (*psi*)

P= *Peak Load at Failure* (*lbf*)

t= *Thickness of specimen* (*in*)

D= *Diamter of specimen* (*in*)

Loading Rate: 2 in/min (50 mm/min)

AASHTO T283 (Modified Lottman Test)

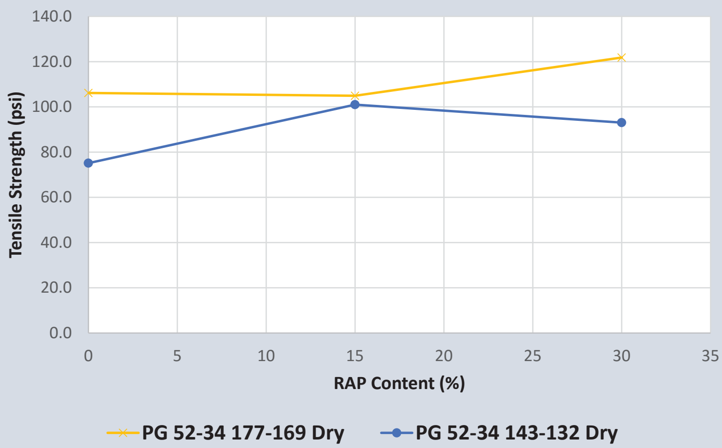
- Method 1: Freeze Thaw Cycle
- Method 2: No Freeze Thaw Cycle
- 3 Samples prepared for each condition

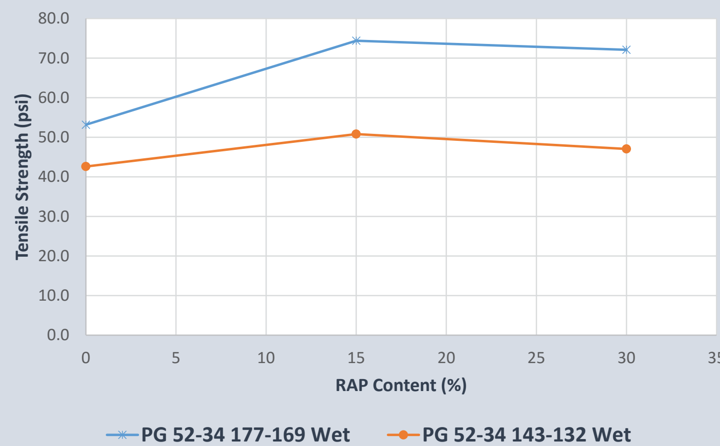
- Method 1: Freeze Thaw Cycle
  - 70%-80% Vacuum Saturation
  - 16 hr -18°C Freeze Cycle
  - 24 hr 60°C Thaw Cycle
  - 2 hr 25°C Equilibration Cycle
- **Method 2: No Freeze Thaw Cycle**
  - 70%-80% Vacuum Saturation
  - 24 hr 60°C Conditioning Cycle
  - 2 hr 25°C Equilibration Cycle

Minimum TSR value 80%

Results and Discussion

Performance Testing: TSR





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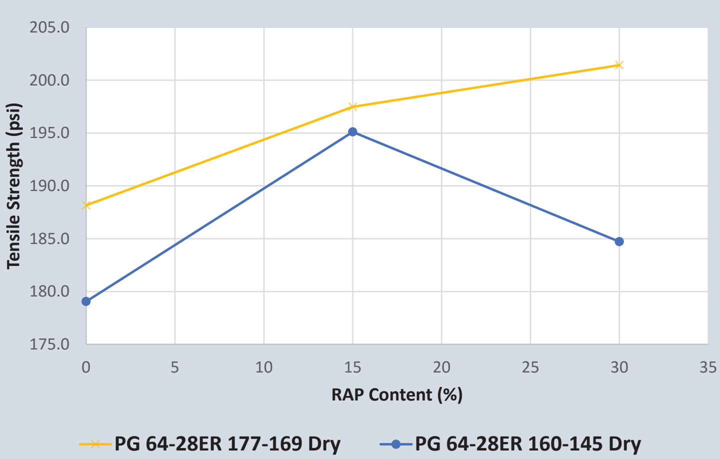
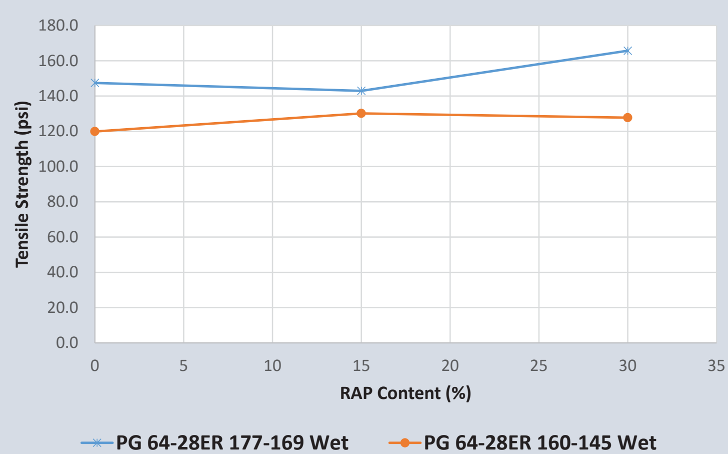
Results and Discussion

Performance Testing: TSR





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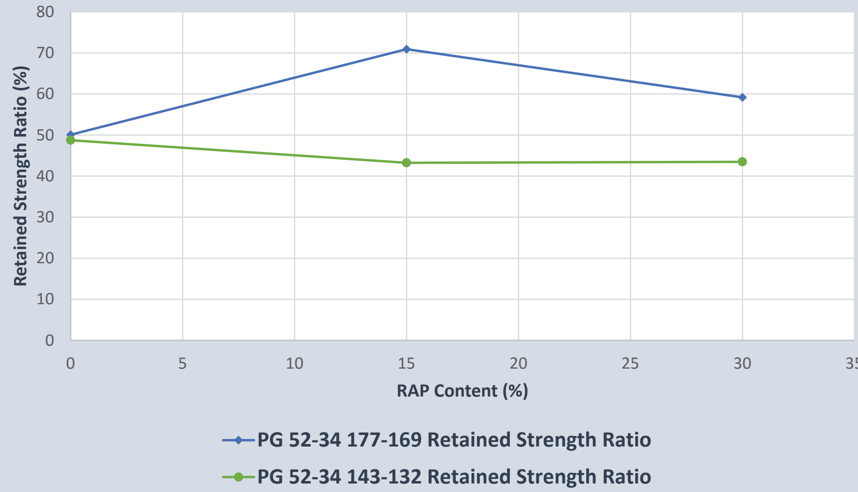
Results and Discussion

Performance Testing: TSR



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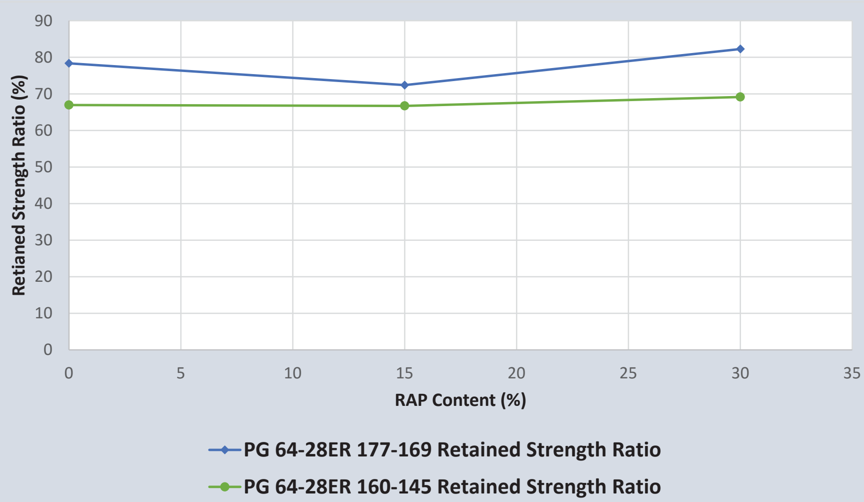
Performance Testing: TSR



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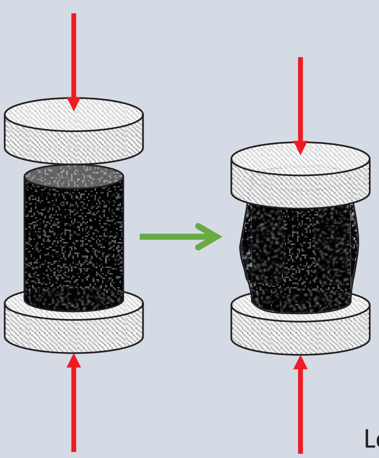
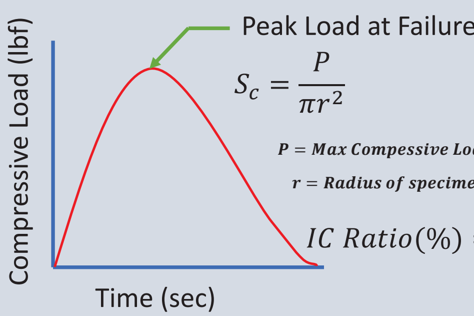
Results and Discussion

Performance Testing: Immersion Compression

Results and Discussion

Performance Testing: Immersion Compression





$$S_c = \frac{P}{\pi r^2}$$

$P = Max\ Compessive\ Load\ at\ Failure\ (lbf)$

$r = Radius\ of\ specimen\ (in)$

$$IC\ Ratio(\%) = \frac{S_{c,wet}}{S_{c,dry}}$$

Loading Rate: 0.2 in/min (5.08 mm/min)

AASHTO T165/T167
ASTM D1074/1075

- Set of 3 samples for each condition are prepared
- Wet sample conditioned at 60°C (140°F) for 24 hrs
- Wet sample is transferred to 25°C (77°F) for 2 hrs
- Dry sample conditioned at 25°C (77°F) air bath for 4 hrs

Minimum IC Ratio value 85% (ITD)

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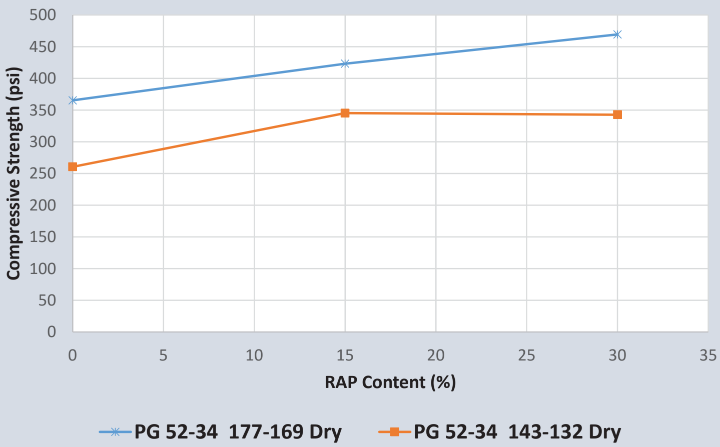
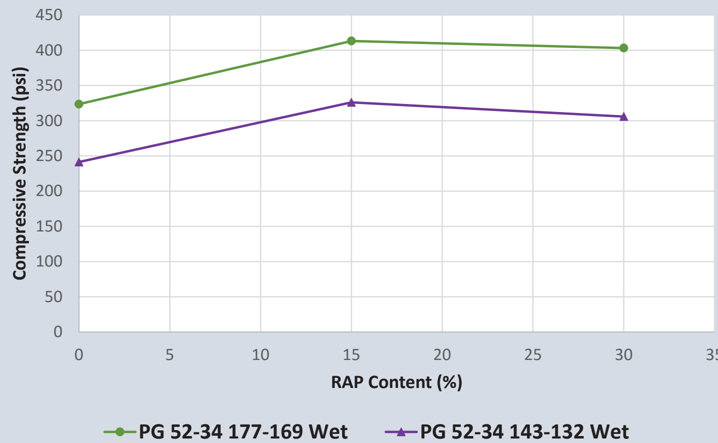
Results and Discussion

Performance Testing: Immersion Compression





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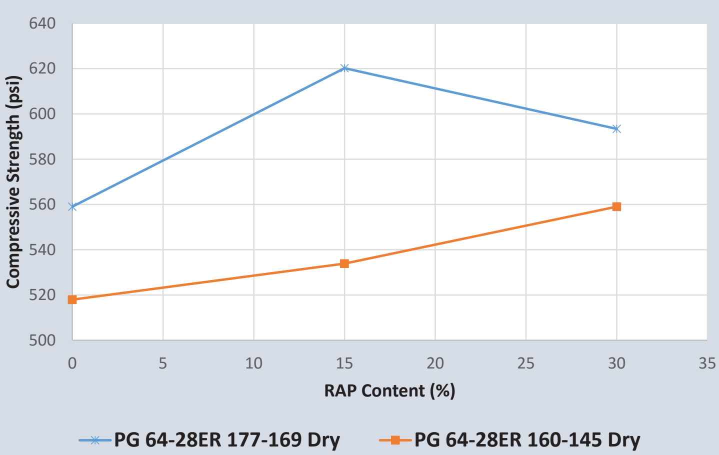
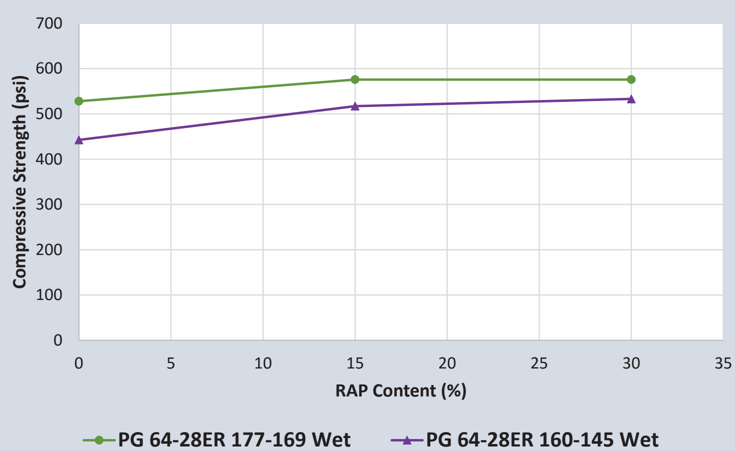
Results and Discussion

Performance Testing: Immersion Compression





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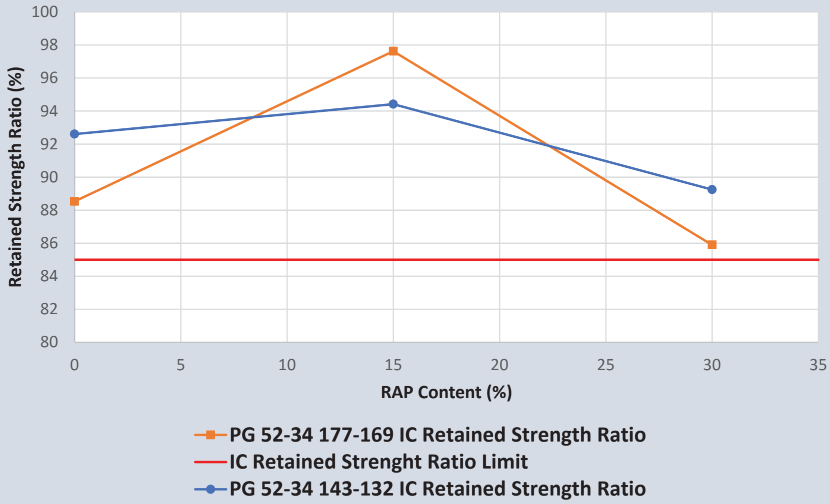
Results and Discussion

Performance Testing: Immersion Compression



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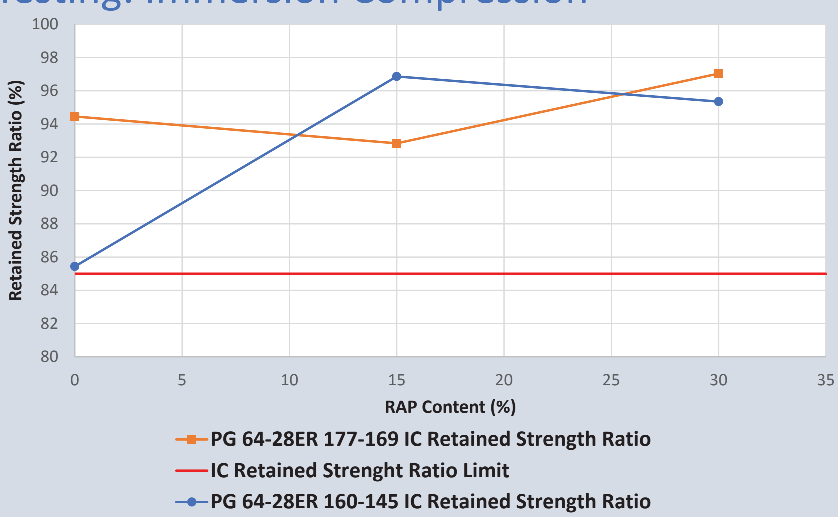
Results and Discussion

Performance Testing: Immersion Compression



Summary of Findings

Summary of Findings

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- Hamburg
  - Higher mixing and compaction temperatures lead to less rutting
    - Not necessary to target RAP temperature
      - Data suggests Target Blend yields same results
- Tensile Strength Ratio (TSR)
  - Higher mixing and compaction temperatures leads to higher tensile strength
  - Mixtures at higher mixing and compaction temperatures have higher tensile strength ratios
  - Target PG Blend yields better results
- Immersion Compression (IC)
  - Higher mixing and compaction temperatures yield higher compressive strength
  - Compressive strength ratios were higher when mix and compacted at hotter temperatures
  - Target PG Blend yielded same if not better results than hottest temperature

Summary of Findings

- Will higher mixing and compaction temperatures affect the mechanical properties for HMA using RAP ?
  - Yes. Higher temperatures → less Distresses (Rut and Stripping)
  - **We should target the mixing and compact temperatures of final/blend PG grade.**

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Going Forward

- Finish performance tests at target blend temperature
- Include testing with other asphalt grades
  - Include other types of polymers
- Investigate the effect of Warm Mix Additives and temperature on mixture performance
- Include higher RAP content (50% RAP)
- Include field RAP
- Investigate Viscosity Temperature Curve
  - Recommended minimum viscosity to achieve better mixture performance

Questions?

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