Ground Tire Rubber (GTR) Field Projects (Part 2)

Matthew Corrigan P.E.

FHWA Mixture Expert Task Group Meeting

September 18, 2014

Mobile Asphalt Testing Trailer

MATT GTR Field Projects

PA1397-Pennsylvania

- PG 64-22 + Evotherm 3G (0.5% Wt. of Binder)
- 15.9 % GTR
- 30 mesh supplied
  - 100% passing No. 16
  - 75% passing No. 30

NJ1499-New Jersey

- PG 64-22 + Evotherm M1 (0.5% Wt. of Binder)
- 20% GTR
- 30 mesh supplied
  - 100% passing No. 16
  - 98% passing No. 30

- No control sections

Mobile Asphalt Testing Trailer

Why do agencies specify these GTR percentages and gradations?

ASTM D 8 Standard Terminology Relating to Materials for Roads and Pavements

- asphalt-rubber, n—a blend of asphalt cement, reclaimed tire rubber, and certain additives in which the rubber component is at least 15 % by weight of the total blend and has reacted in the hot asphalt cement sufficiently to cause swelling of the rubber particles.

Why do agencies specify these GTR percentages and gradations?

ASTM D 6114 Standard Specification for Asphalt-Rubber Binder

- NOTE 1—It has been found that at least 15 % rubber by weight of the total blend is usually necessary to provide acceptable properties of asphalt-rubber.
- Recommended that no rubber particles should be retained on the 2.36 mm (No. 8) sieve.

Why do agencies specify these GTR percentages and gradations?

ASTM D 6114 Standard Specification for Asphalt-Rubber Binder

- Rubber gradation should be agreed upon between purchaser and asphalt-rubber supplier for the specific mixture applications.
- NOTE 3—It has been found that rubber gradation may affect the physical properties and performance of hot paving mixtures using asphalt-rubber binder.

Ground Tire Rubber (GTR) Field Project PA1397

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Previously presented at Mixture Expert Task Group Meeting
April 1, 2014

Project Description

- Project Location:
  - o Lewisburg, Pennsylvania

    SR-15 to SR-11 near Shamokin Dam
- Produced by Eastern Industries Inc.
- Pavement Structure: Surface Layer
  - 3 - 30 MESAL
  - N_{design} = 100
  - NMAS = 12.5 mm

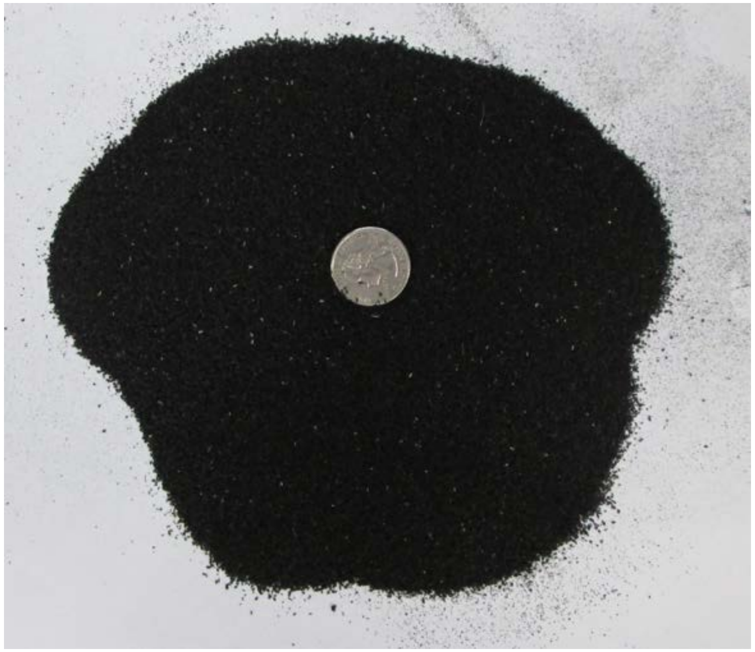
Materials

- **Binder**
  - PG 64-22 + Evotherm 3G (0.5% Wt. of Binder)
- **GTR**
  - Manufactured by Mahantango Enterprises, Inc.
- **Aggregate Stockpile**
  - A7-SS: Sandstone (Coarse)
  - A8-SS: Sandstone (Coarse)
  - B3-LS: Limestone (Fine)
- **Mix**
  - PMLC (7 Samples) and LMLC (6 mixes)

GTR Gradation

Sieve Size (mm)	Percent Passing (%)	PennDOT Spec
2.36 (No. 8)	100	100
1.18 (No. 16)	100	90-100
0.6 (No. 30)	74.3	25-100
0.3 (No. 50)	16.1	0-45
0.15 (No. 100)	1.2	-
0.075 (No. 200)	0.0	0-5

ASTM D5644 allows up to 10% oversize material for 30 to 100 mesh GTR stockpiles



ASTM D5644 Standard Test Methods for Rubber Compounding Materials—Determination of Particle Size Distribution of Recycled Vulcanizate Particulate Rubber

Materials

- **Binder**
  - PG 64-22 + Evotherm 3G (0.5% Wt. of Binder)
  - PMLC4 (Full Reaction)

    PG 64-22+0.5 % Evotherm + 15.9 % GTR
  - PMLC6 (Full Reaction)

    PG 64-22+0.5 % Evotherm + 15.9 % GTR
  - PMLC7 (Full Reaction)

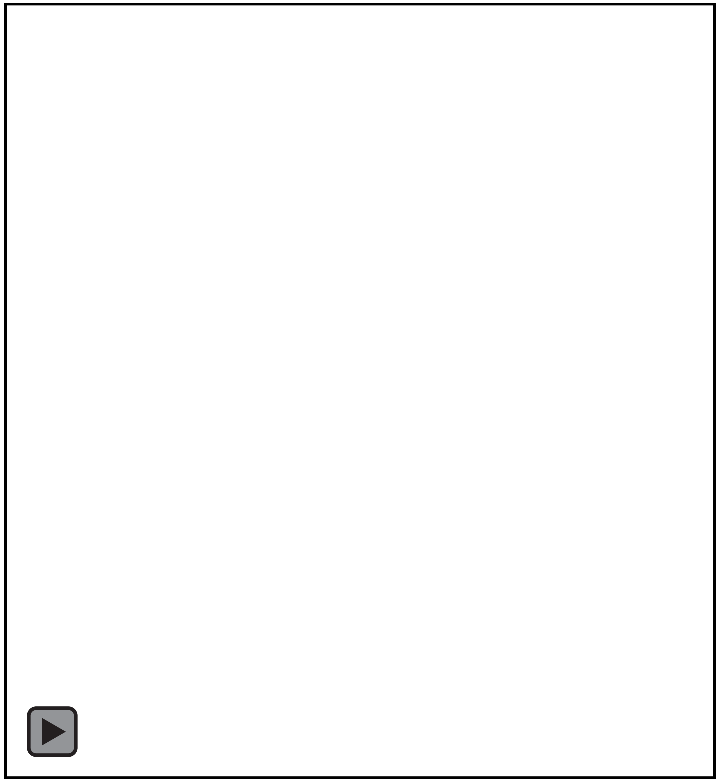
    PG 64-22+0.5 % Evotherm + 15.9% GTR

Testing

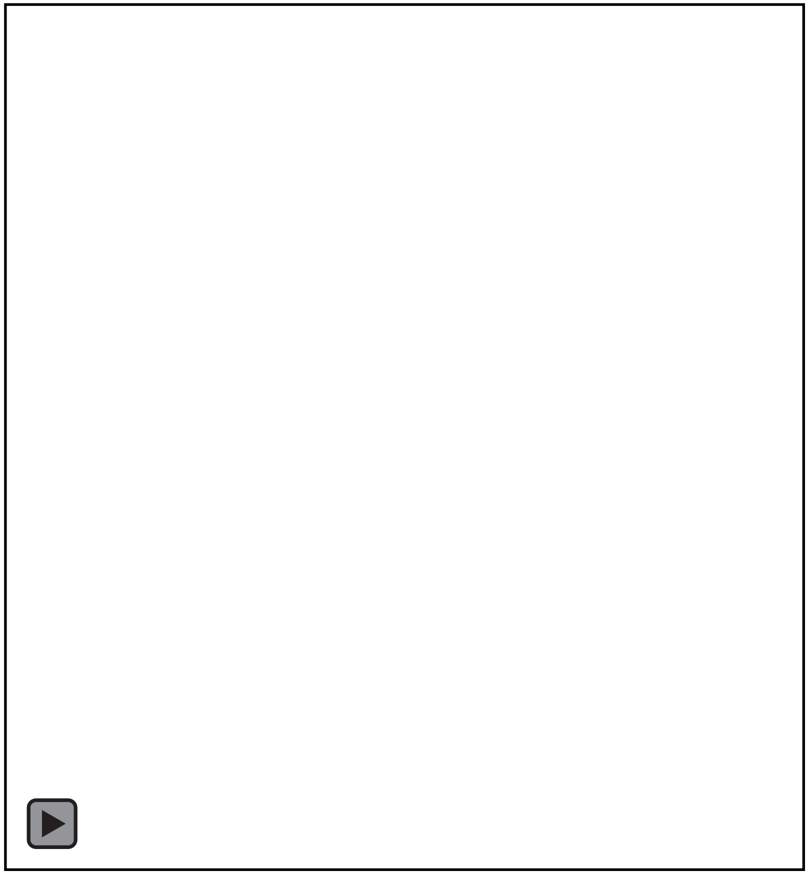
- **Fabrication of Specimens**
  - Pre-blend Samples
  - Reheated at 160°C - 175°C

- **DSR**
  - 25 mm Parallel Plate
  - 1 mm gap setting

Videos of Reheating Procedure



5 Gallon Container



Gallon Container

Images of PA64-22 plus GTR

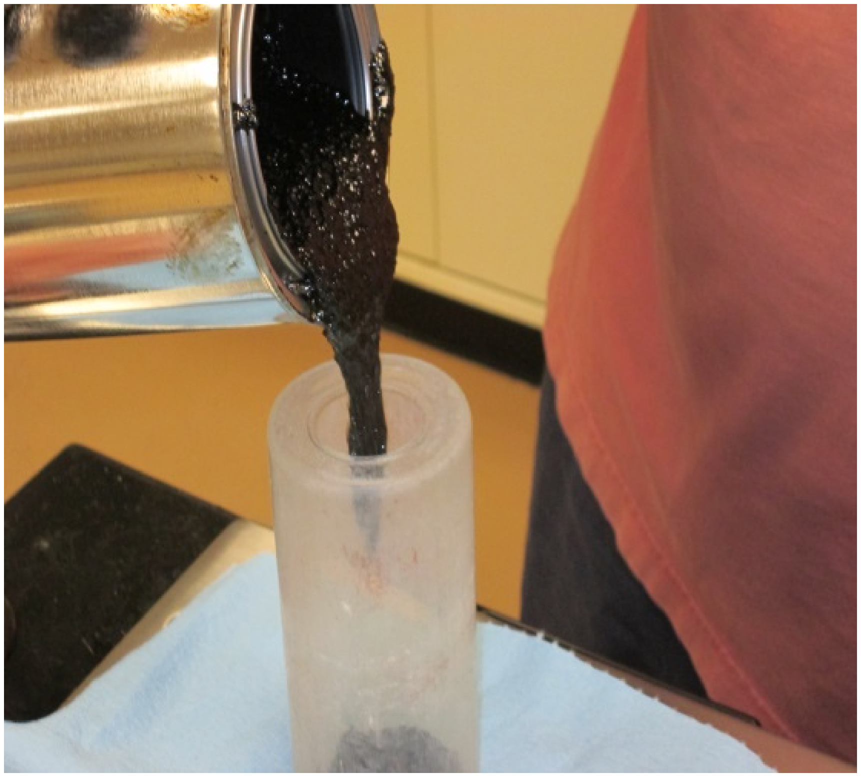
Sample Before Mixing

Sample Poured in Silicone Mold

Stirring with Mechanical Mixer

Asphalt Being Poured

Images of PA64-22 plus GTR



RTFO Conditioning Issues

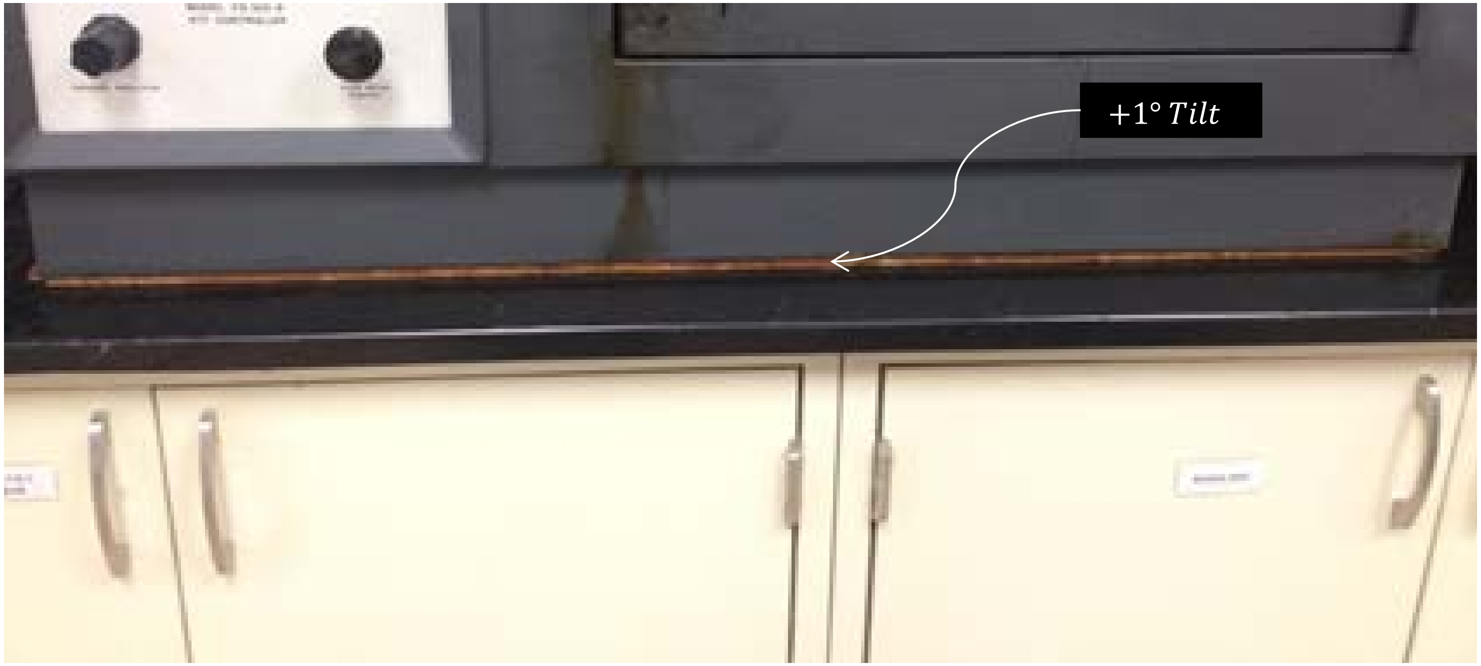
- Sample crawled out of the bottles

Asphalt binder dripping out during test

Asphalt Binder dripped onto Heating Elements inside RTFO Oven

Deviation from Standard

– Tilted the RTFO oven by +1°



Result

- Bottles did not coat completely

RTFO bottles after aging

Images of BBR Beams

PG 64-22 + GTR (Original) BBR Beams
No RTFO or PAV conditioning

Difficult to prepare GTR test specimens for BBR, DTT, and ABCD

Results**

➢ Performance Grade (M320 and M332)

Binder ID	AASHTO M320			Critical Low Cracking Temperature (°C)	$J_{nr3.2}$ (1/kPa)	J_{nrdiff} (%)	AASHTO M332
	M320 T1	M320 T2	M320 T1 Continuous				
	PG Grade						
PG 64-22+Evotherm	PG 64-22	PG 64-22	PG 67.0-26.1	-23.6	1.170	9.2	PG 58-22H
PMLC4 - full reaction	PG 88-22		PG 88.3-24.9		0.042	75.9	PG 58-22E
PMLC6 - full reaction	PG 88-22		PG 88.7-26.6		0.059	245.7	PG 58-22E
PMLC7 - full reaction	PG 82-22		PG 85.0-25.9		0.093	133.3	PG 58-22E

**These results are not reliable due to issues with oven conditioning, deviations from the AASHTO standard procedure, and GTR particle size of these GTR modified binders!!

Challenges

- DSR Testing
  - Reheating and processing GTR modified binders
  - Sample Trimming and Edge Effects
  - GTR Particle Size Limits
  - Distribution of GTR Particles within sample or test specimens
  - High GTR percent by weight of binder

Observations

- GTR percentage should be established through engineering and a targeted final PG grade; not simply to meet ASTM definition
- GTR binders should be handled carefully. Special attention must be given for blending, reheating, and mixing process. These include equipment selection, mixing time, temperature, and rotation speed.
- GTR evaluation should include gradation (particle sizes), distribution, and settlement/segregation.
- Test specimen preparation and trimming is not a trivial item when testing GTR samples in PP geometry.

Observations

- Investigate machine compliance when testing PAV-aged GTR samples.
- The Concentric Cylinder (CC) test geometry configuration should be considered to overcome some of the PP geometry and specimen issues.
- Practical limits on GTR percentage should be established to ensure the current grading system is applicable.
- Alternative evaluation of GTR-based mastics or Fine Aggregate Mixes (FAM) should be investigated and may be more appropriate at high GTR percentages.

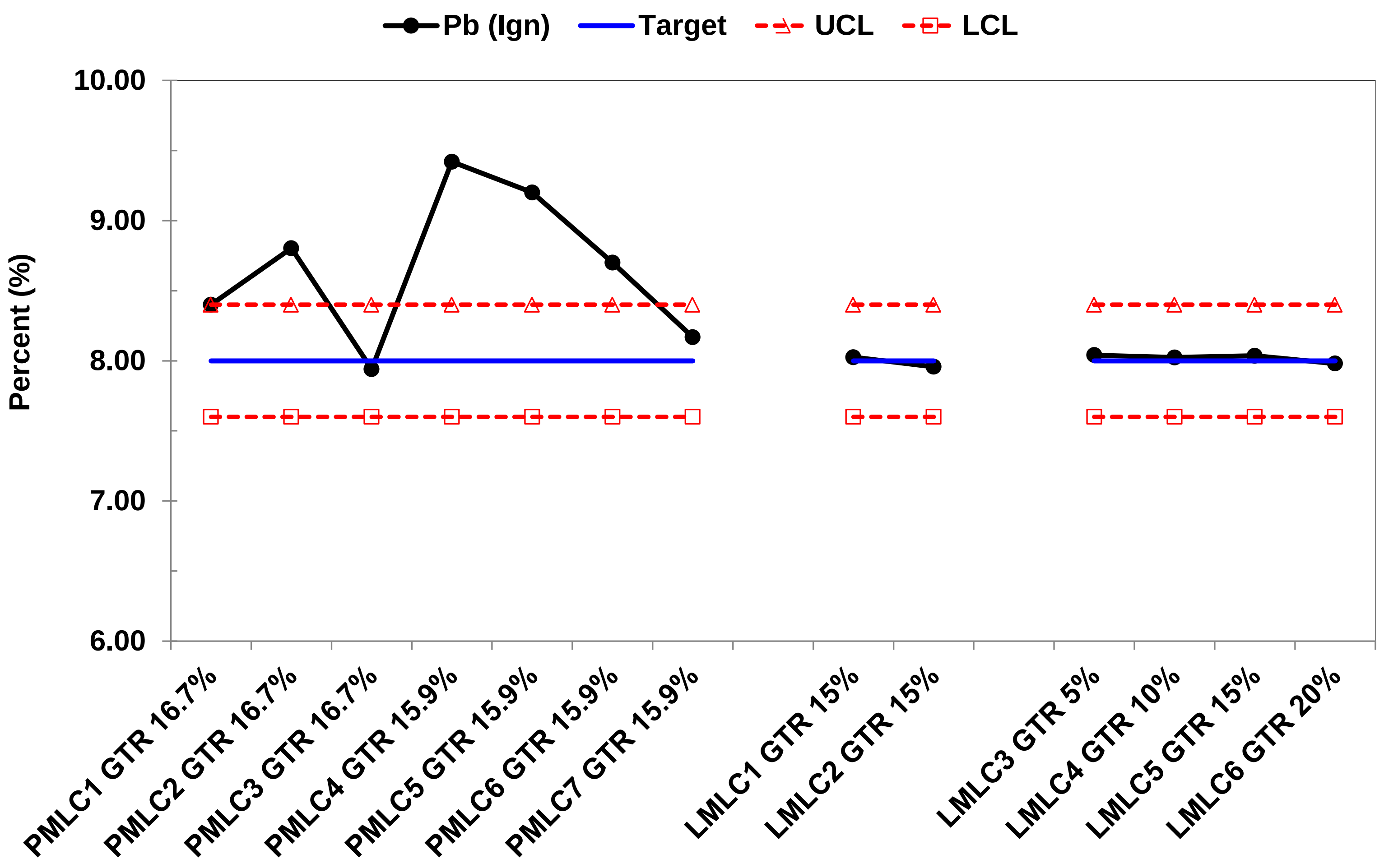
Mixes

- **7 PMLC Samples**
  - PMLC1 GTR 16.7%
  - PMLC2 GTR 16.7%
  - PMLC3 GTR 16.7%
  - PMLC4 GTR 15.9%
  - PMLC5 GTR 15.9%
  - PMLC6 GTR 15.9%
  - PMLC7 GTR 15.9%

- **6 LMLC Mixes**
  - LMLC1 GTR 15%
  - LMLC2 GTR 15%*
  - LMLC3 GTR 5%
  - LMLC4 GTR 10%
  - LMLC5 GTR 15%
  - LMLC6 GTR 20%

* GTR modified binder field blended by the contractor

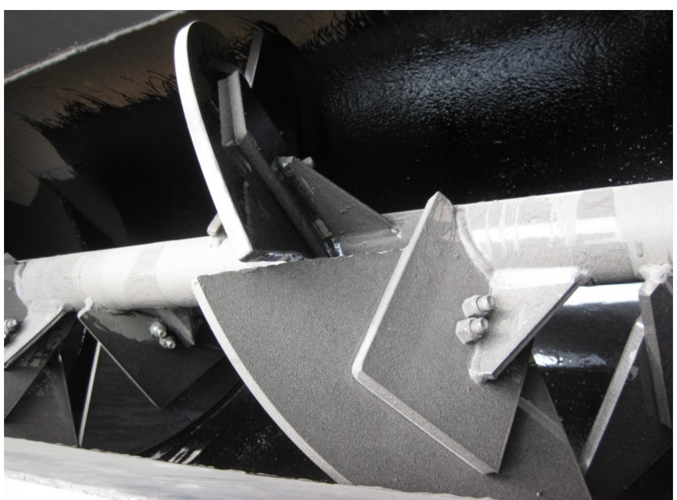
Pb Verification



Mix Plant

GTR Blender

- Production rate
  - 500 tons/hrs.
  - Bag-house Collector System



AMPT Capabilities

- **Dynamic Modulus (|E*|)**

  Stiffness

- **Fatigue (S-VECD)**

  Fatigue Cracking

- **Flow Number (Fn)**

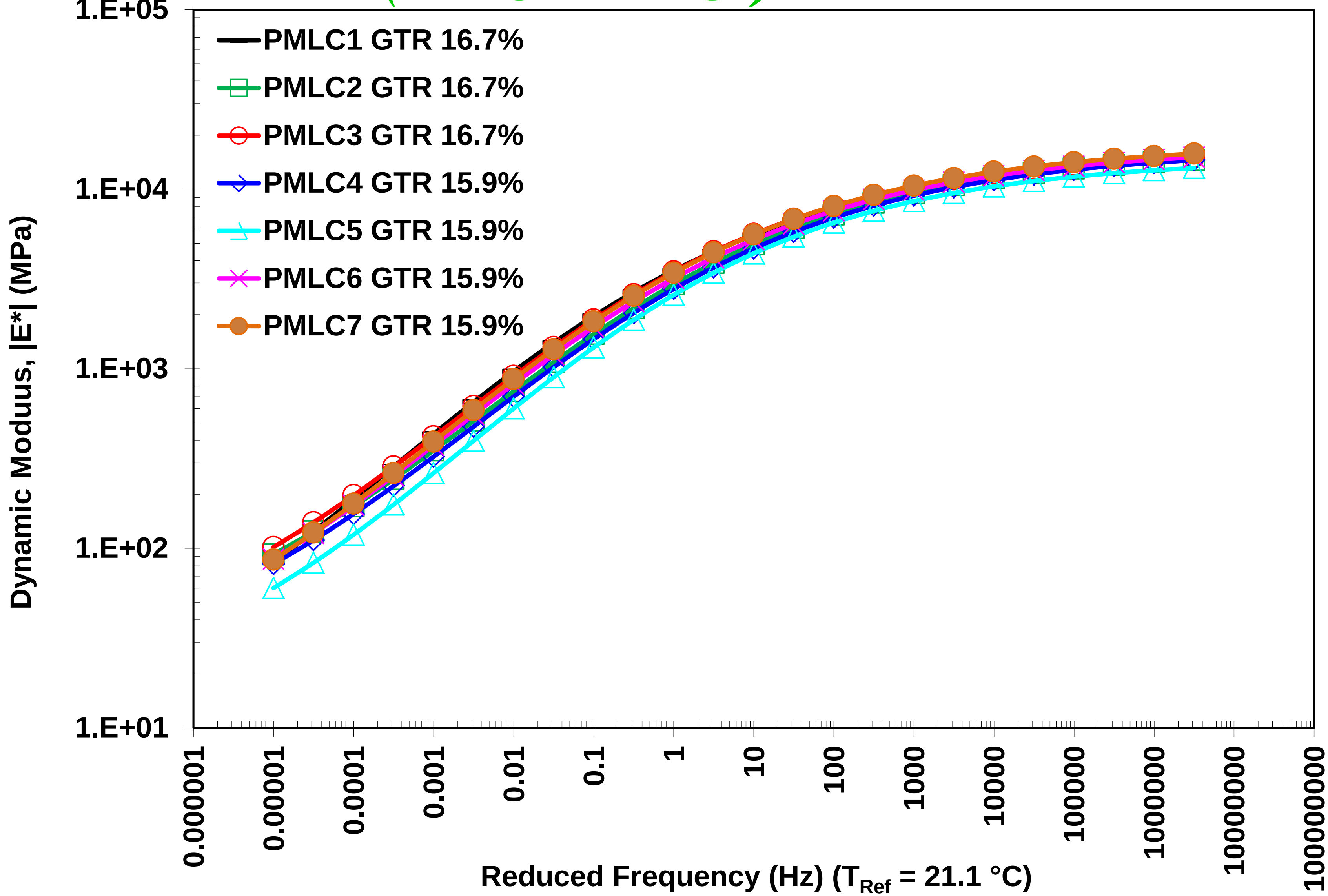
  Permanent Deformation

- **Overly Tester**

  Reflective/Fatigue Cracking

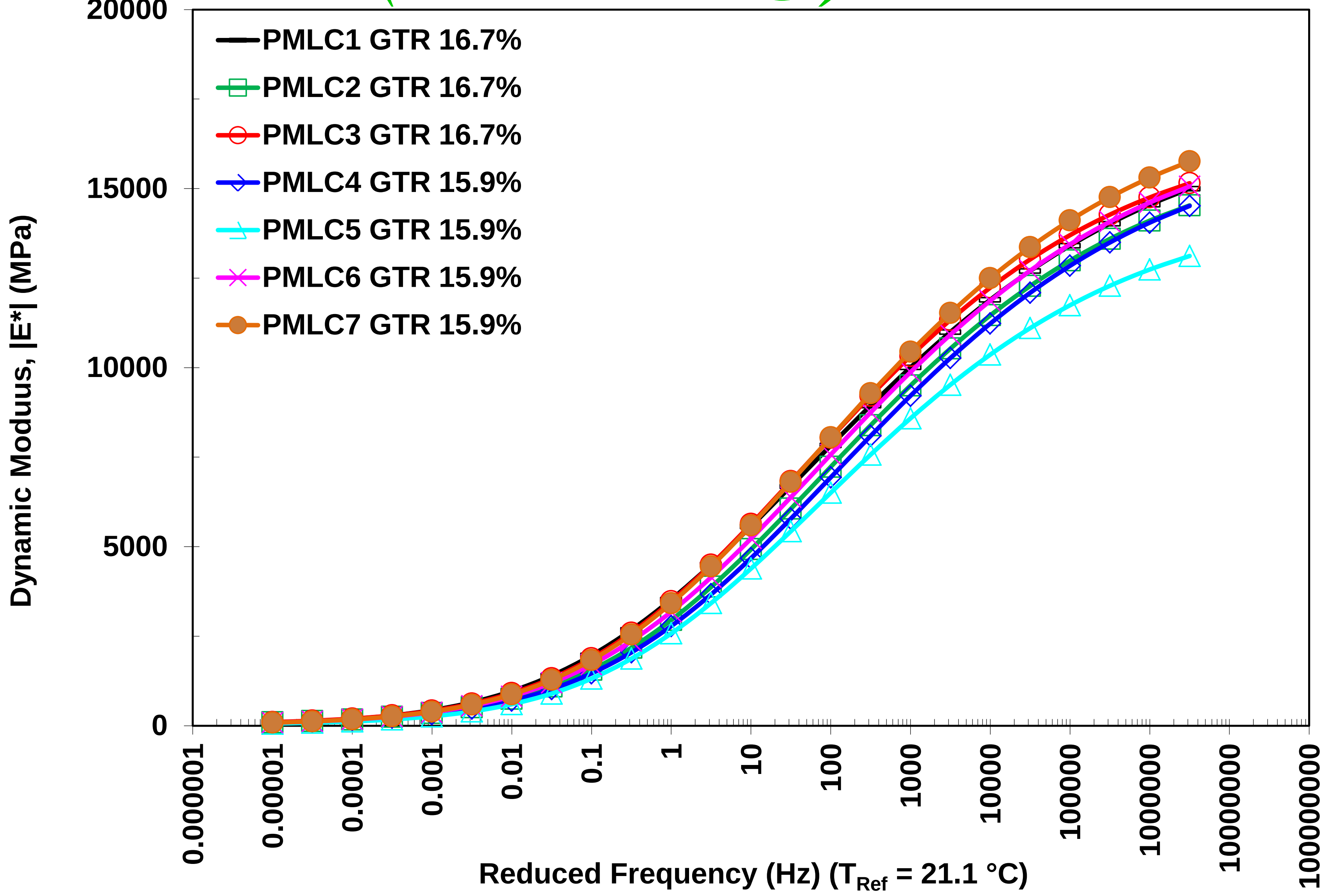
AMPT (IPC Global)

PMLC (log-log)

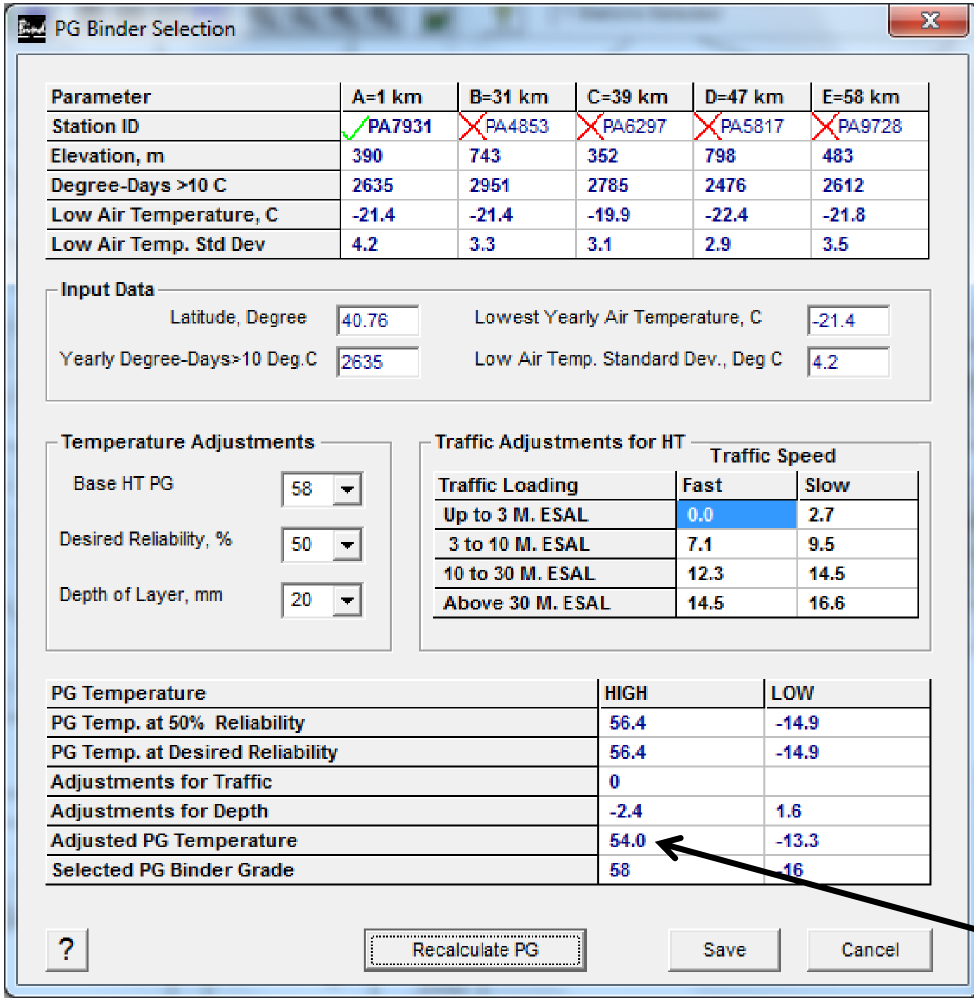


PMLC1 GTR 16.7%
PMLC2 GTR 16.7%
PMLC3 GTR 16.7%
PMLC4 GTR 15.9%
PMLC5 GTR 15.9%
PMLC6 GTR 15.9%
PMLC7 GTR 15.9%
Dynamic Moduus, |E*| (MPa)
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
0.0000001
0.000001
0.0001
0.001
0.01
0.1
1
10
100
1000
10000
100000
1000000
10000000
100000000
Reduced Frequency (Hz) (T_Ref = 21.1 °C)

PMLC (semi-log)



Selection of Test Temperature


PG Binder Selection

Parameter	A=1 km	B=31 km	C=39 km	D=47 km	E=58 km
Station ID	PA7931	PA4853	PA6297	PA5817	PA9728
Elevation, m	390	743	352	798	483
Degree-Days >10 C	2635	2951	2785	2476	2612
Low Air Temperature, C	-21.4	-21.4	-19.9	-22.4	-21.8
Low Air Temp. Std Dev	4.2	3.3	3.1	2.9	3.5

Input Data

Latitude, Degree 40.76

Lowest Yearly Air Temperature, C -21.4

Yearly Degree-Days>10 Deg.C 2635

Low Air Temp. Standard Dev., Deg C 4.2

Temperature Adjustments

Base HT PG 58

Desired Reliability, % 50

Depth of Layer, mm 20

Traffic Adjustments for HT

	Traffic Speed	
Traffic Loading	Fast	Slow
Up to 3 M. ESAL	0.0	2.7
3 to 10 M. ESAL	7.1	9.5
10 to 30 M. ESAL	12.3	14.5
Above 30 M. ESAL	14.5	16.6

PG Temperature	HIGH	LOW
PG Temp. at 50% Reliability	56.4	-14.9
PG Temp. at Desired Reliability	56.4	-14.9
Adjustments for Traffic	0	
Adjustments for Depth	-2.4	1.6
Adjusted PG Temperature	54.0	-13.3
Selected PG Binder Grade	58	-16

? Recalculate PG Save Cancel

LTPPBind V3.1

<u>Closest Weather Station</u>

PA 7931 (Selinsgrove, PA)

<u>Adjustments</u>

50% Reliability

20 mm Depth

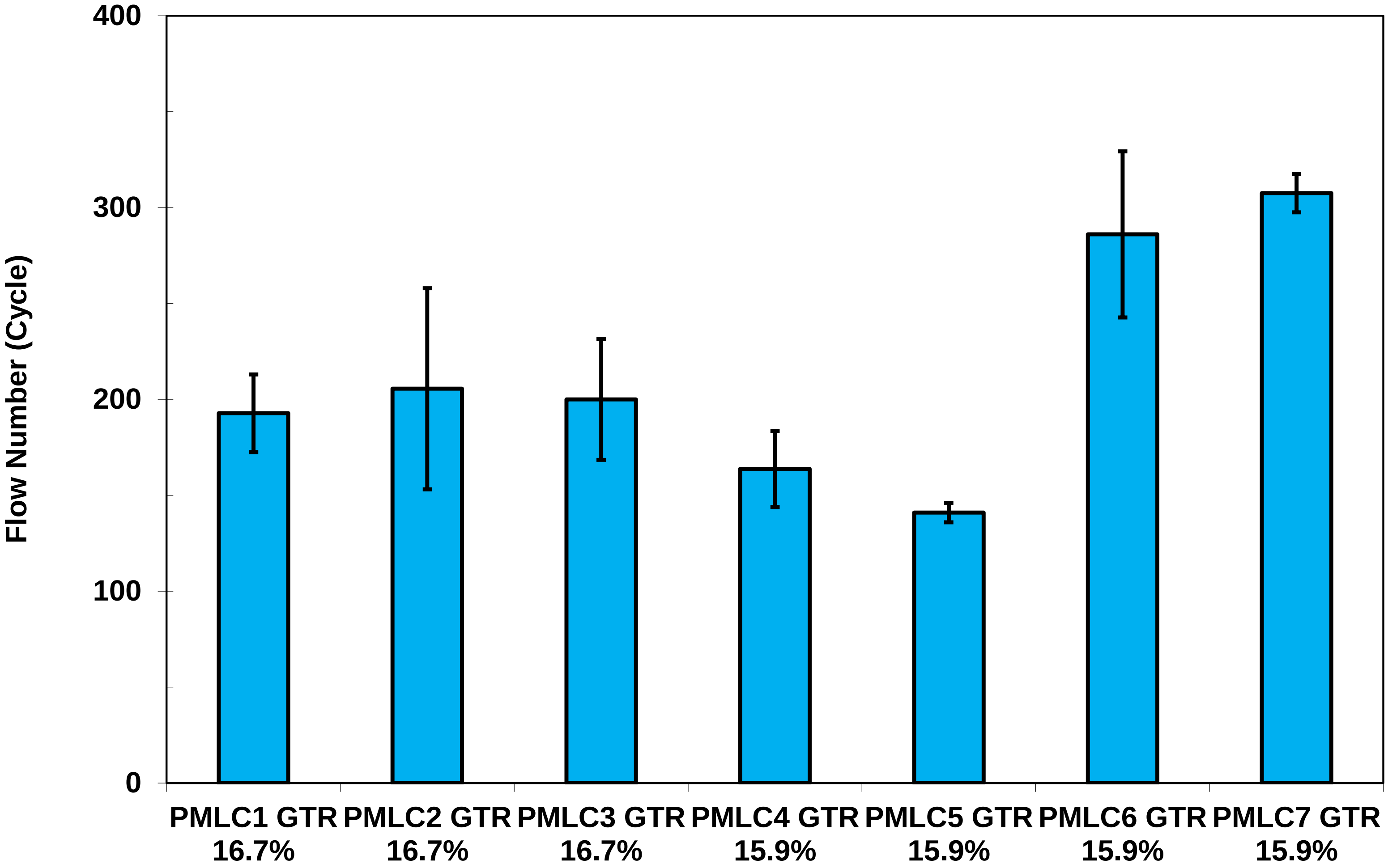
PG Temp = 54.0 °C

Flow Number Test

Mix ID	Unconfined FN (Confinement = 0 kPa)			Confined FN (Confinement = 69 kPa)		
	600 kPa	690 kPa	800 kPa	600 kPa	690 kPa	800 kPa
LMLC1 GTR 15%	Yes			Yes		
LMLC2 GTR 15%	Yes			Yes		
LMLC3 GTR 5%	Yes	Yes	Yes	Yes	Yes	Yes
LMLC4 GTR 10%	Yes	Yes	Yes	Yes	Yes	Yes
LMLC5 GTR 15%	Yes	Yes	Yes	Yes	Yes	Yes
LMLC6 GTR 20%	Yes	Yes	Yes	Yes	Yes	Yes
PMLC1 GTR 16.7%	Yes			Yes		
PMLC2 GTR 16.7%	Yes			Yes		
PMLC3 GTR 16.7%	Yes			Yes		
PMLC4 GTR 15.9%	Yes			Yes		
PMLC5 GTR 15.9%	Yes			Yes		
PMLC6 GTR 15.9%	Yes			Yes		
PMLC7 GTR 15.9%	Yes			Yes		

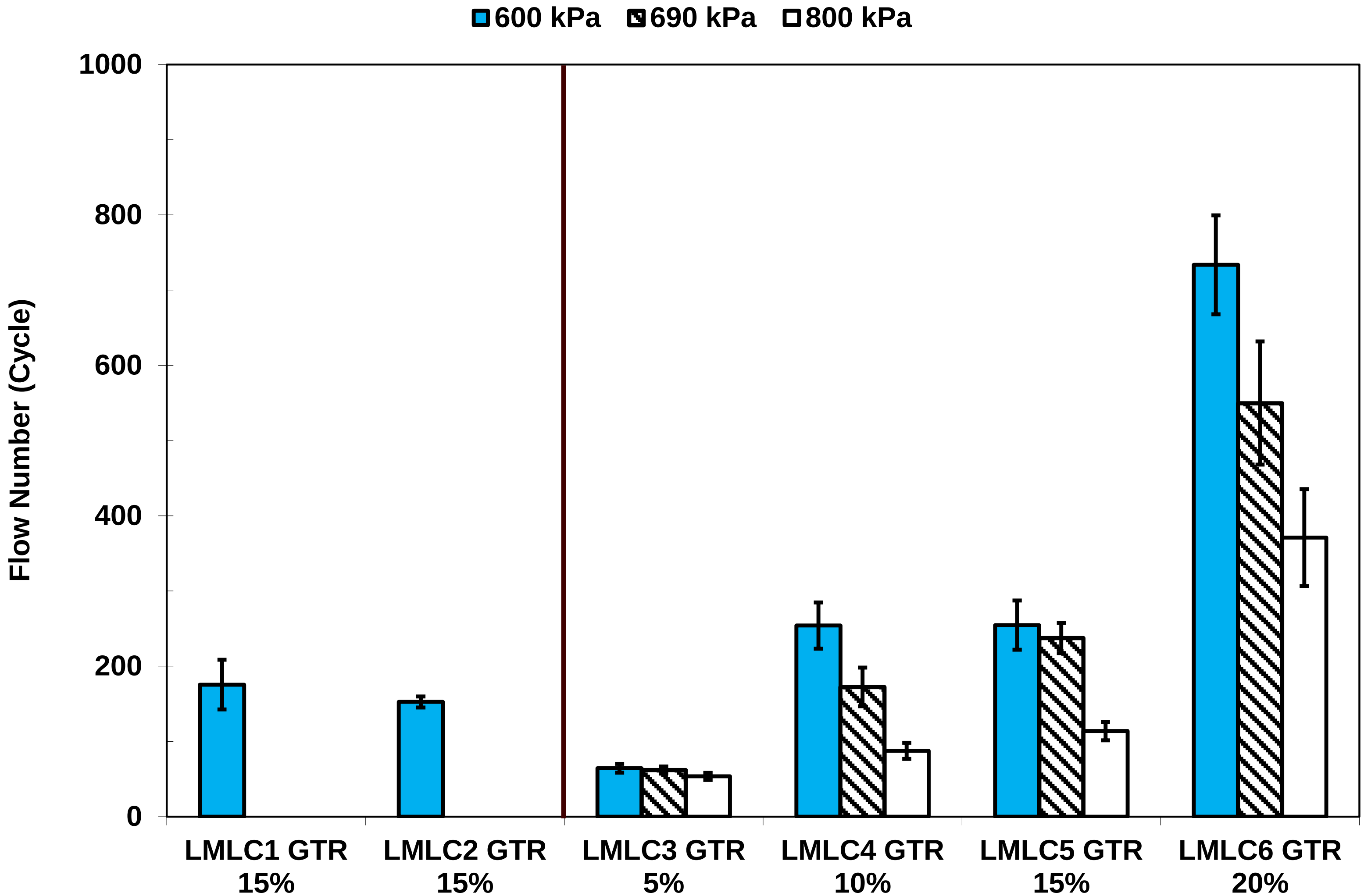
- 4 Replicates for each mix
- Stopping Criterion: 10,000 Cycles **or** 50,000 Microstrain

PMLC (600/0 kPa)



TP79 min. Flow Number criteria is 190 for HMA designed for 10 to <30 MESAL

LMLC (Unconfined)



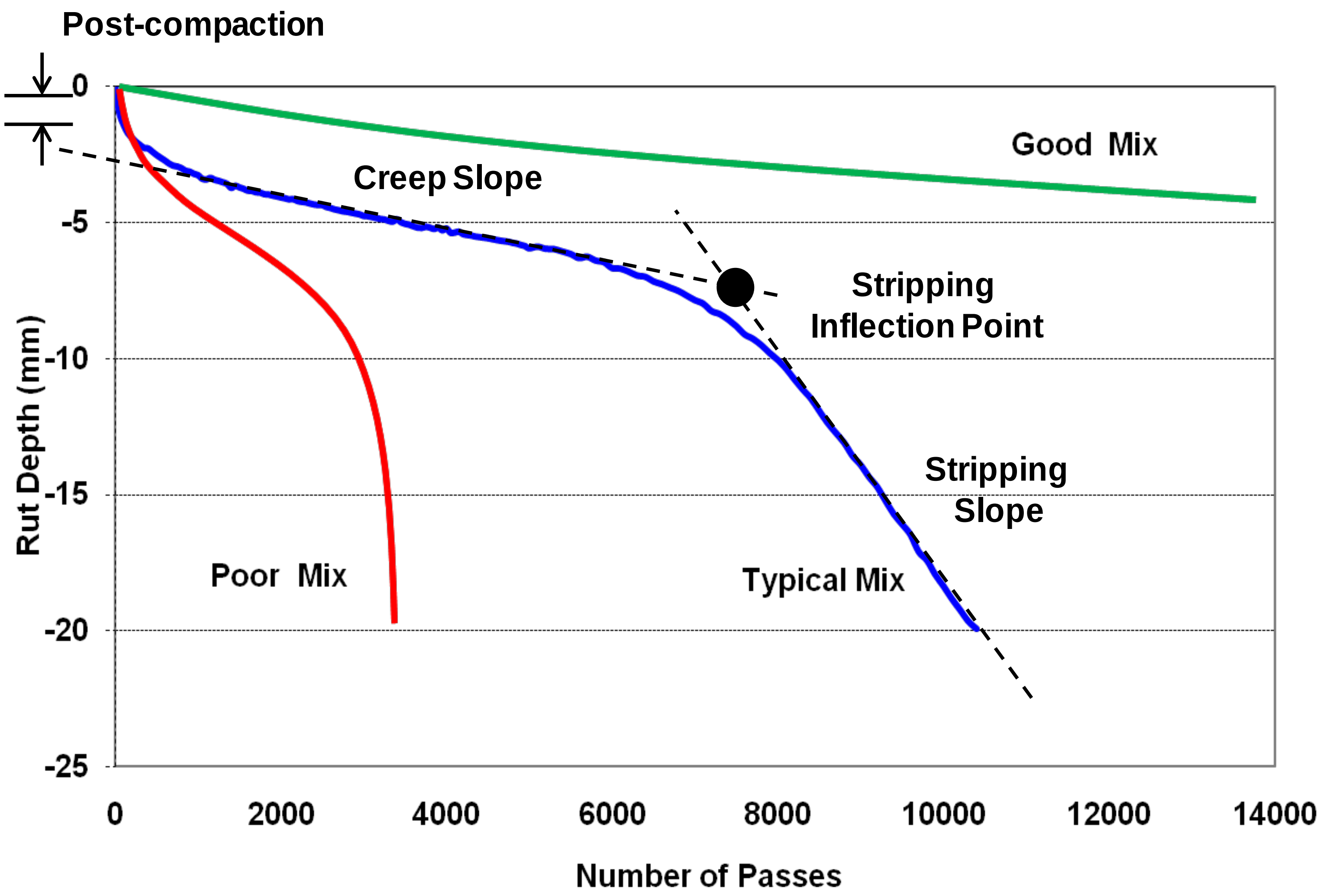
Hamburg Test

- AASHTO T324 Test Protocol
- Specimen (Diameter, Height): 150 X 61±1 mm
- Temperature: 50 °C
- Target Air Voids: 7+0.5%
- Wheel Load: 705+4.5 kN
- Stopping Criterion:

  20,000 Passes or 20 mm Rut

- PennDOT does not currently specify Hamburg test requirements

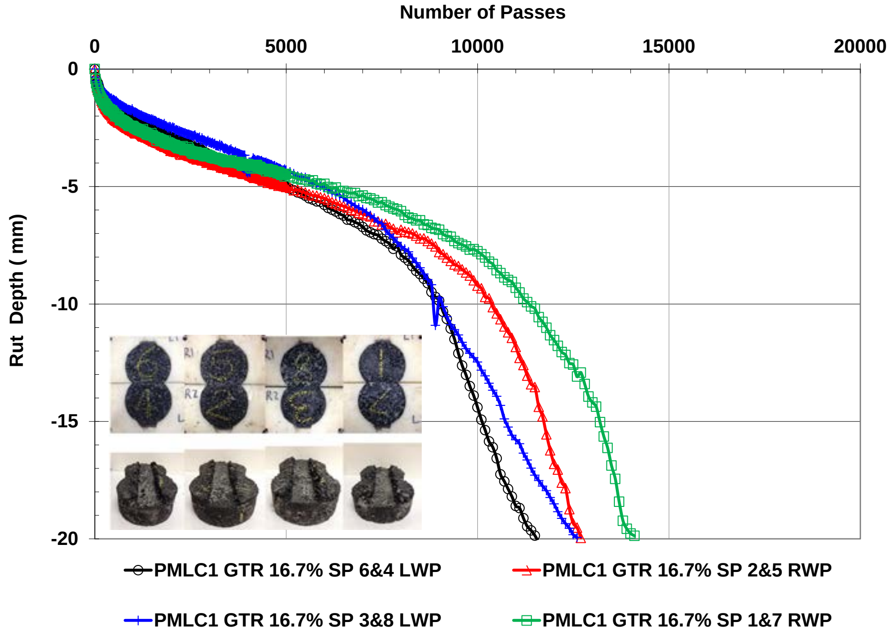
Hamburg Test



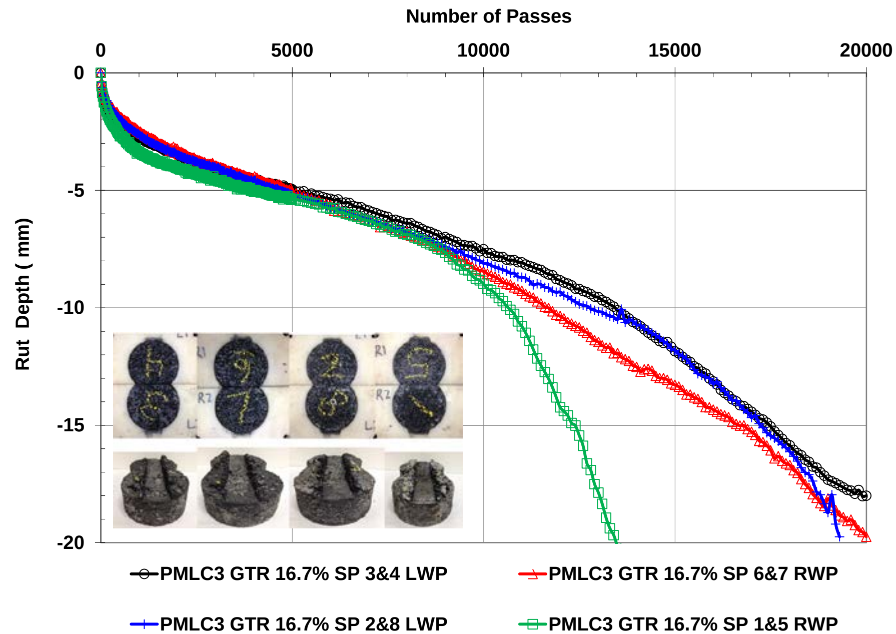
Hamburg Test

Mix ID	No. of Replicate	Remark
PMLC1 GTR 16.7%	4 Replicates	Plant Produced
PMLC2 GTR 16.7%	4 Replicates	
PMLC3 GTR 16.7%	4 Replicates	
PMLC4 GTR 15.9%	4 Replicates	
PMLC5 GTR 15.9%	4 Replicates	
PMLC6 GTR 15.9%	4 Replicates	
PMLC7 GTR 15.9%	4 Replicates	
LMLC1 GTR 15%	4 Replicates	Mix Design Replication
LMLC2 GTR 15%	4 Replicates	
LMLC3 GTR 5%	4 Replicates	
LMLC4 GTR 10%	4 Replicates	
LMLC5 GTR 15%	4 Replicates	
LMLC6 GTR 20%	4 Replicates	

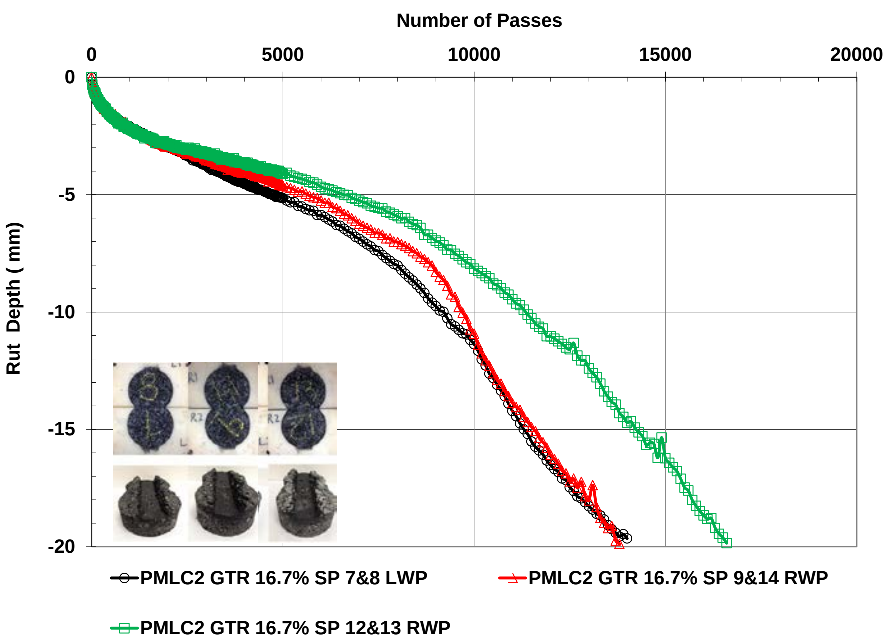
PMLC (GTR 16.7%)



Number of Passes
0
5000
10000
15000
20000
Rut Depth (mm)
0
-5
-10
-15
-20
PMLC1 GTR 16.7% SP 6&4 LWP
PMLC1 GTR 16.7% SP 2&5 RWP
PMLC1 GTR 16.7% SP 3&8 LWP
PMLC1 GTR 16.7% SP 1&7 RWP

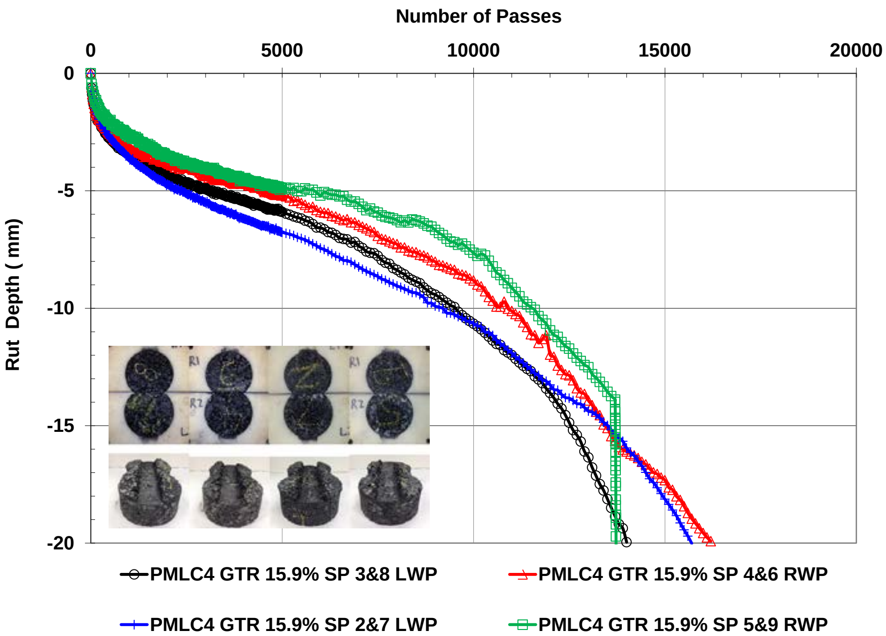


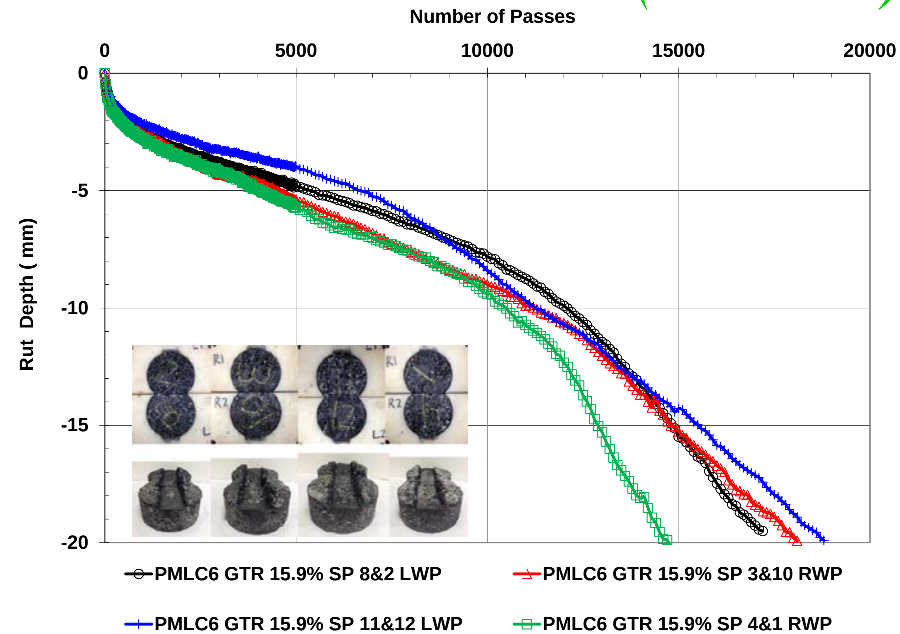
Number of Passes
0
5000
10000
15000
20000
Rut Depth (mm)
0
-5
-10
-15
-20
PMLC3 GTR 16.7% SP 3&4 LWP
PMLC3 GTR 16.7% SP 6&7 RWP
PMLC3 GTR 16.7% SP 2&8 LWP
PMLC3 GTR 16.7% SP 1&5 RWP

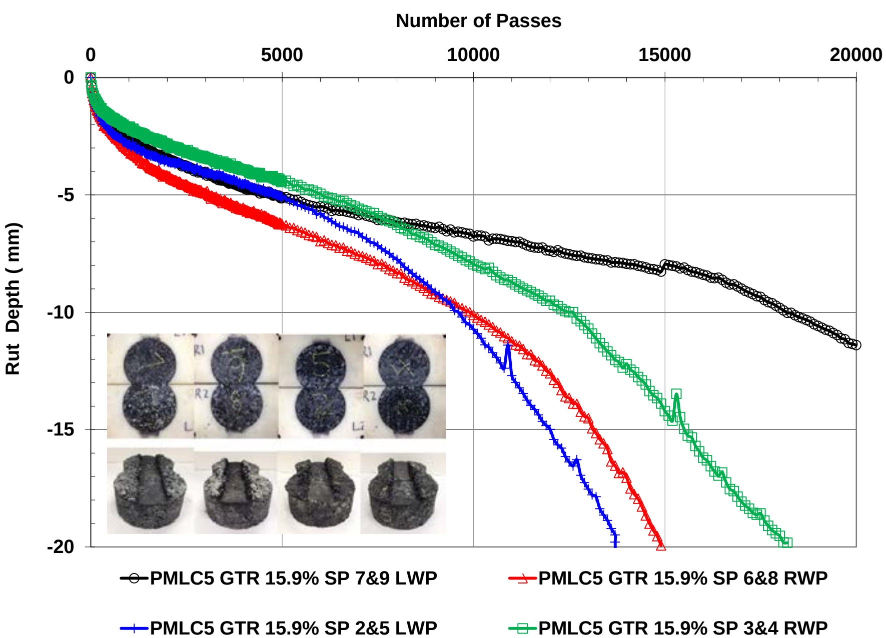


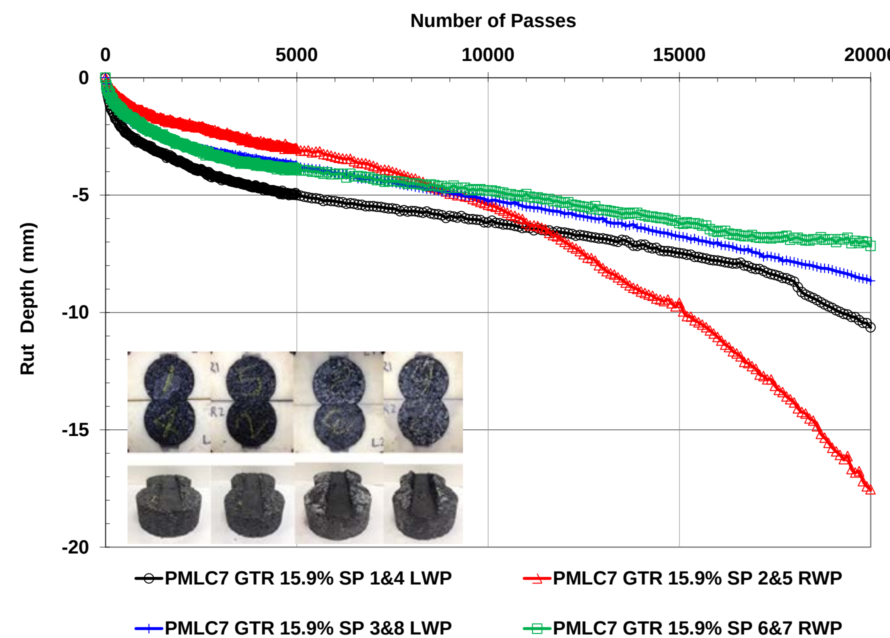
Number of Passes
0
5000
10000
15000
20000
Rut Depth (mm)
0
-5
-10
-15
-20
PMLC2 GTR 16.7% SP 7&8 LWP
PMLC2 GTR 16.7% SP 9&14 RWP
PMLC2 GTR 16.7% SP 12&13 RWP

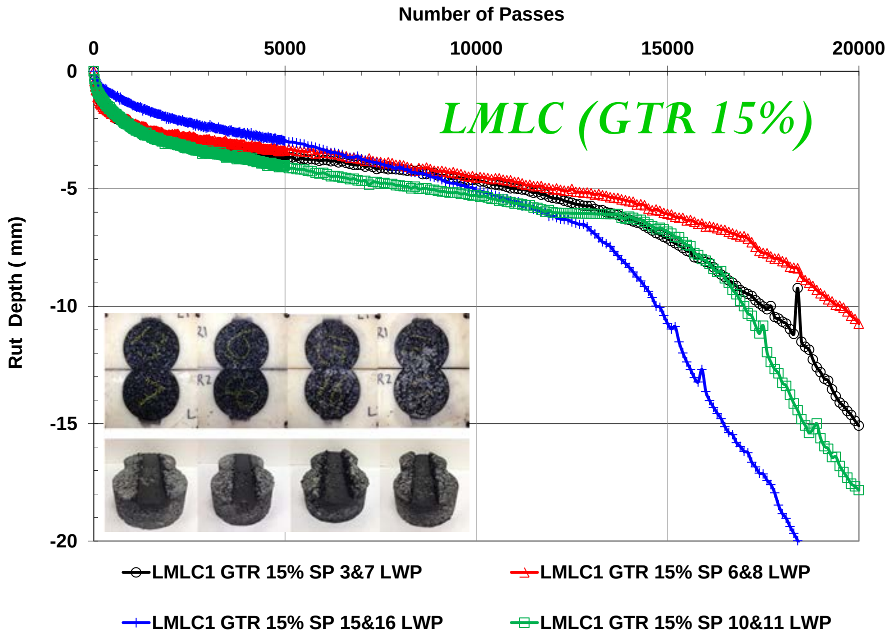
PMLC (GTR15.9%)


Number of Passes
0
5000
10000
15000
20000
0
-5
-10
-15
-20
Rut Depth (mm)
PMLC4 GTR 15.9% SP 3&8 LWP
PMLC4 GTR 15.9% SP 4&6 RWP
PMLC4 GTR 15.9% SP 2&7 LWP
PMLC4 GTR 15.9% SP 5&9 RWP

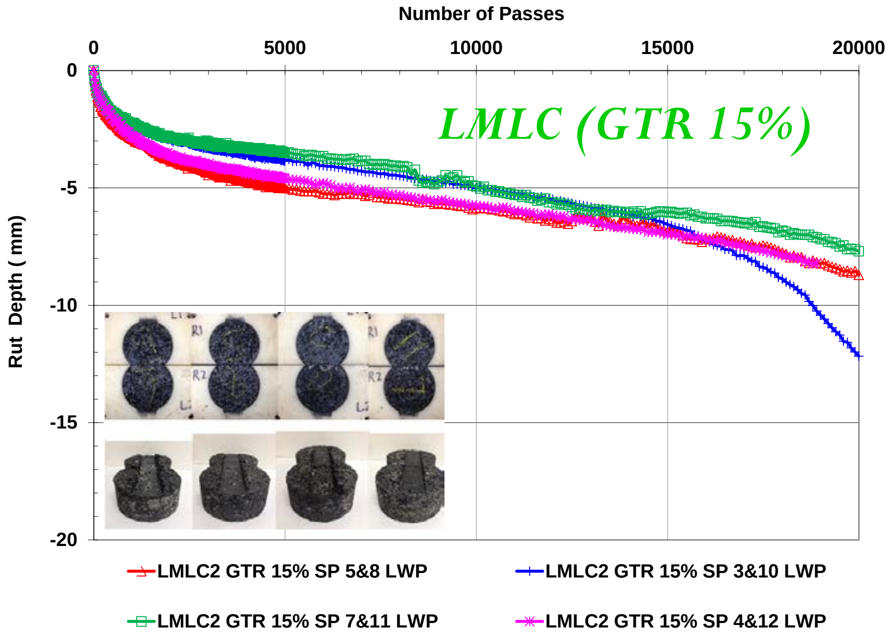

Number of Passes
0
5000
10000
15000
20000
0
-5
-10
-15
-20
Rut Depth (mm)
PMLC6 GTR 15.9% SP 8&2 LWP
PMLC6 GTR 15.9% SP 3&10 RWP
PMLC6 GTR 15.9% SP 11&12 LWP
PMLC6 GTR 15.9% SP 4&1 RWP


Number of Passes
0
5000
10000
15000
20000
0
-5
-10
-15
-20
Rut Depth (mm)
PMLC5 GTR 15.9% SP 7&9 LWP
PMLC5 GTR 15.9% SP 6&8 RWP
PMLC5 GTR 15.9% SP 2&5 LWP
PMLC5 GTR 15.9% SP 3&4 RWP

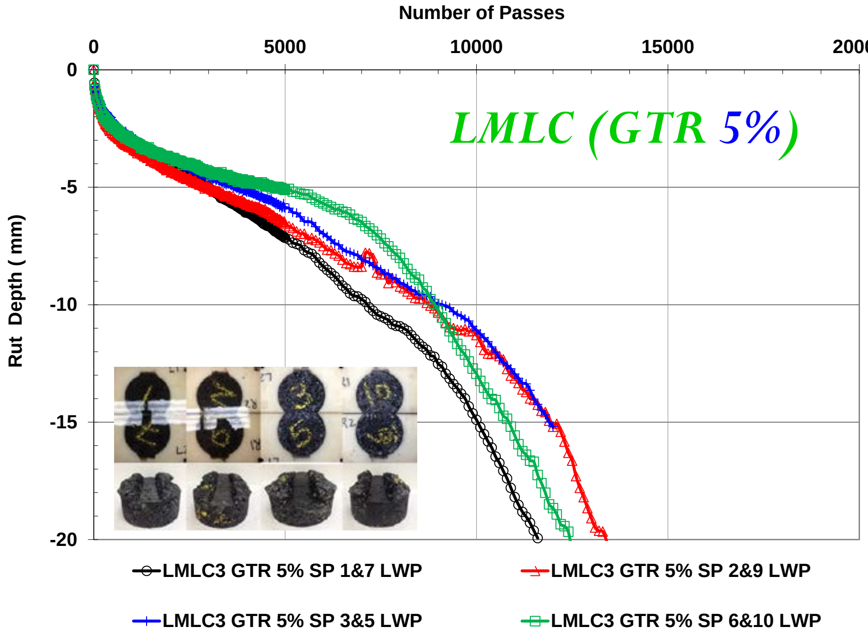

Number of Passes
0
5000
10000
15000
20000
0
-5
-10
-15
-20
Rut Depth (mm)
PMLC7 GTR 15.9% SP 1&4 LWP
PMLC7 GTR 15.9% SP 2&5 RWP
PMLC7 GTR 15.9% SP 3&8 LWP
PMLC7 GTR 15.9% SP 6&7 RWP

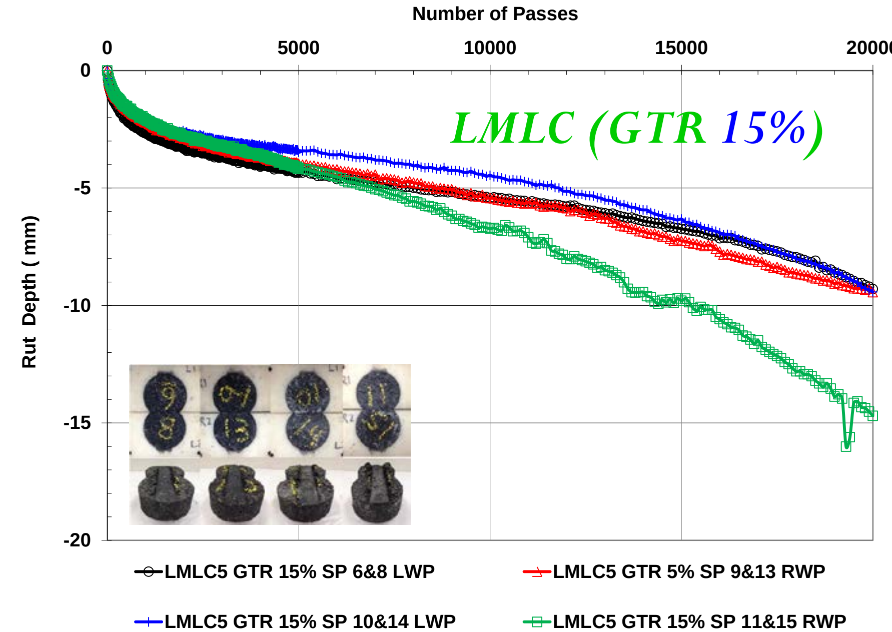


Number of Passes
0
5000
10000
15000
20000
0
-5
-10
-15
-20
Rut Depth (mm)
LMLC (GTR 15%)
LMLC1 GTR 15% SP 3&7 LWP
LMLC1 GTR 15% SP 6&8 LWP
LMLC1 GTR 15% SP 15&16 LWP
LMLC1 GTR 15% SP 10&11 LWP



Number of Passes
0
5000
10000
15000
20000
0
-5
-10
-15
-20
Rut Depth (mm)
LMLC (GTR 15%)
LMLC2 GTR 15% SP 5&8 LWP
LMLC2 GTR 15% SP 3&10 LWP
LMLC2 GTR 15% SP 7&11 LWP
LMLC2 GTR 15% SP 4&12 LWP


Number of Passes
0
5000
10000
15000
20000
Rut Depth (mm)
0
-5
-10
-15
-20
LMLC (GTR 5%)
LMLC3 GTR 5% SP 1&7 LWP
LMLC3 GTR 5% SP 2&9 LWP
LMLC3 GTR 5% SP 3&5 LWP
LMLC3 GTR 5% SP 6&10 LWP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20000
Rut Depth (mm)
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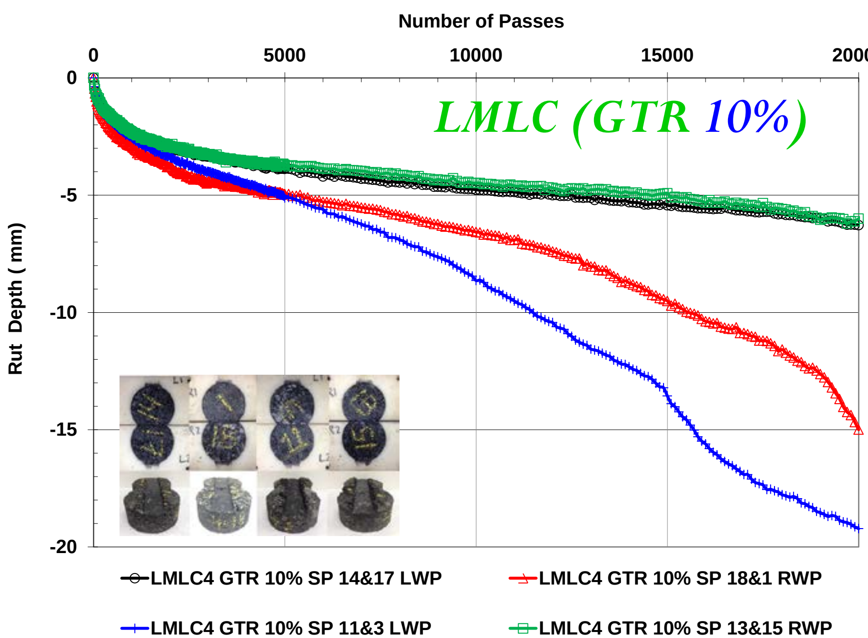
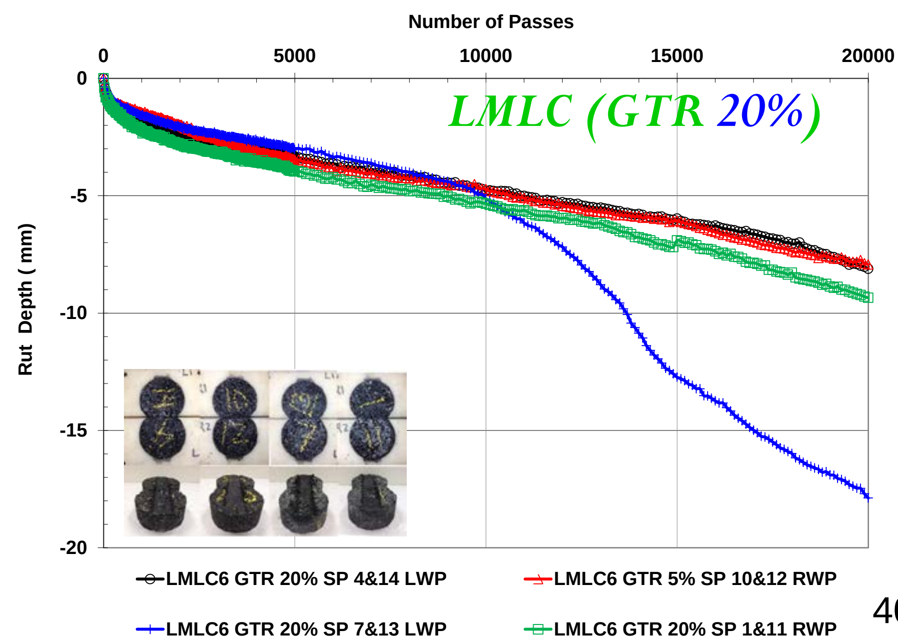
-5
-10
-15
-20
LMLC (GTR 15%)
LMLC5 GTR 15% SP 6&8 LWP
LMLC5 GTR 5% SP 9&13 RWP
LMLC5 GTR 15% SP 10&14 LWP
LMLC5 GTR 15% SP 11&15 RWP


Number of Passes
0
5000
10000
15000
20000
Rut Depth (mm)
0
-5
-10
-15
-20
LMLC (GTR 10%)
LMLC4 GTR 10% SP 14&17 LWP
LMLC4 GTR 10% SP 18&1 RWP
LMLC4 GTR 10% SP 11&3 LWP
LMLC4 GTR 10% SP 13&15 RWP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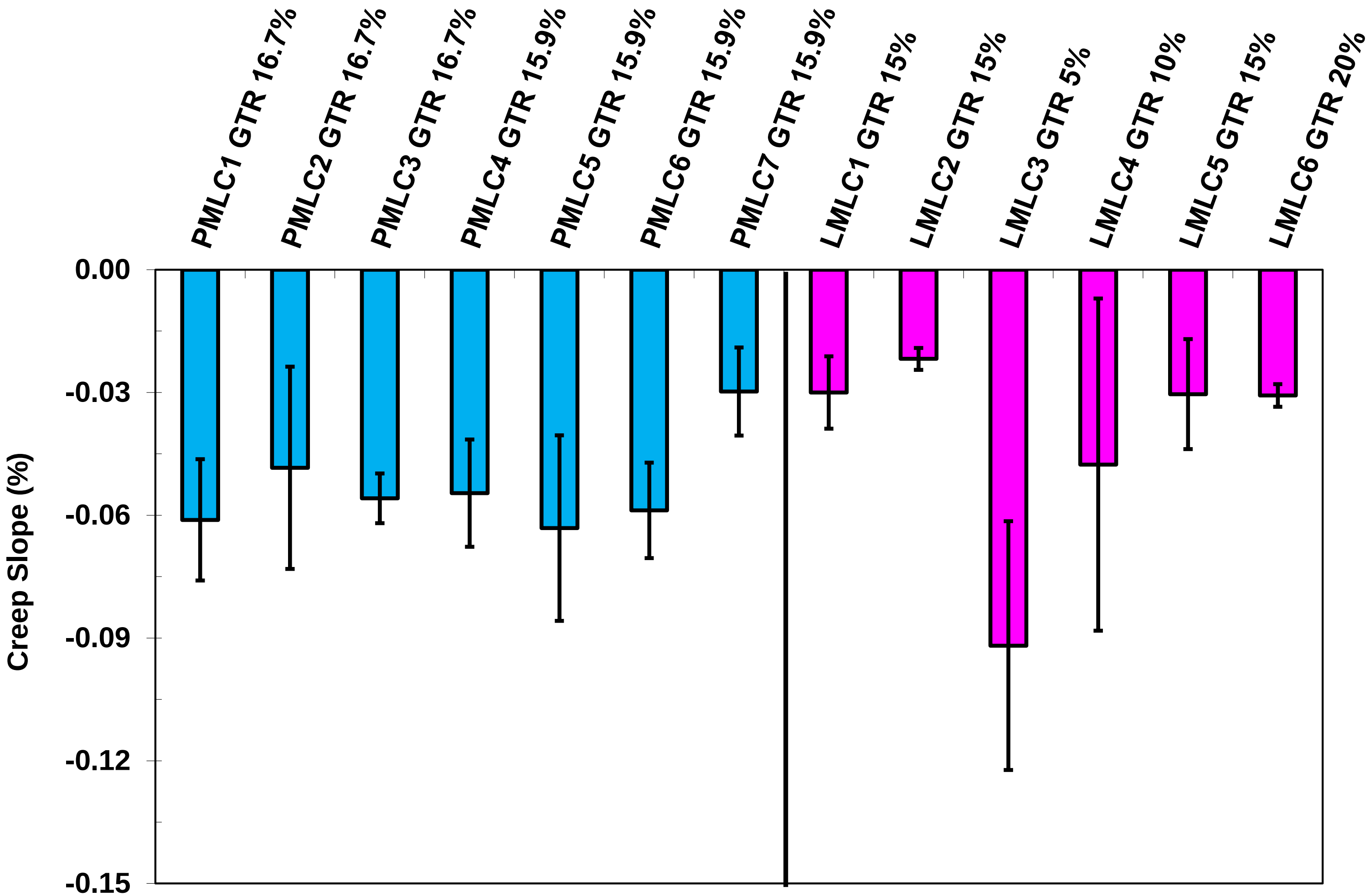
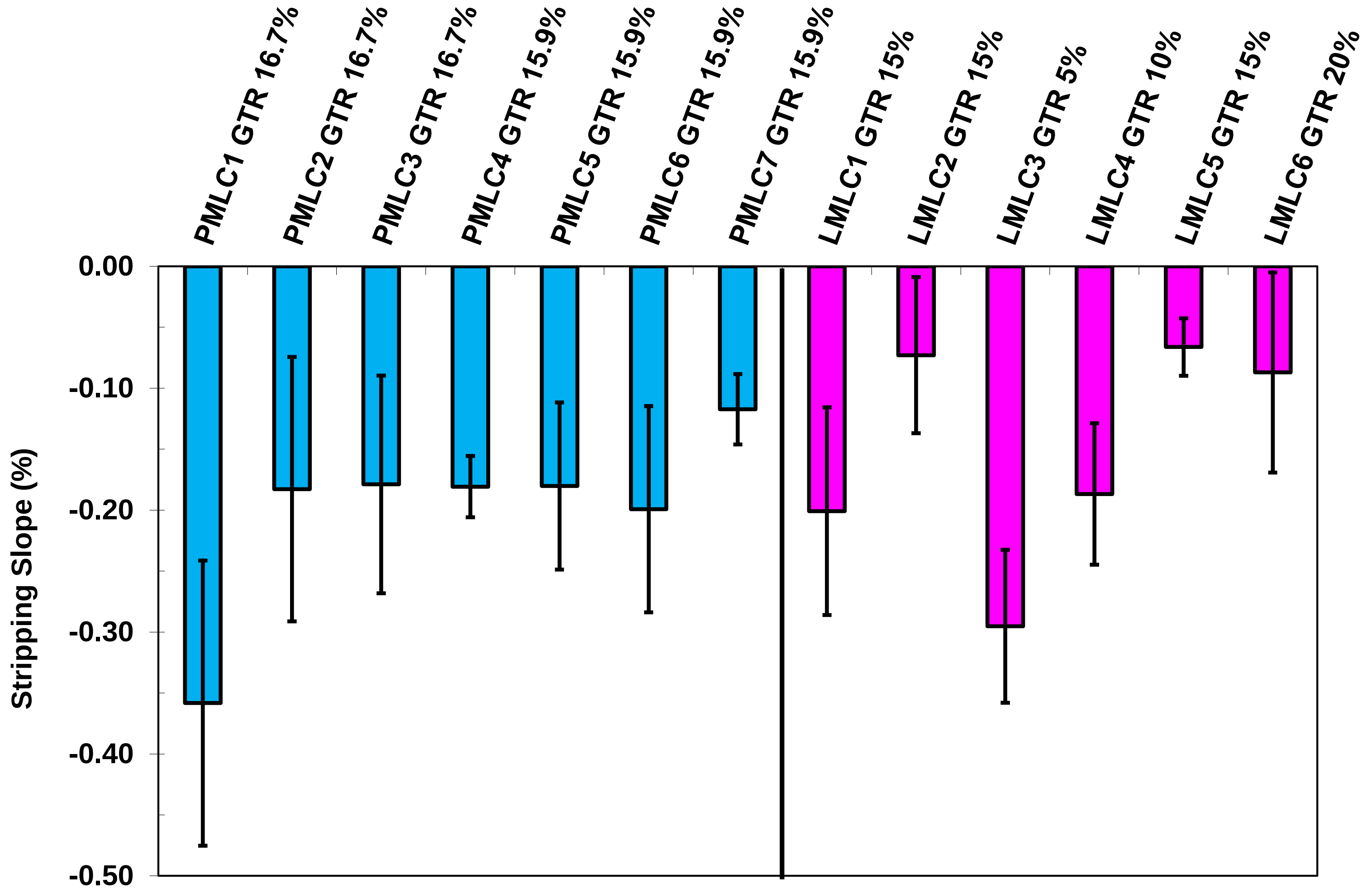
5000
10000
15000
20000
Rut Depth (mm)
0
-5
-10
-15
-20
LMLC (GTR 20%)
LMLC6 GTR 20% SP 4&14 LWP
LMLC6 GTR 5% SP 10&12 RWP
LMLC6 GTR 20% SP 7&13 LWP
LMLC6 GTR 20% SP 1&11 RWP

Creep Slope

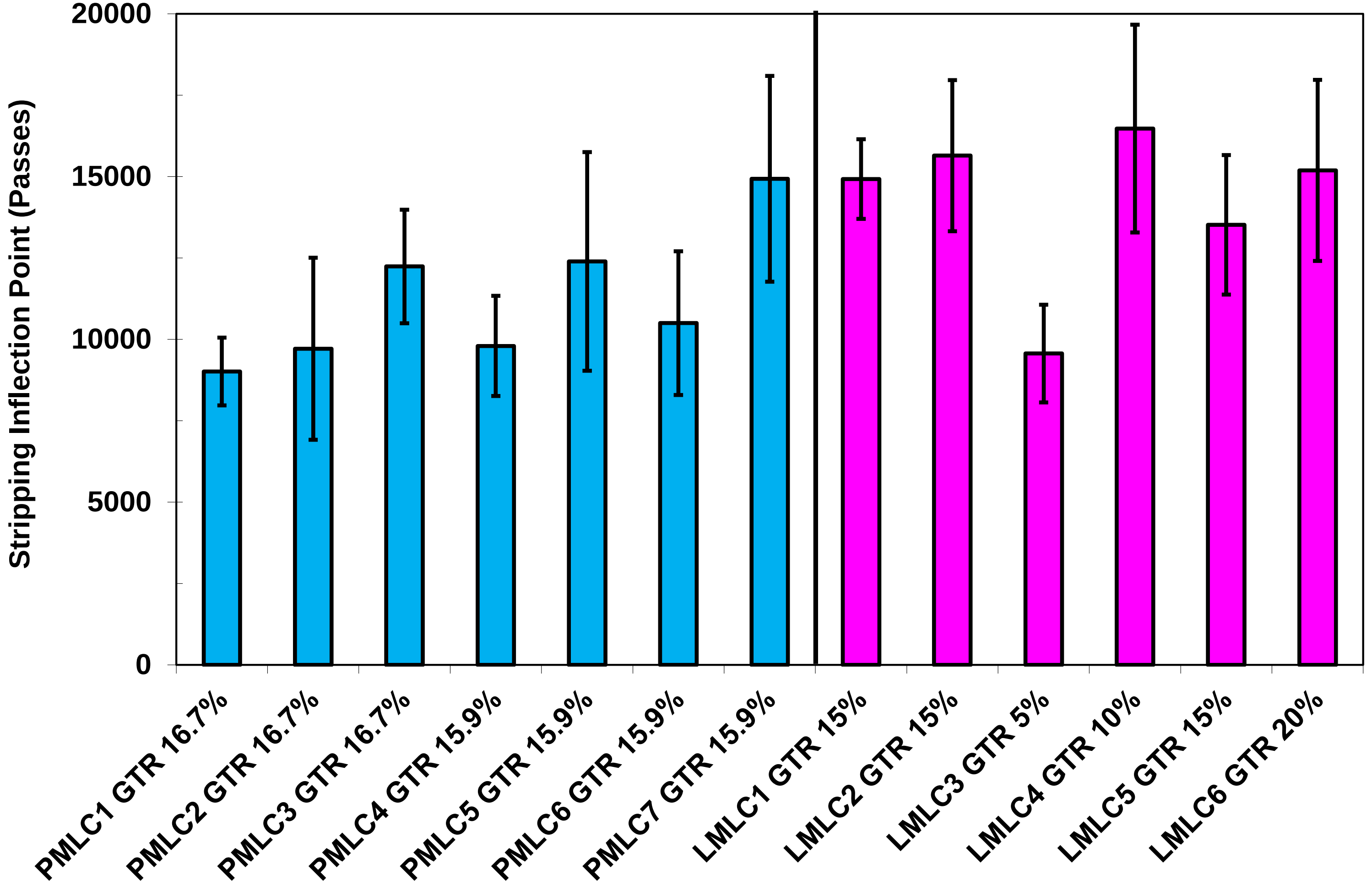


PMLC1 GTR 16.7%
PMLC2 GTR 16.7%
PMLC3 GTR 16.7%
PMLC4 GTR 15.9%
PMLC5 GTR 15.9%
PMLC6 GTR 15.9%
PMLC7 GTR 15.9%
LMLC1 GTR 15%
LMLC2 GTR 15%
LMLC3 GTR 5%
LMLC4 GTR 10%
LMLC5 GTR 15%
LMLC6 GTR 20%
0.00
-0.03
-0.06
-0.09
-0.12
-0.15
Creep Slope (%)

Stripping Slope



Stripping Inflection Point



Fatigue (S-VECD)

- AASHTO TP 107
- Simplified Viscoelastic Continuum Damage (S-VECD) Model
- Damage Characteristic Curve (C versus S)

$$\boxed{C = e^{aS^b}}$$

C = Material Integrity or Pseudo Stiffness

S = Amount of Damage

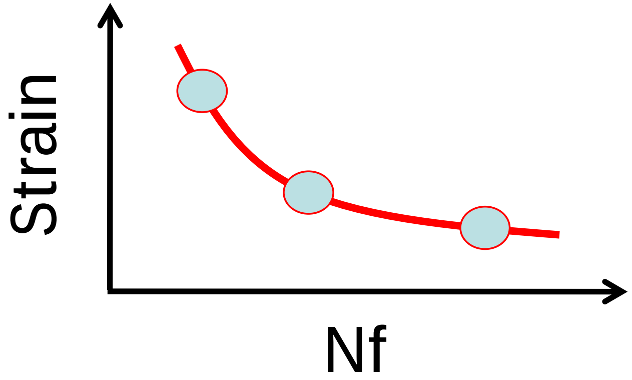
- S-VECD Test Includes:
  - o |E*| Linear Viscoelastic (LVE) Test
  - o |E*| Dynamic Modulus (Finger Print) Test
  - o Pull-Pull Fatigue Test

Fatigue (S-VECD)

- At least 3 Replicates
- Frequency = 10 Hz
- Temperature = 21 °C

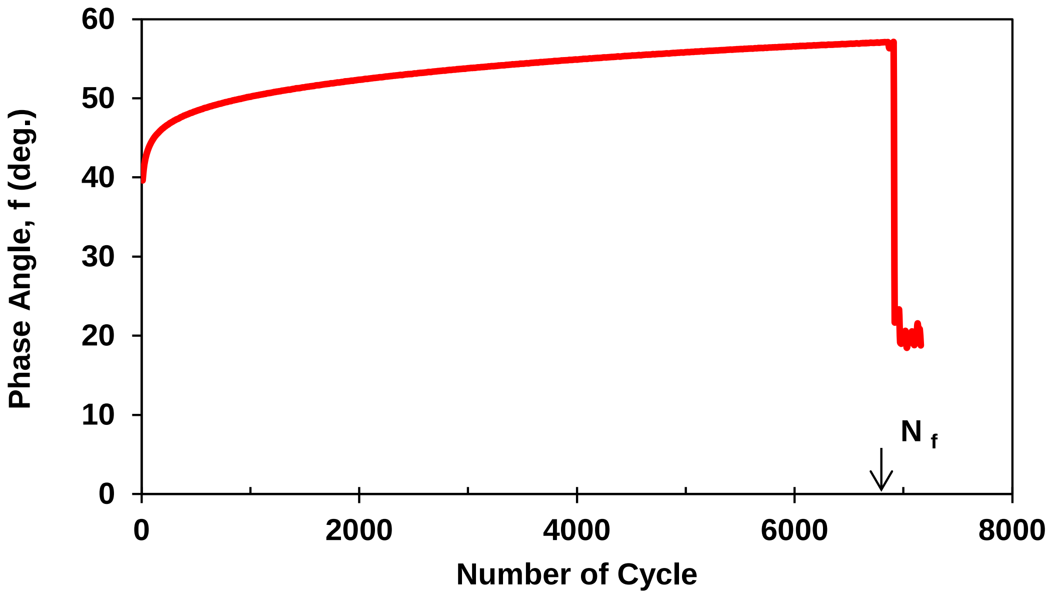
$$\text{Temp. (°C)} = \min\left(21°\text{C}, \frac{PG\ (High+Low)}{2} - 3\right)$$

- Three on-specimen Strain Levels
  - o 350, 450, and 600 μstrain

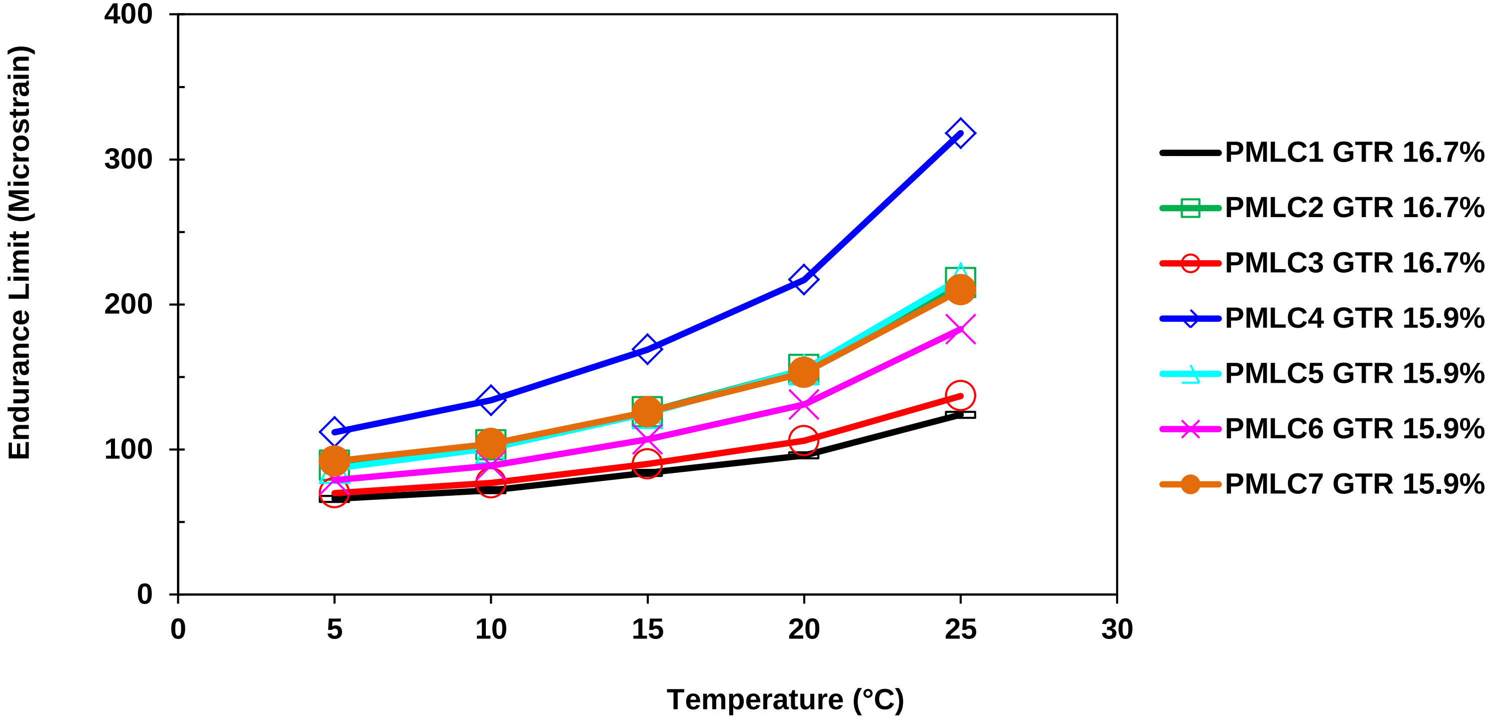


Fatigue (S-VECD)

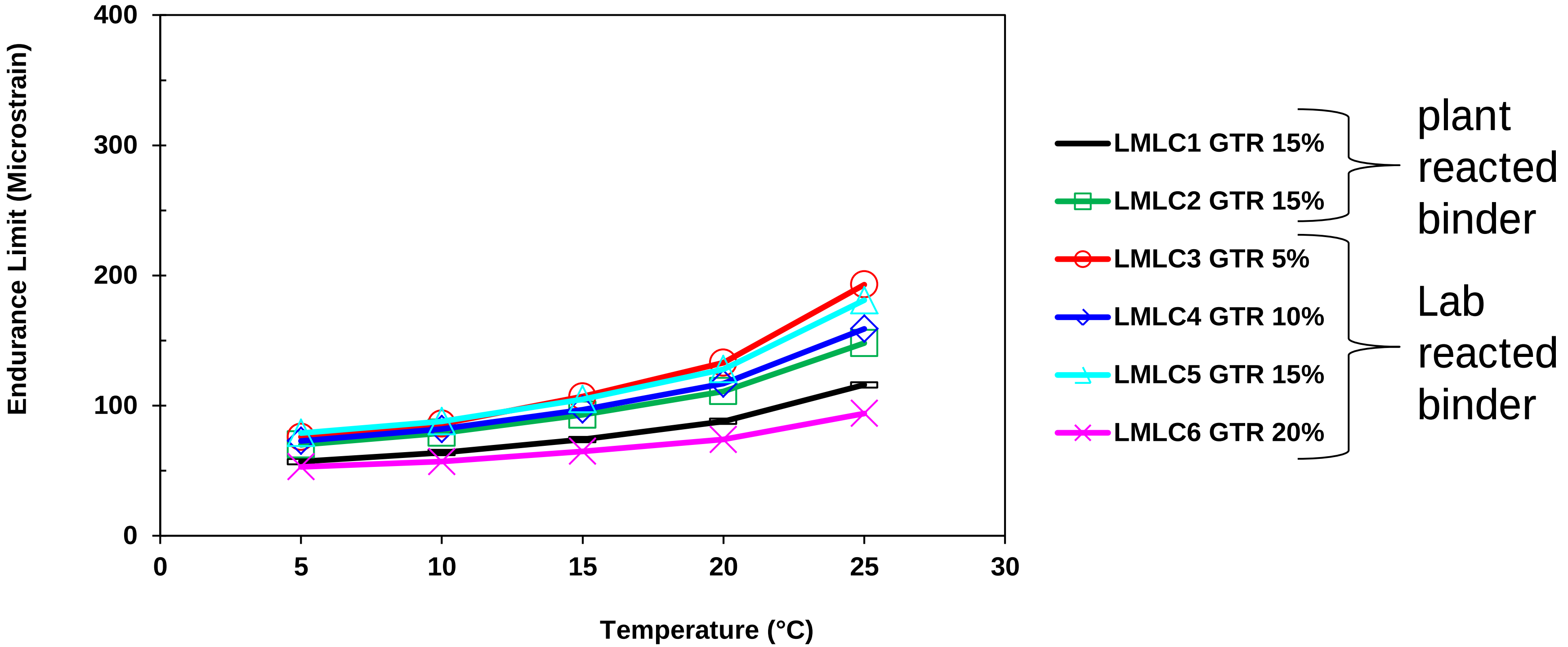
- ALPHA-Fatigue Software
- Failure Mechanism → Mid-Failure
- Stopping Criterion
  - o Sudden Drop in Phase Angle



Endurance Limit (PMLC)



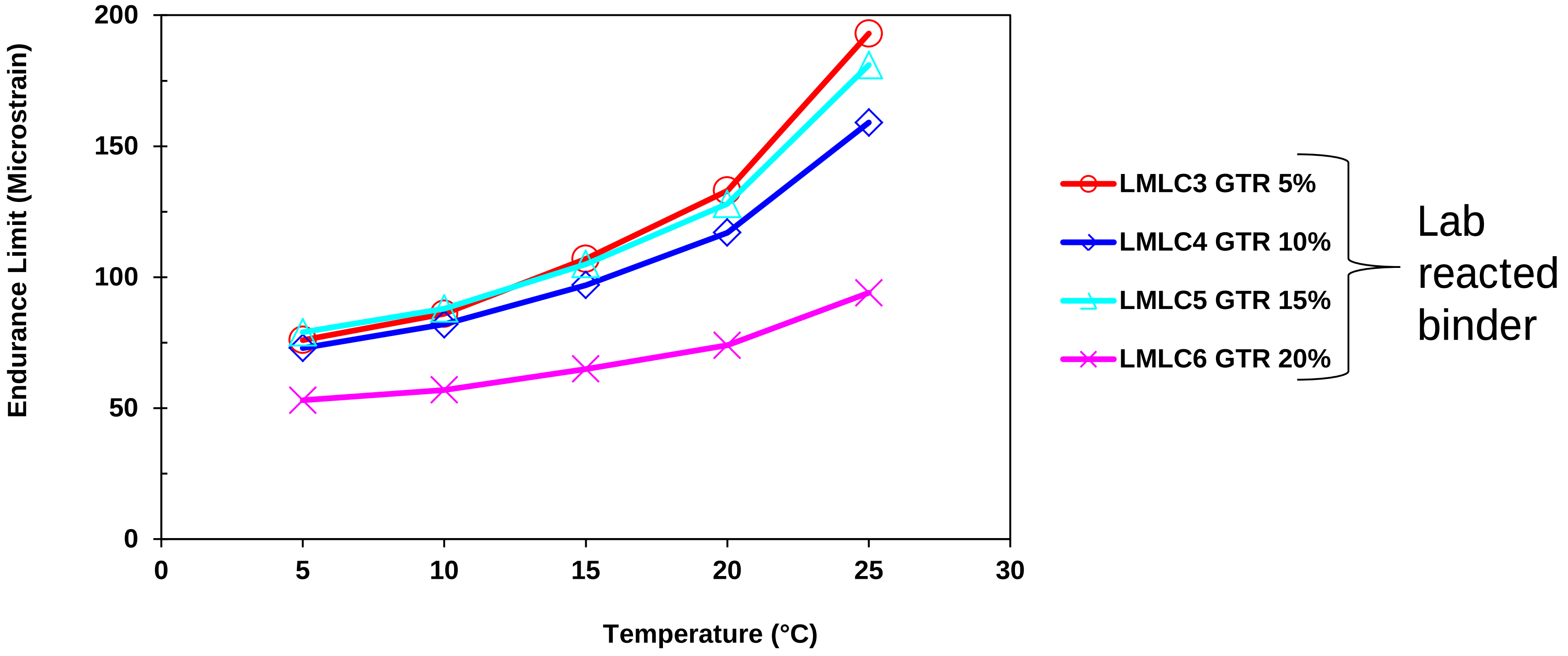
Endurance Limit (LMLC)



Fatigue performance similar for mixtures using 5-15% lab reacted GTR binders.

Why does fatigue performance decrease for the 20% GTR mixture?

Endurance Limit (LMLC)



Why does fatigue performance decrease for the 20% GTR mixture?

Project Findings

- Overall, GTR increases the overall stiffness, and improves permanent deformation and moisture damage properties of the asphalt mixes.
- Fatigue resistance of the LMLC mixes consistent up to 15% GTR content.
- Binder content is shown to affect the performance of the PMLC mixes.
- Handling GTR mixes is not trivial.

Acknowledgments

Federal Highway Administration
Office of Pavement Technology

MOBILE ASPHALT TESTING LABORATORY PROGRAM

Long Life Asphalt Pavements for the 21st Century

Superpave Performance Testing
of
WMA Mixtures Containing Ground Tire Rubber (GTR)
for the
Pennsylvania Department of Transportation (PennDOT)

March 2014

- **PennDOT**
- **Eastern Industries, Inc.**
  - Gregory Brouse (QC Manager)
  - Steven Grimm (QC Tech)
- **Mobile Asphalt Testing Trailer Program - Engineers and Technicians**

Ground Tire Rubber (GTR) Field Project NJ1499

(Preliminary Results)

Matthew Corrigan P.E., FHWA
Chuck Paugh
Habtamu Zelelew
Eyoab Teshale
Satish Belagutti

Mixture Expert Task Group Meeting
Sept 18, 2014

Project Description

- Project Location:
  - Ocean County, New Jersey

    Routes US 9 and 72 (Maintenance and Repair)
- Produced by:
  - ECOPATH Contracting LLC
  - Western Technologies Inc. (WT)
- Pavement Structure: Surface Layer
  - 0.3 - 3 MESAL
  - $N_{design} = 75$
  - NMAS = 12.5 mm

Materials

- **Binder**
  - PG 64-22 + Evotherm M1 (0.5% Wt. of Binder)
  - Supplier: Axeon Asphalt Refinery, Paulsboro, NJ
- **GTR**
  - Supplier: ECOPATH Industries, LLC
- **Aggregate Stockpile**
  - MFG Sand
  - Birdsboro#7
  - Birdsboro#8
  - Birdsboro#10
  - RAP

Materials

- **Mix (GTR=20% and RAP=10%)**
  - PMLC1-GTR20-RAP10
  - PMLC2-GTR20-RAP10

- **Mix (GTR=20% without RAP)**
  - PMLC3-GTR20

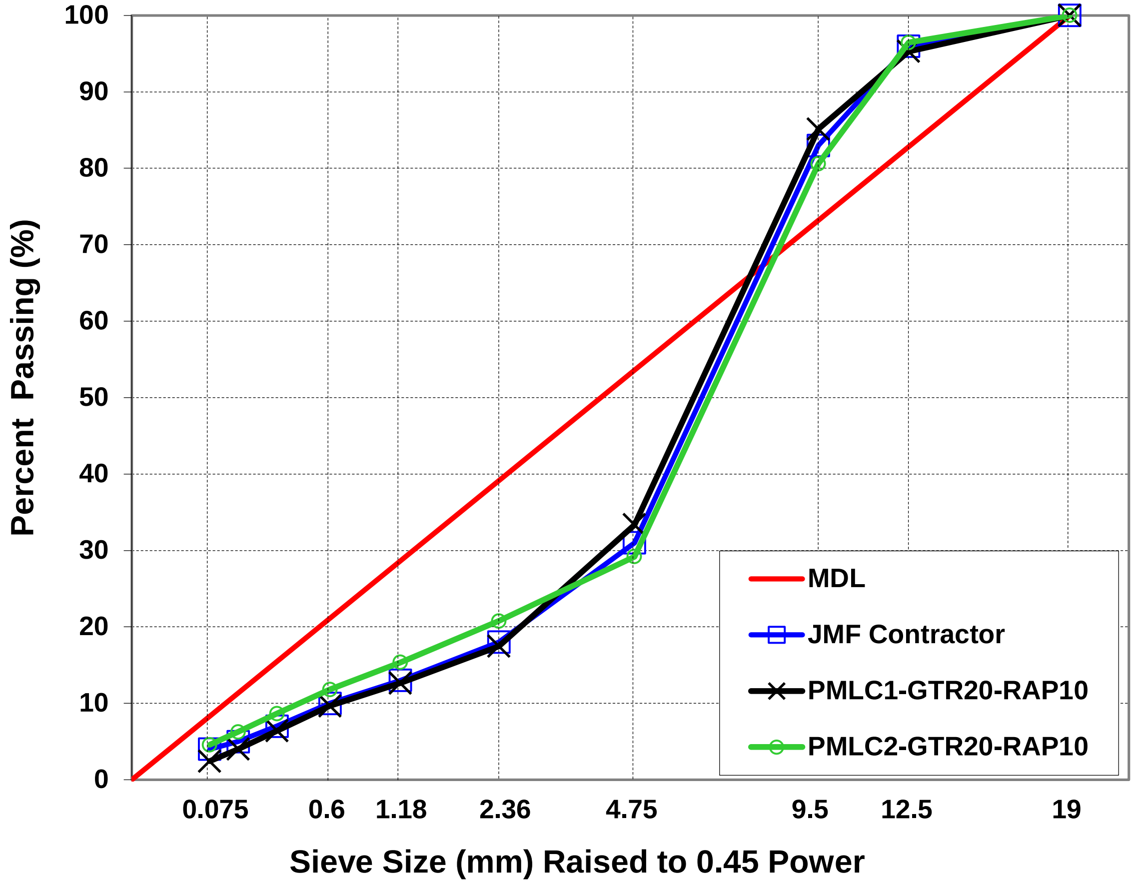
Mixture Design

- 0.3 - 3 MESAL
- N_{design} = 75
- NMAS = 12.5 mm

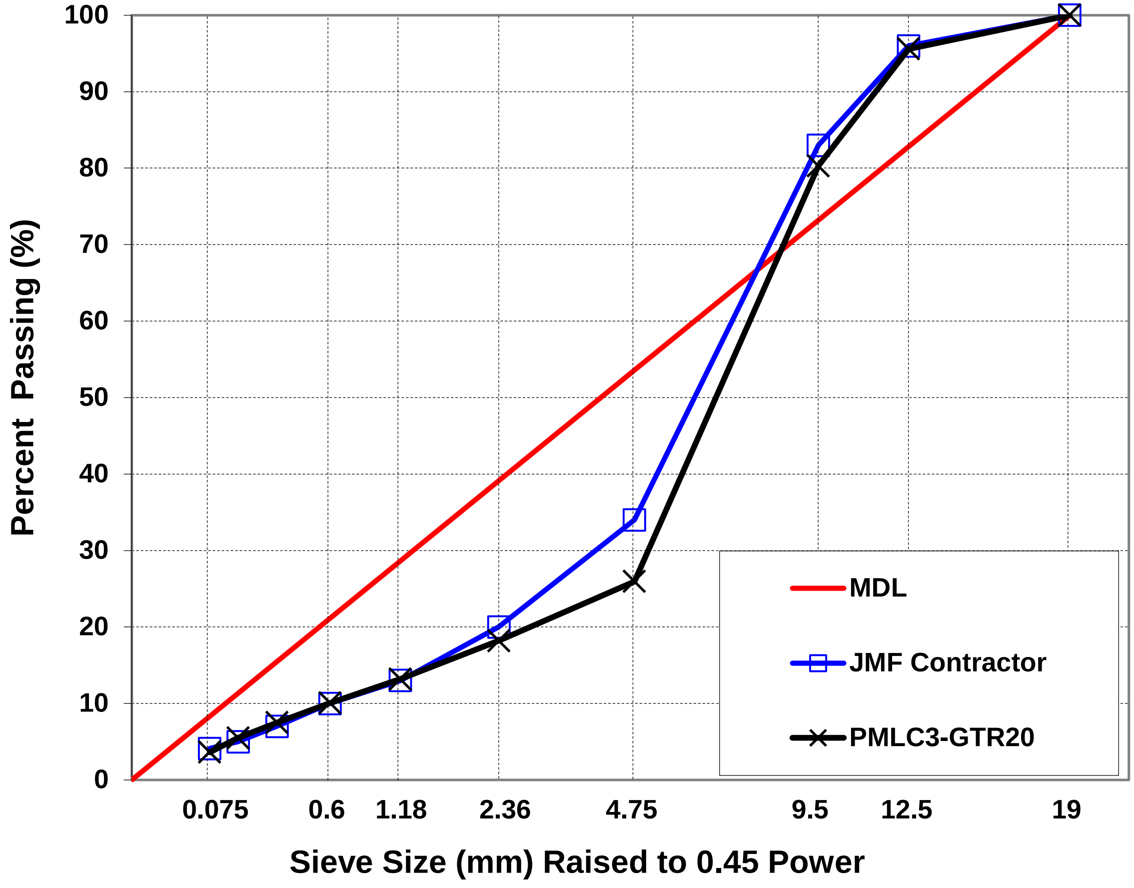
Property	Contractor JMF	PMLC1	PMLC2
Binder Grade	PG 64-22	PG 64-22	PG 64-22
Evotherm (%)	0.5	0.5	0.5
GTR (%)	20	20	20
RAP (%)	10	10	10
Sampling Temp (°F)	300-310	292.8	301.4
Compaction Temp (°F)	285	285	285
P_b (%)	7.7	7.71	7.38
V_a (%)	4.0	6.0	2.3
VMA (%)	22.2	23.0	18.8
VFA (%)	81.8	73.8	87.8
F/P_{be}	0.6	0.33	0.68
P_b: binder content; V_a: air voids; VMA: voids in mineral aggregates; VFA: voids filled with asphalt; and F/P_{be}: dust to effective binder ratio			

Property	Contractor JMF	PMLC3
Binder Grade	PG 64-22	PG 64-22
Evotherm (%)	0.5	0.5
GTR (%)	20	20
RAP (%)	0	0
Sampling Temp (°F)	300-310	290
Compaction Temp (°F)	285	285
P_b (%)	7.6	7.20
V_a (%)	4.0	3.9
VMA (%)	21.9	20.7
VFA (%)	81.8	81.0
F/P_{be}	0.6	0.53
P_b: binder content; V_a: air voids; VMA: voids in mineral aggregates; VFA: voids filled with asphalt; and F/P_{be}: dust to effective binder ratio		

Mixture Design



Mixture Design



GTR Gradation

Sieve Size (mm)	Passing (%)	NJDOT Spec
2.36 (No. 8)	100	100
1.18 (No. 16)	100	65 - 100
0.6 (No. 30)	98	20 - 100
0.3 (No. 50)	29	0 - 45
0.075 (No. 200)	1.1	0 - 5

ASTM D5644 allows up to 10% oversize material for 30 to 100 mesh designated GTR stockpiles

ASTM D5644 Standard Test Methods for Rubber Compounding Materials—Determination of Particle Size Distribution of Recycled Vulcanizate Particulate Rubber

Mix Plant

GTR Reaction Plant

AMPT Capabilities

- **Dynamic Modulus (|E*|)**

  Stiffness

- **Fatigue (S-VECD)**

  Fatigue Cracking

- **Flow Number (Fn)**

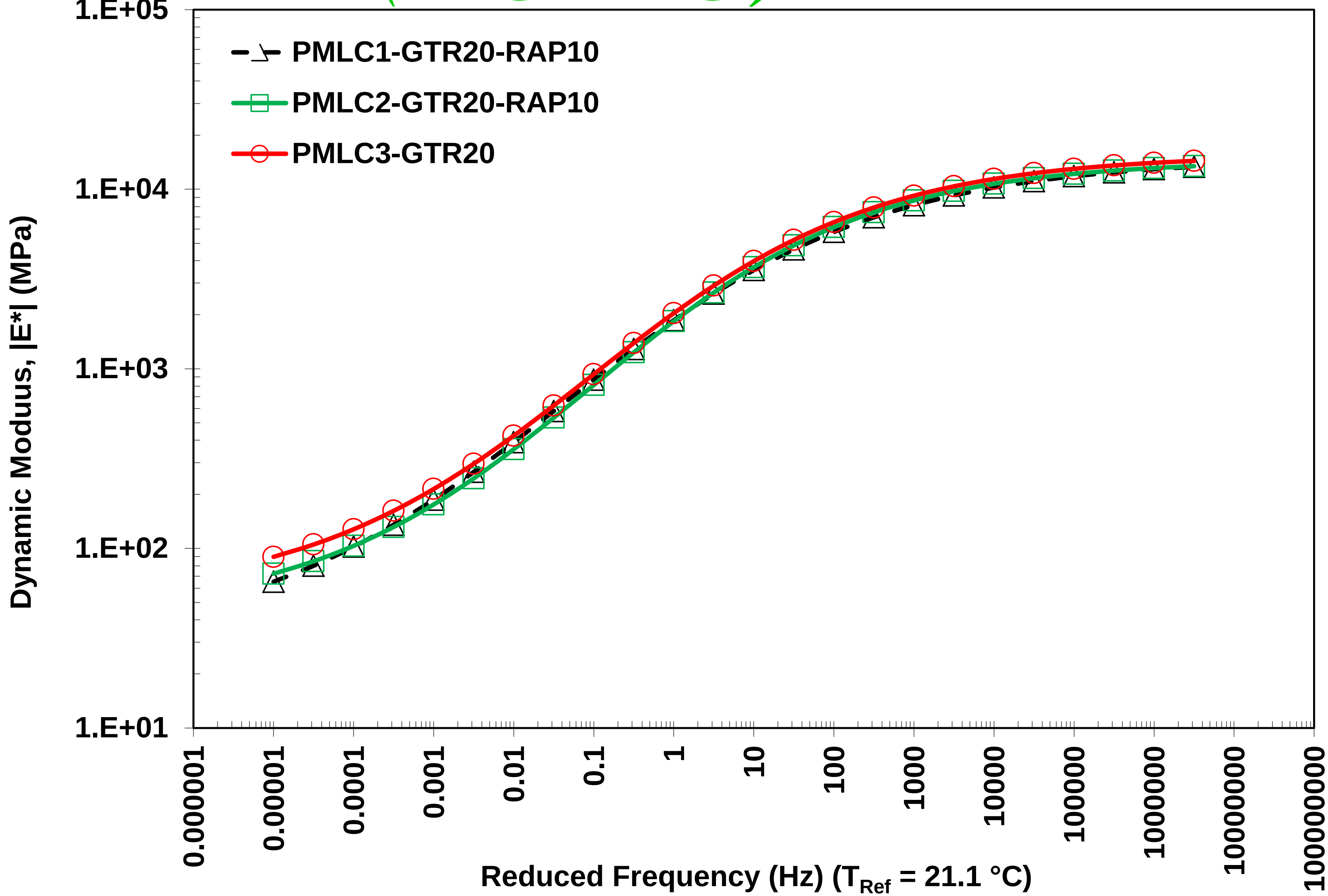
  Permanent Deformation

- **Overly Tester**

  Reflective/Fatigue Cracking

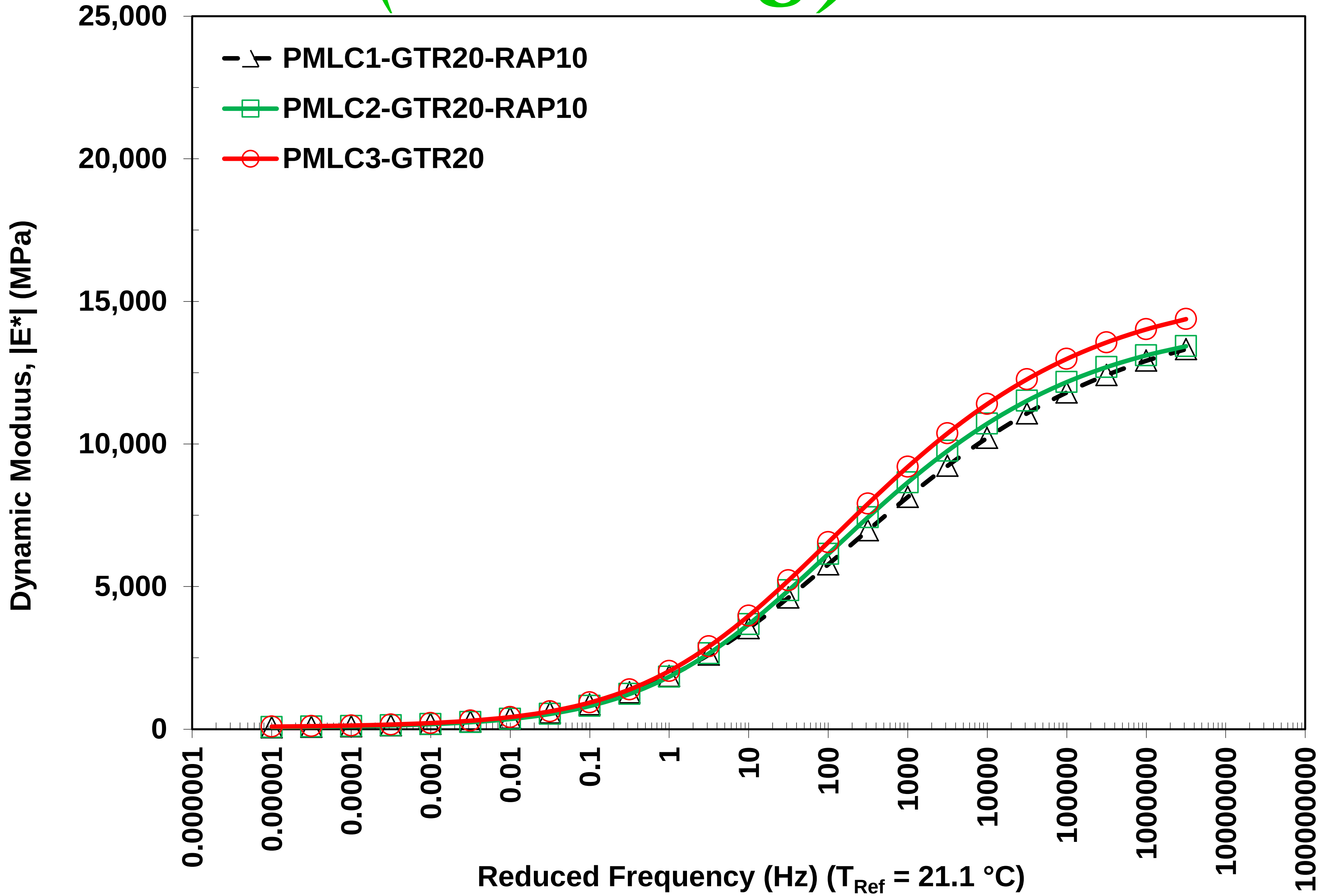
AMPT (IPC Global)

PMLC (log-log)

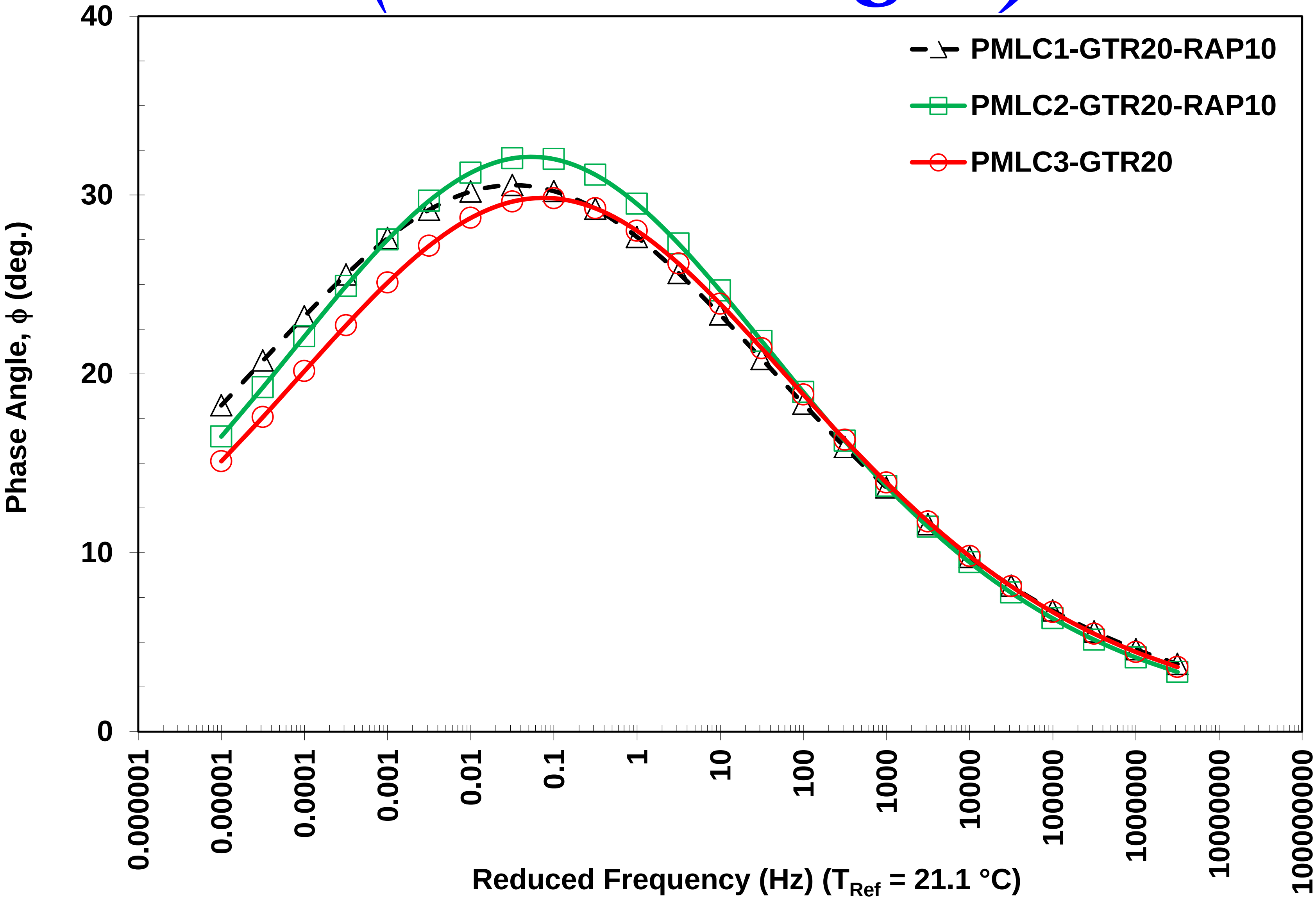


PMLC1-GTR20-RAP10
PMLC2-GTR20-RAP10
PMLC3-GTR20
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
Dynamic Moduus, |E*| (MPa)
0.0000001
0.000001
0.0001
0.001
0.01
0.1
1
10
100
1000
10000
100000
1000000
10000000
100000000
Reduced Frequency (Hz) (T_{Ref} = 21.1 °C)

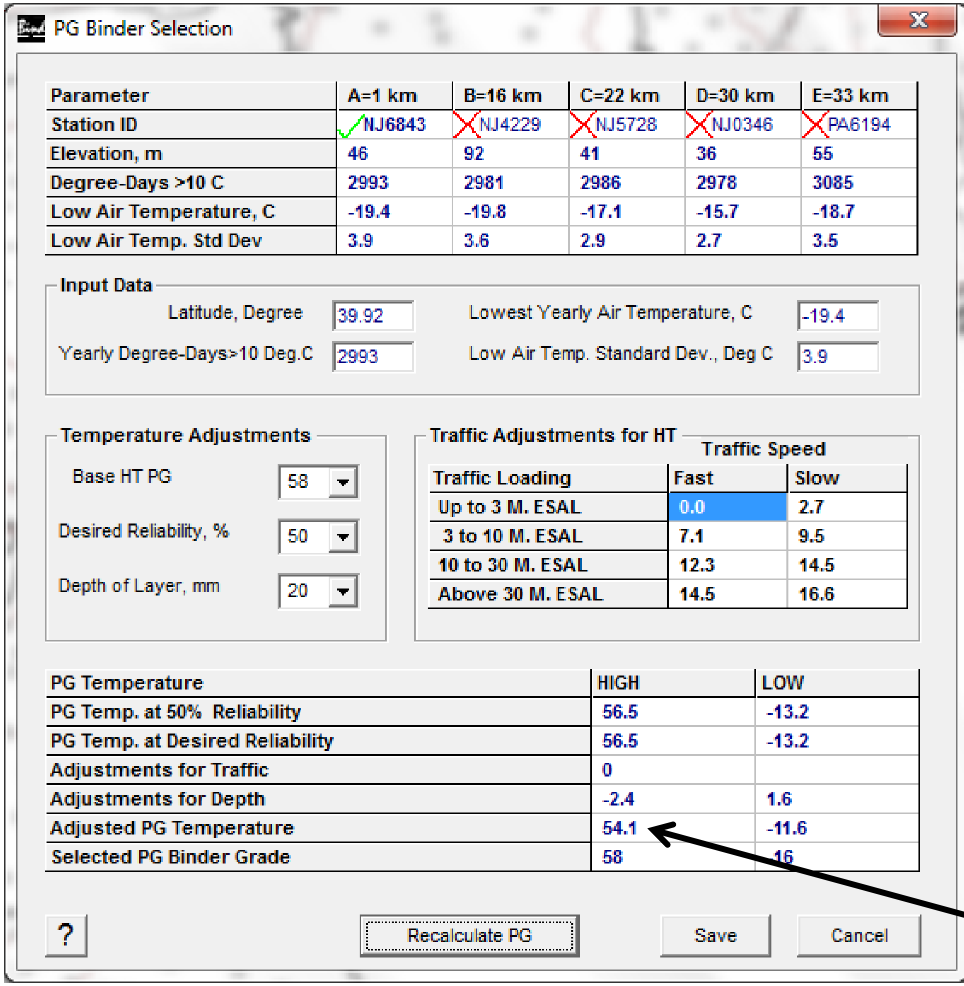
PMLC (semi-log)



PMLC (Phase Angle)



Selection of Test Temperature



PG Binder Selection

Parameter	A=1 km	B=16 km	C=22 km	D=30 km	E=33 km
Station ID	NJ6843	NJ4229	NJ5728	NJ0346	PA6194
Elevation, m	46	92	41	36	55
Degree-Days >10 C	2993	2981	2986	2978	3085
Low Air Temperature, C	-19.4	-19.8	-17.1	-15.7	-18.7
Low Air Temp. Std Dev	3.9	3.6	2.9	2.7	3.5

Input Data

Latitude, Degree 39.92 — Lowest Yearly Air Temperature, C -19.4

Yearly Degree-Days>10 Deg.C 2993 — Low Air Temp. Standard Dev., Deg C 3.9

Temperature Adjustments

Base HT PG 58

Desired Reliability, % 50

Depth of Layer, mm 20

Traffic Adjustments for HT

Traffic Loading	Traffic Speed: Fast	Slow
Up to 3 M. ESAL	0.0	2.7
3 to 10 M. ESAL	7.1	9.5
10 to 30 M. ESAL	12.3	14.5
Above 30 M. ESAL	14.5	16.6

PG Temperature	HIGH	LOW
PG Temp. at 50% Reliability	56.5	-13.2
PG Temp. at Desired Reliability	56.5	-13.2
Adjustments for Traffic	0	
Adjustments for Depth	-2.4	1.6
Adjusted PG Temperature	54.1	-11.6
Selected PG Binder Grade	58	-16

? Recalculate PG Save Cancel

LTPPBind V3.1

<u>Closest Weather Station</u>

NJ 684331

(Pemberton, NJ)

<u>Adjustments</u>

50% Reliability

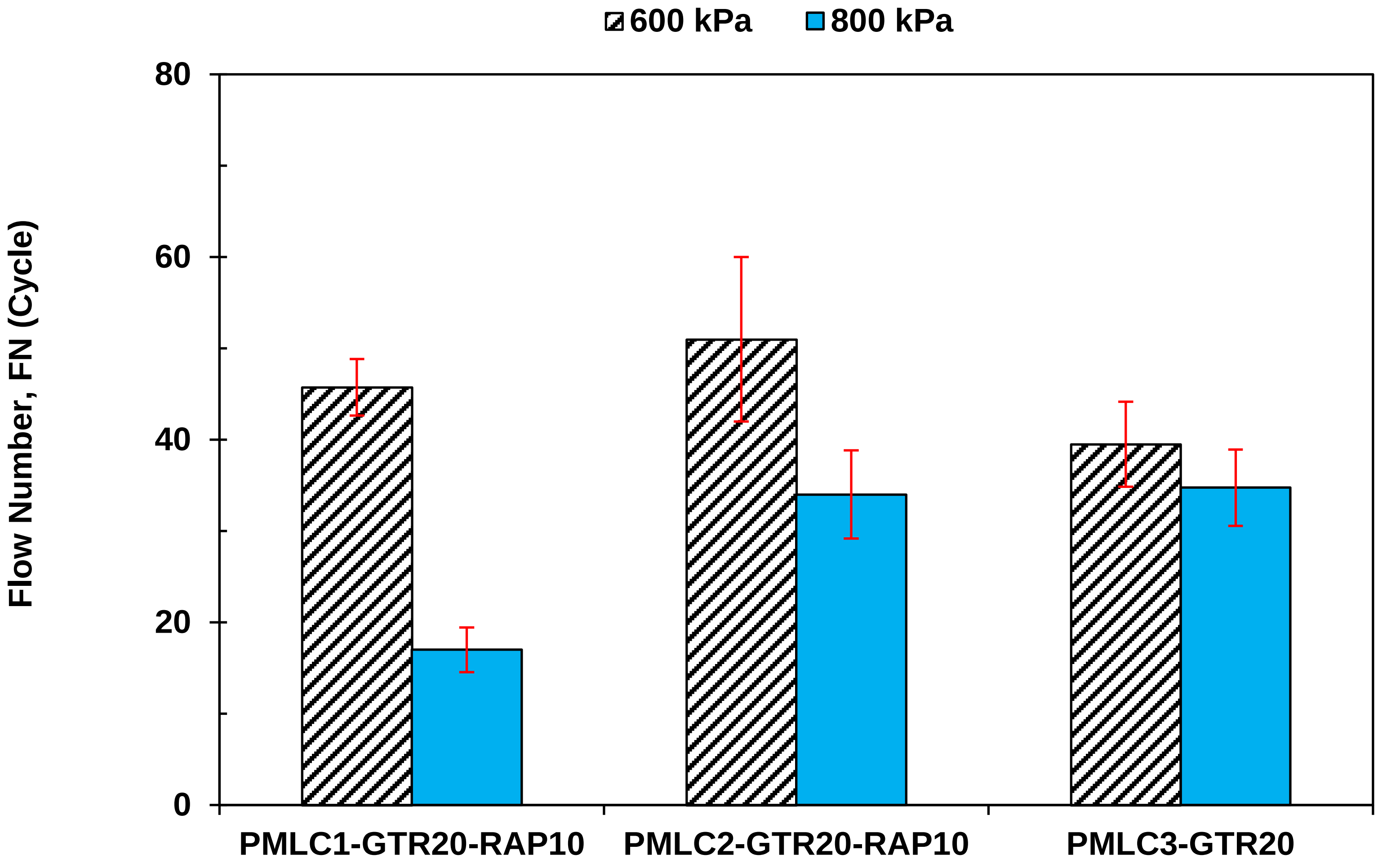
20 mm Depth

PG Temp = 54.1 °C

Flow Number Test

- 4 Replicates
- Unconfined FN Test
  - 600 and 800 kPa
- Confined FN Test
  - 600 and 800 kPa
- Stopping Criterion
  - 10,000 Cycles, or
  - 50,000 Microstrain

Unconfined FN Test

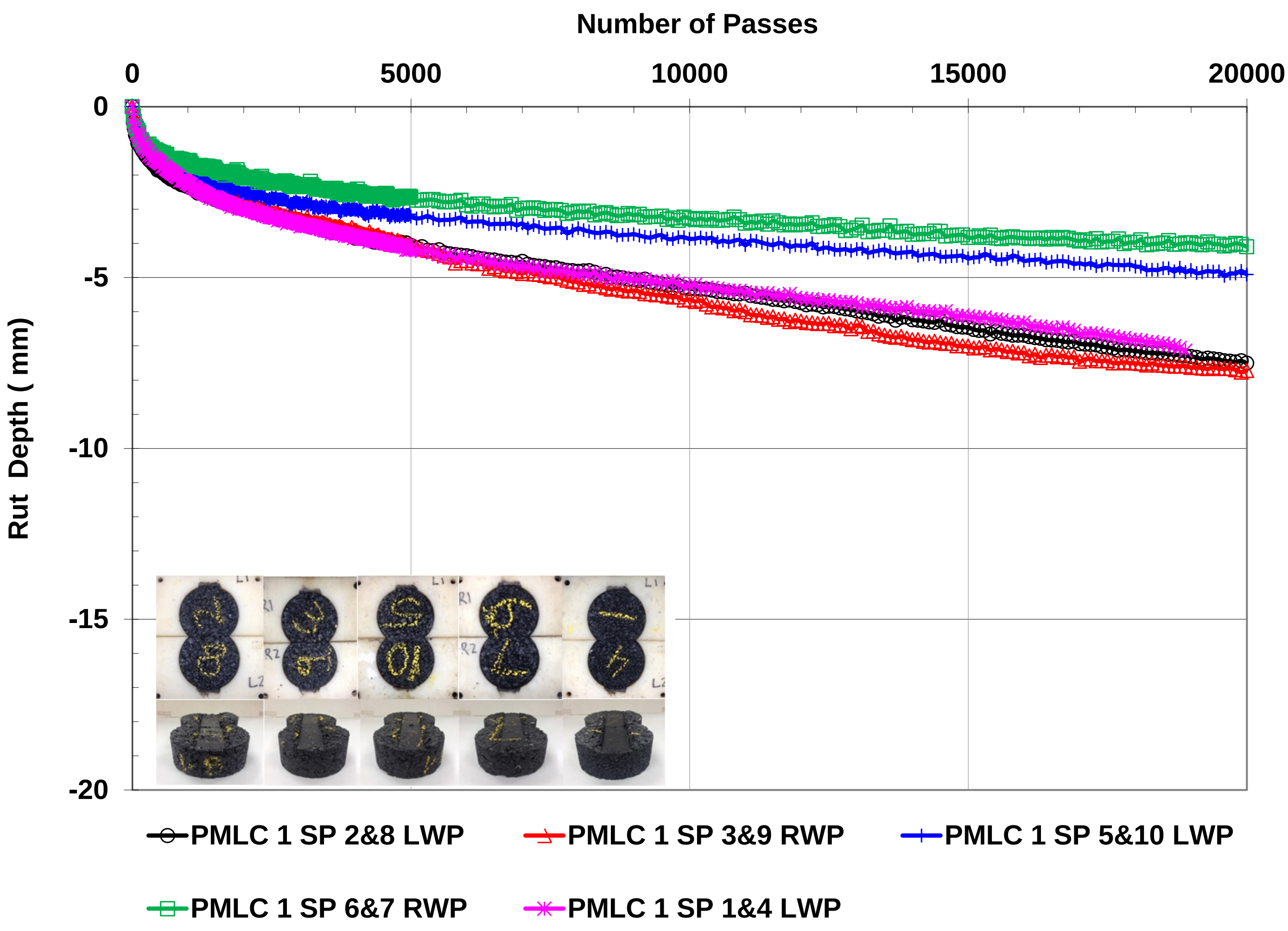


No TP79 min. Flow Number criteria for HMA designed for <3 MESAL

Hamburg Test

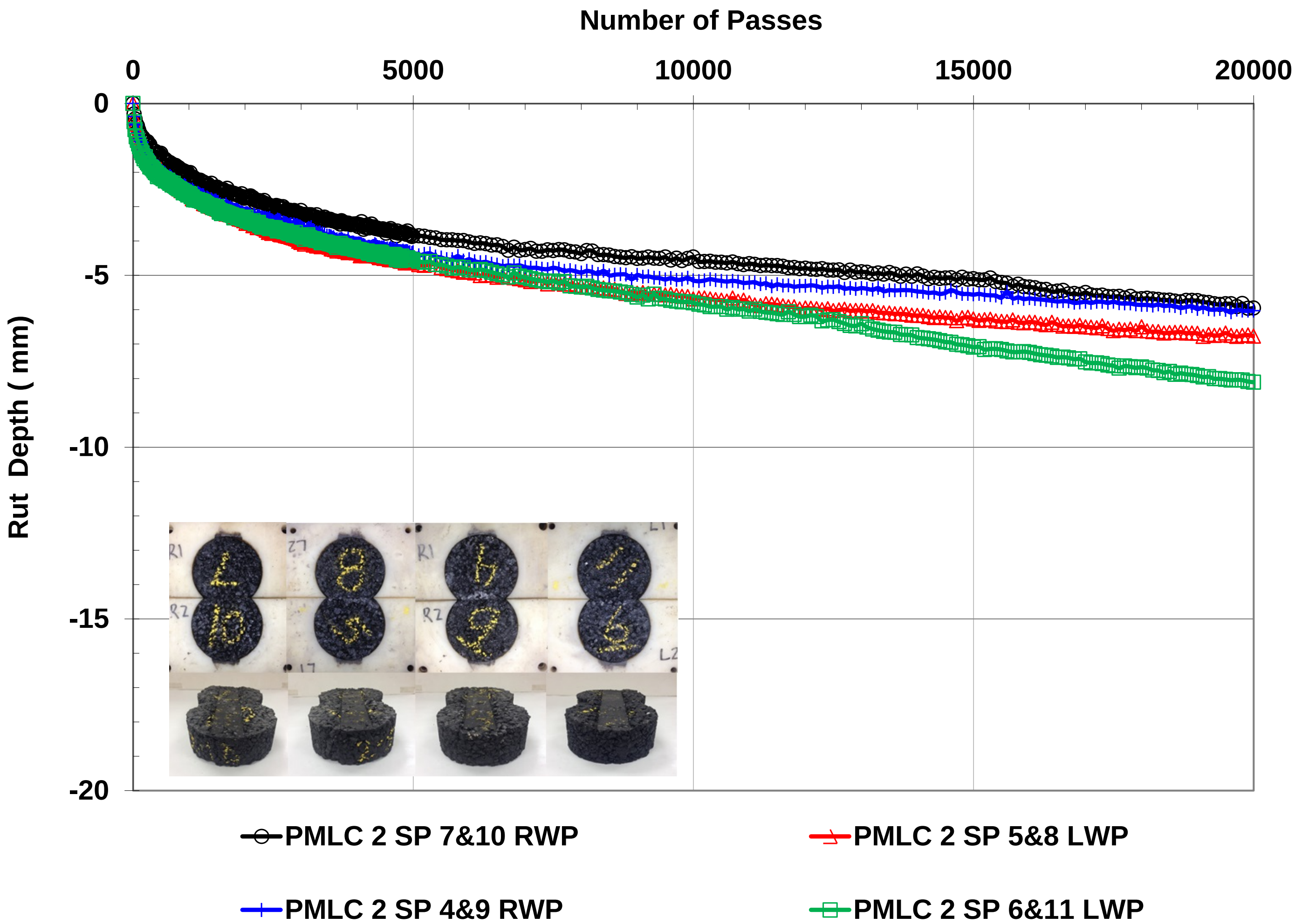
- NJDOT does not currently specify Hamburg test requirements
- Replicates
  - LMLC1-GTR20-RAP10 (10 Replicates)
  - LMLC2-GTR20-RAP10 (8 Replicates)
  - LMLC3-GTR20 (8 Replicates)

Hamburg Test



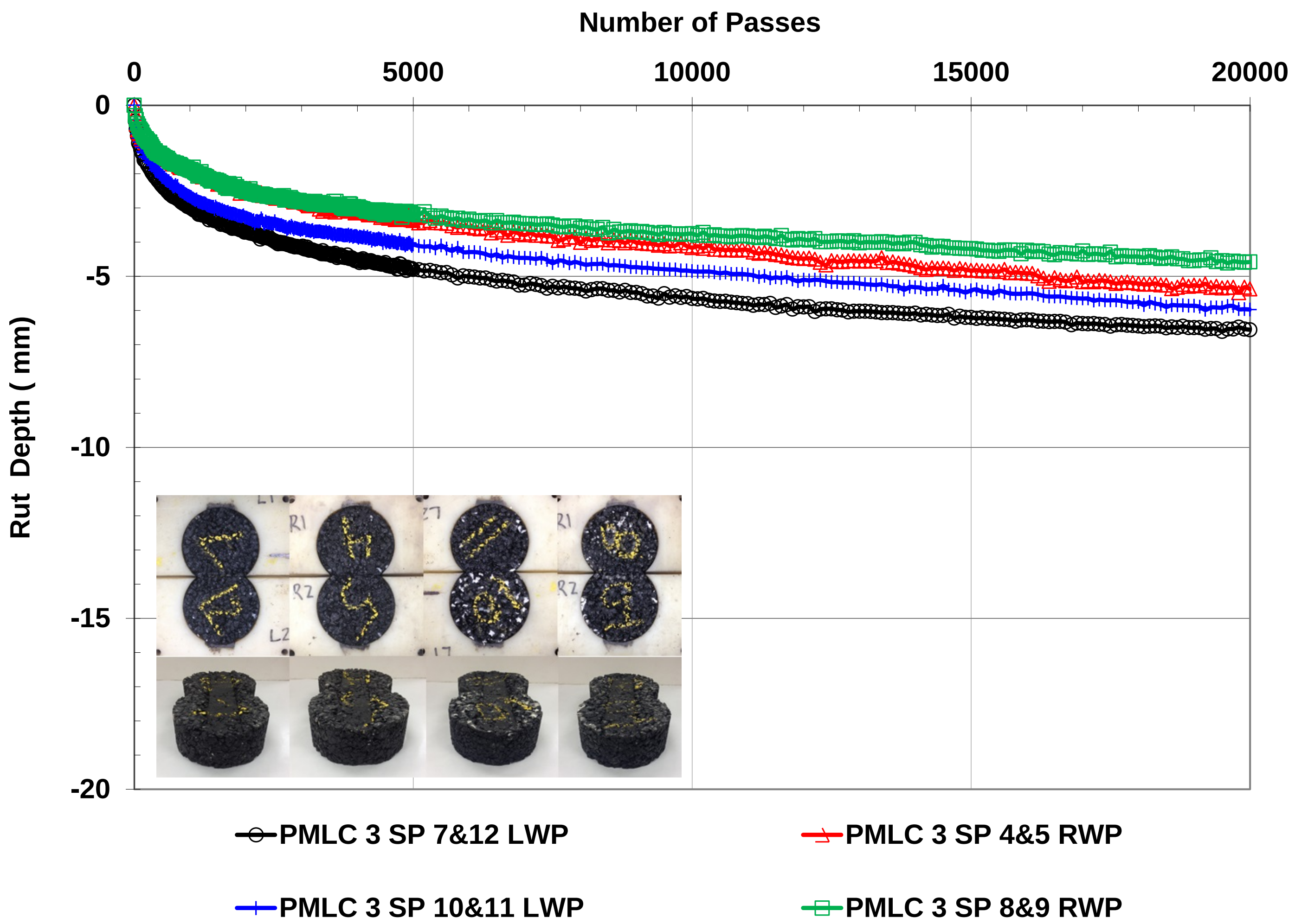
LMLC1

Hamburg Test



LMLC2

Hamburg Test



LMLC3

Fatigue (S-VECD)

- AASHTO TP 107
- Simplified Viscoelastic Continuum Damage (S-VECD) Model
- Damage Characteristic Curve (C versus S)

$$\boxed{C = e^{aS^b}}$$

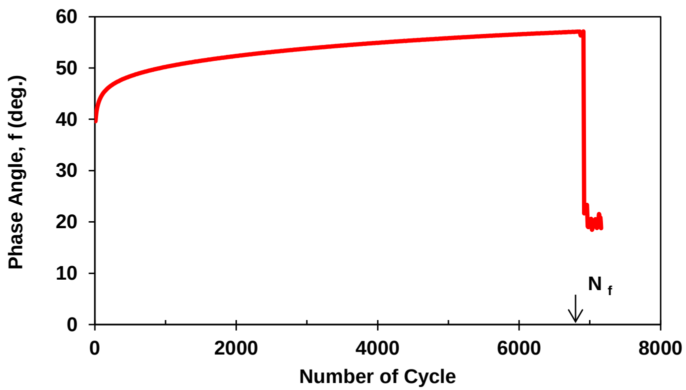
C = Material Integrity or Pseudo Stiffness

S = Amount of Damage

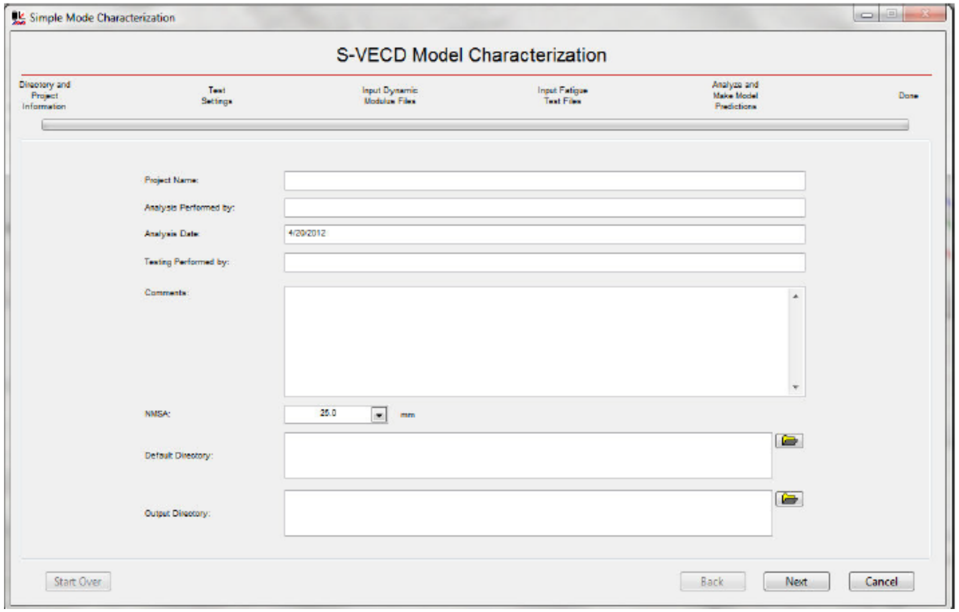
- S-VECD Test Includes:
  - o |E*| Linear Viscoelastic (LVE) Test
  - o Pull-Push (Finger Print) Test
  - o Pull-Pull Fatigue Test

Fatigue (S-VECD)

- Stopping Criterion
  - o Sudden Drop in Phase Angle



- ALPHA-F Software

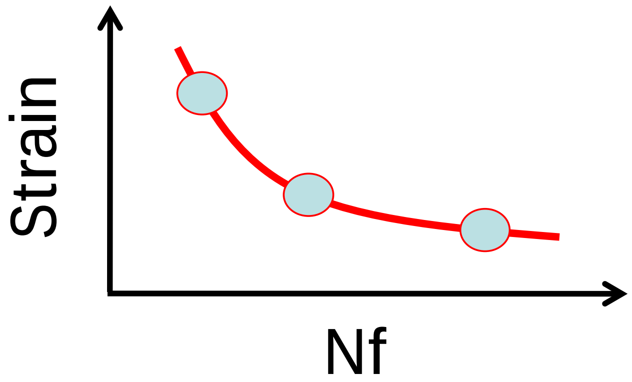


Fatigue (S-VECD)

- At least 3 Replicates
- Frequency = 10 Hz
- Temperature = 21 °C

$$\text{Temp. (°C)} = \min\left(21\text{°C}, \frac{PG\ (High+Low)}{2} - 3\right)$$

- Three on-specimen Strain Levels
  - o 450, 550, and 600 Microstrain



Fatigue (S-VECD)

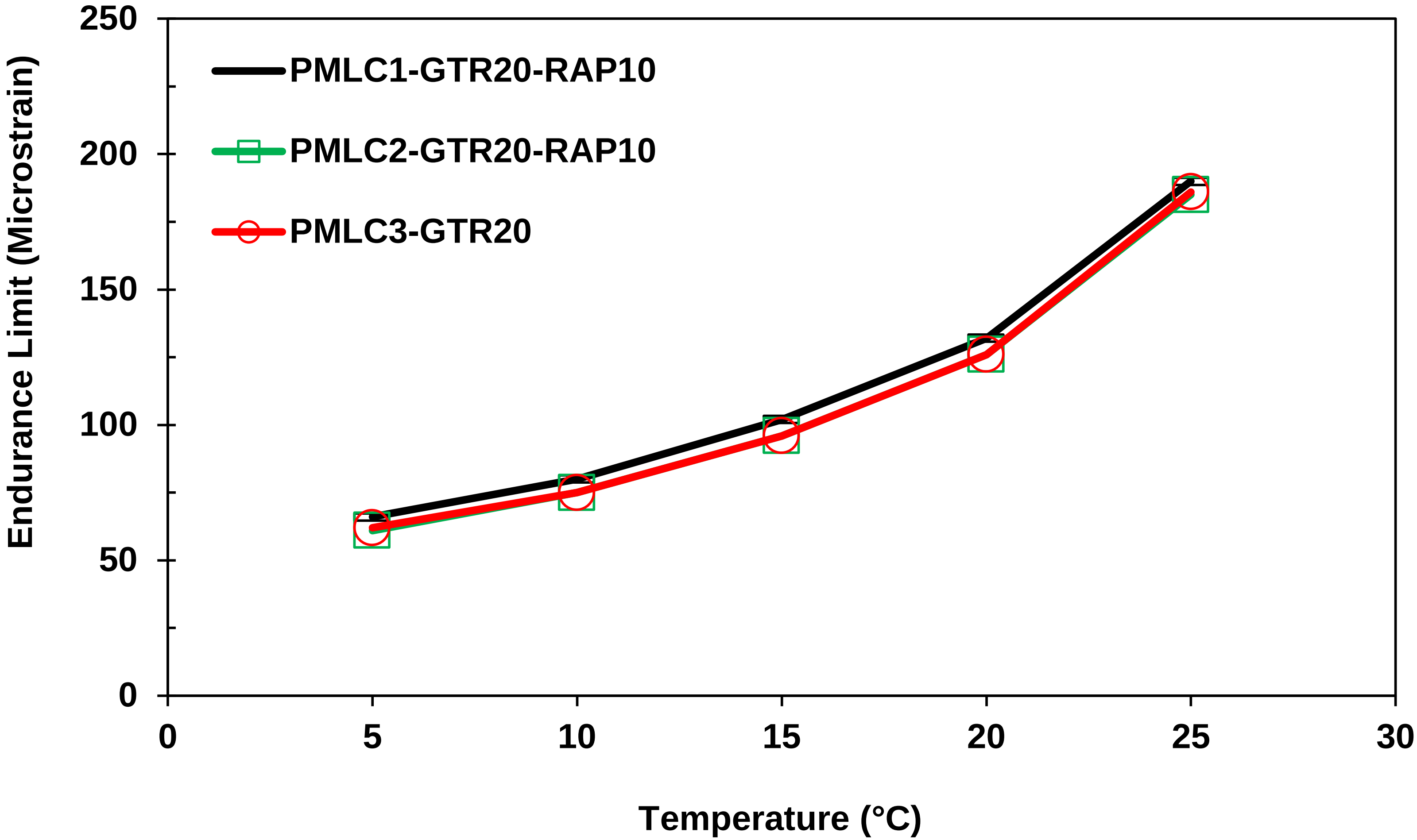
- **LMLC1-GTR20-RAP10**
  - o Failure Mechanism → Mid-Failure
  - o On-specimen Strains (Microstrian)

450

550

600

Endurance Limit



Project Findings

- The Asphalt Mixes Included in the Study Exhibited Similar Performance Results
  - o Stiffness (|E*|)
  - o Fatigue Cracking Resistance (S-VECD)
  - o Permanent Deformation (FN)
  - o Rutting and Stripping (Hamburg)
- The Inclusion of RAP (10%) did not Significantly Impact Performance Test Results.

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September 2014

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1200 New Jersey Ave., SE
Washington, DC 20590

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- **ECOPATH Contracting LLC**
- **Western Technologies Inc**
- **Keith Sterling (A. E. Stone Inc)**

- **Mobile Asphalt Testing Trailer Program - Engineers and Technicians**