Outline

- Experimental Design – Refresher
- ALF Loading Status
- Laboratory Test Results
  - S-VECD – ***Loose Mix/Gyratory Unaged and Aged***
  - Texas Overlay Tester - ***Cores***
- Comparison of Lab Cracking Tests vs. Field
- Future Steps

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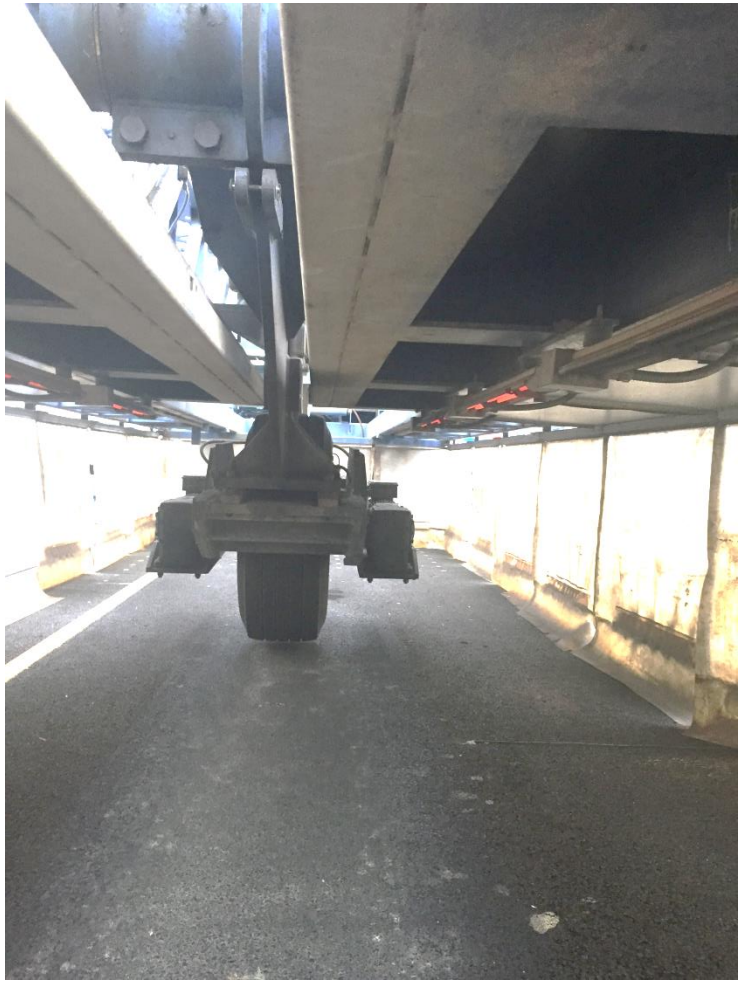
ALF Experimental Design

Recycle Content	HMA / WMA Production Temperature	300°F - 320°F		240°F - 270°F	
	Warm Mix Technology	-		Foam	Chem.
0%		✔ PG64-22		-	-
20% ABR RAP ≈ 23% by weight		✔ PG64-22		✔ PG64-22	✔ PG64-22
20% ABR RAS ≈ 6% Shingle by weight		✔ PG64-22	✔ PG58-28	-	-
40% ABR RAP ≈ 44% by weight		✔ PG64-22	✔ PG58-28	✔ PG58-28	✔ PG58-28

ALF Loading Conditions

- Controlled 20°C @ 20mm
- Loading only one direction
- Lateral Wander
- 425 Super Single Tire
- 100 psi inflation
- 14,200 lb load
- ~4-inch thick asphalt
- ~22-inch thick agg base



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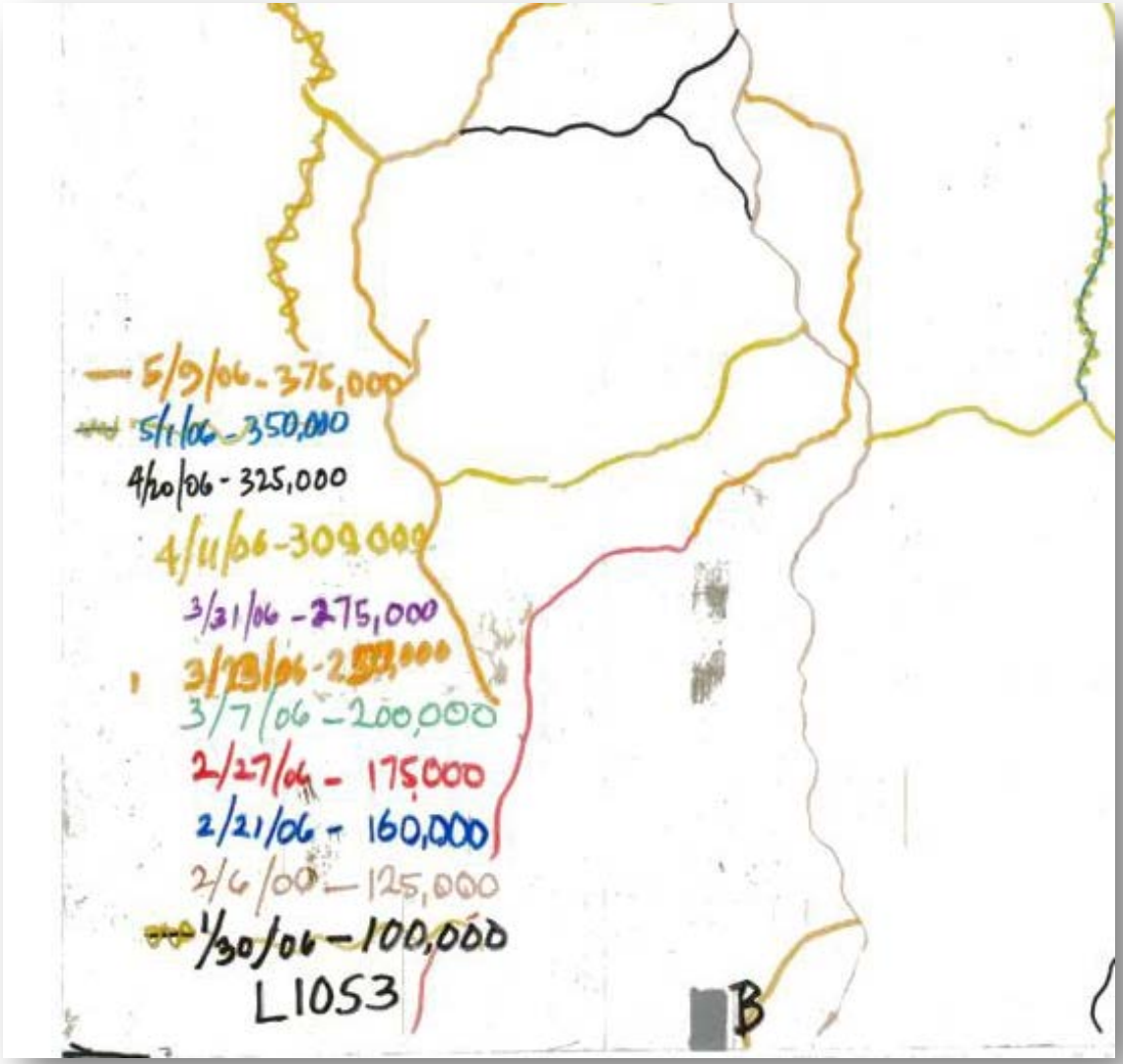
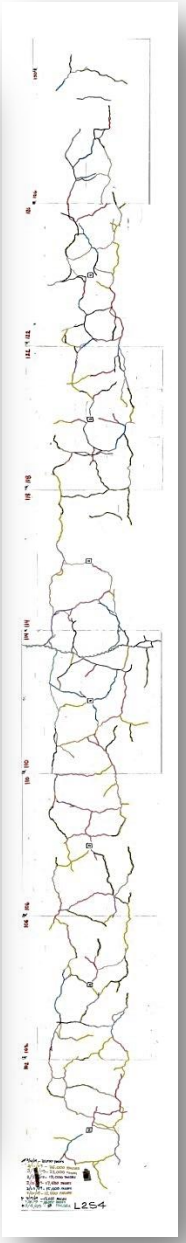
60% Complete

Lane 9	**WMA-Foam 20% ABR**	**Complete**
Lane 11	**WMA-Chem 40% ABR 58-28**	**Complete**
Lane 5	**HMA 40% ABR**	**Complete**
Lane 1	**HMA 0% Control**	**Complete**
Lane 3	**HMA 20% ABR RAS**	**Complete**
Lane 4	**WMA-Chem 20% ABR**	**Complete**
Lane 7	**HMA 20% ABR RAS 58-28**	**Loading Now…**
Lane 2	**WMA-Foam 40% ABR 58-28**	**Loading Now…**
Lane 8	**HMA 40% ABR 58-28**	**Next**
Lane 6	**HMA 20% ABR**	**Next**

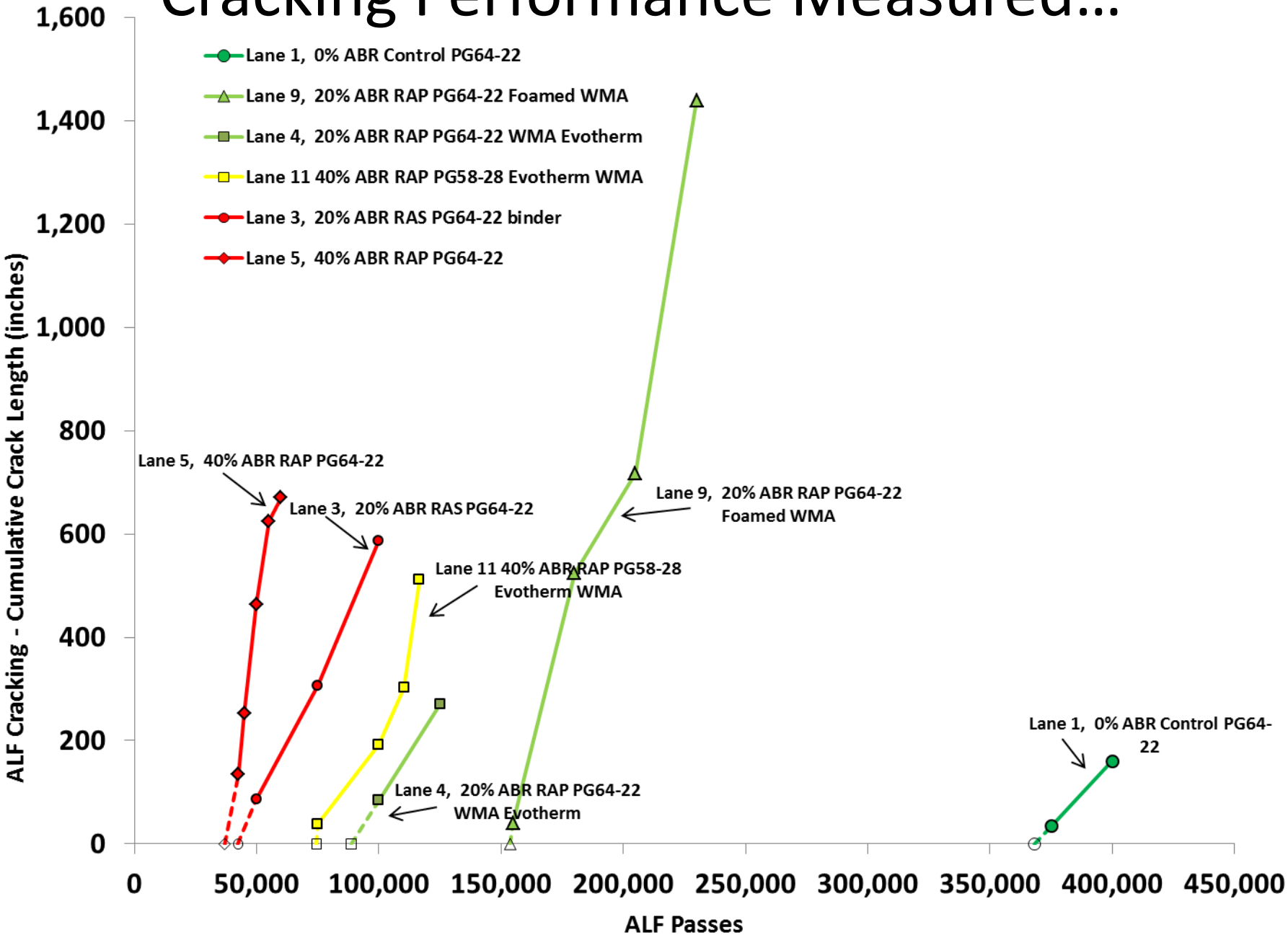
Cracking Performance Measured…





Crack lengths are individually traced with “map-measure”

Cracking Performance Measured…



Cracking Performance Measured…

Lane & Mix	ALF Passes to First Crack
Lane 9 WMA-Foam 20% ABR	142,000
Lane 11 WMA-Chem 40% ABR 58-28	60,000
Lane 5 HMA 40% ABR	37,000
Lane 1 HMA 0% Control	368,000
Lane 3 HMA 20% ABR RAS	42,000
Lane 4 WMA-Chem 20% ABR	90,000

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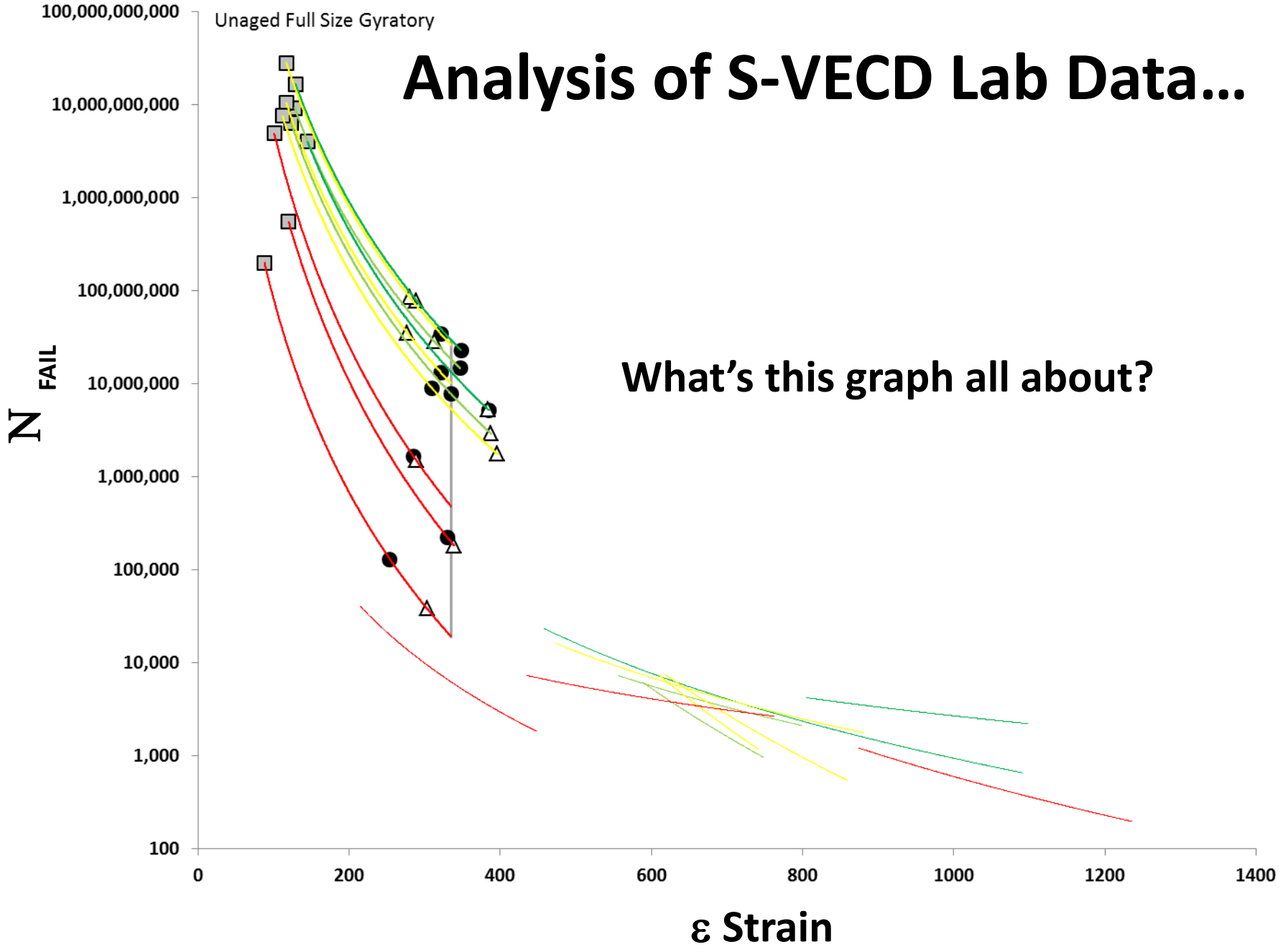
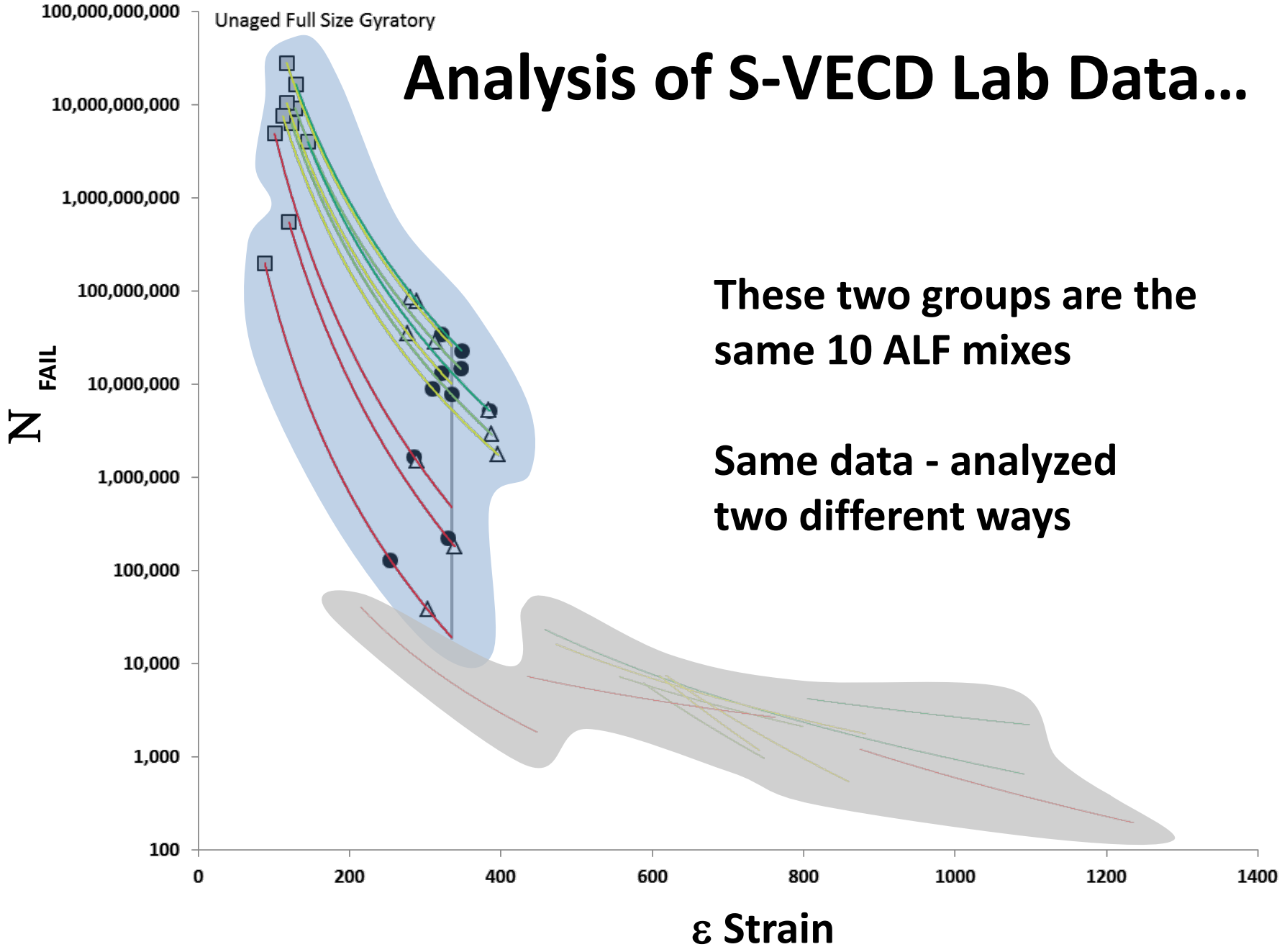
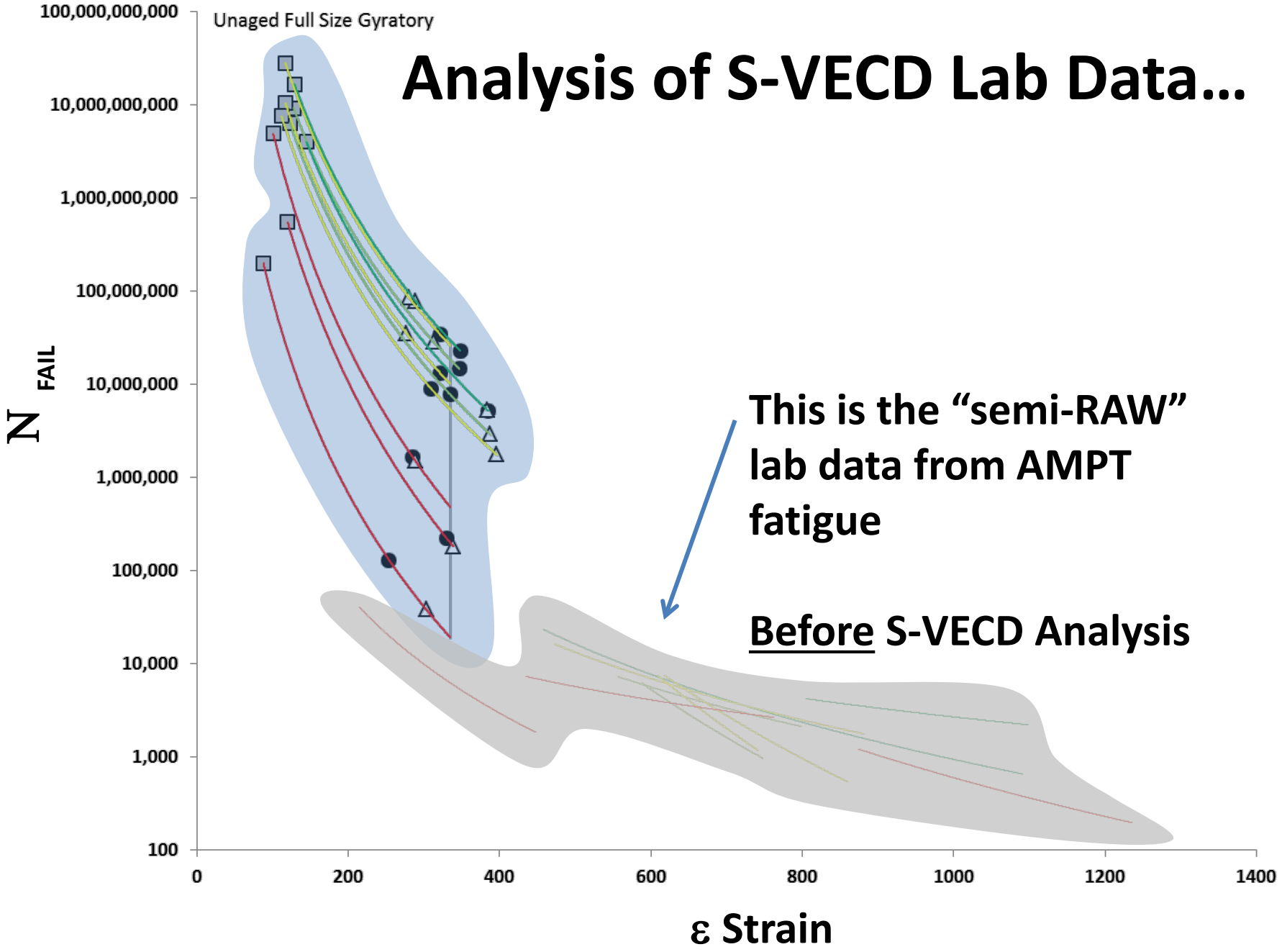

Unaged Full Size Gyratory
Analysis of S-VECD Lab Data…
What's this graph all about?
N FAIL
100,000,000,000
10,000,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
0
200
400
600
800
1000
1200
1400
ε Strain


Unaged Full Size Gyratory
Analysis of S-VECD Lab Data…
These two groups are the same 10 ALF mixes
Same data - analyzed two different ways
100,000,000,000
10,000,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
N FAIL
0
200
400
600
800
1000
1200
1400
ε Strain

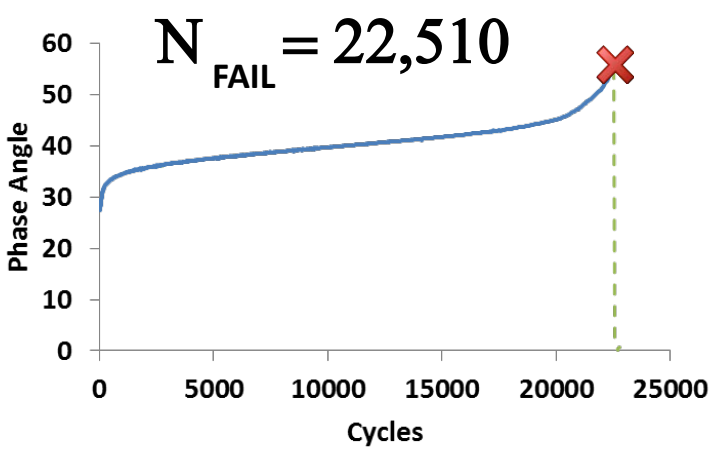

Unaged Full Size Gyratory
Analysis of S-VECD Lab Data…
This is the "semi-RAW" lab data from AMPT fatigue
Before S-VECD Analysis
N FAIL
100,000,000,000
10,000,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
0
200
400
600
800
1000
1200
1400
ε Strain

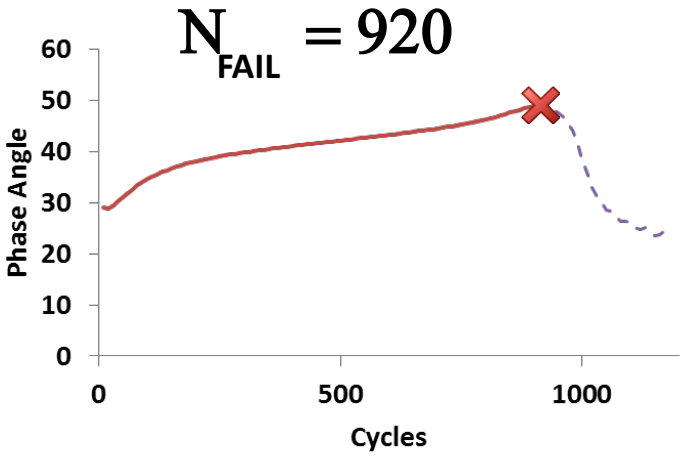
Case Example – Data from AMPT

Sample "A"

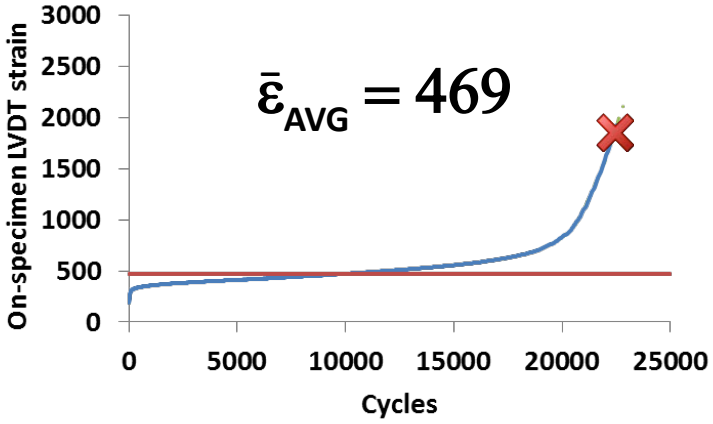
Sample "B"

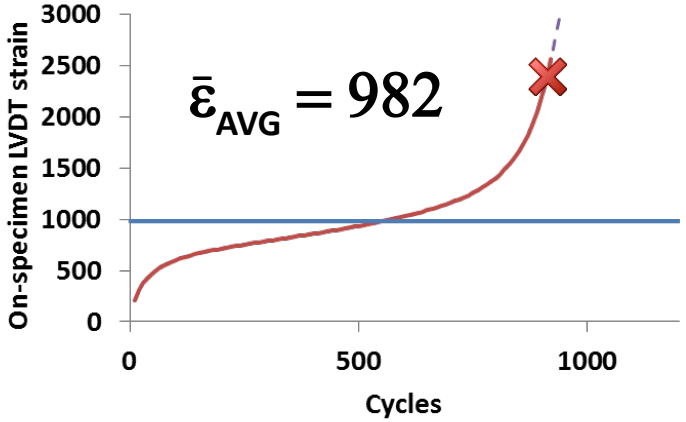
δ Phase Angle

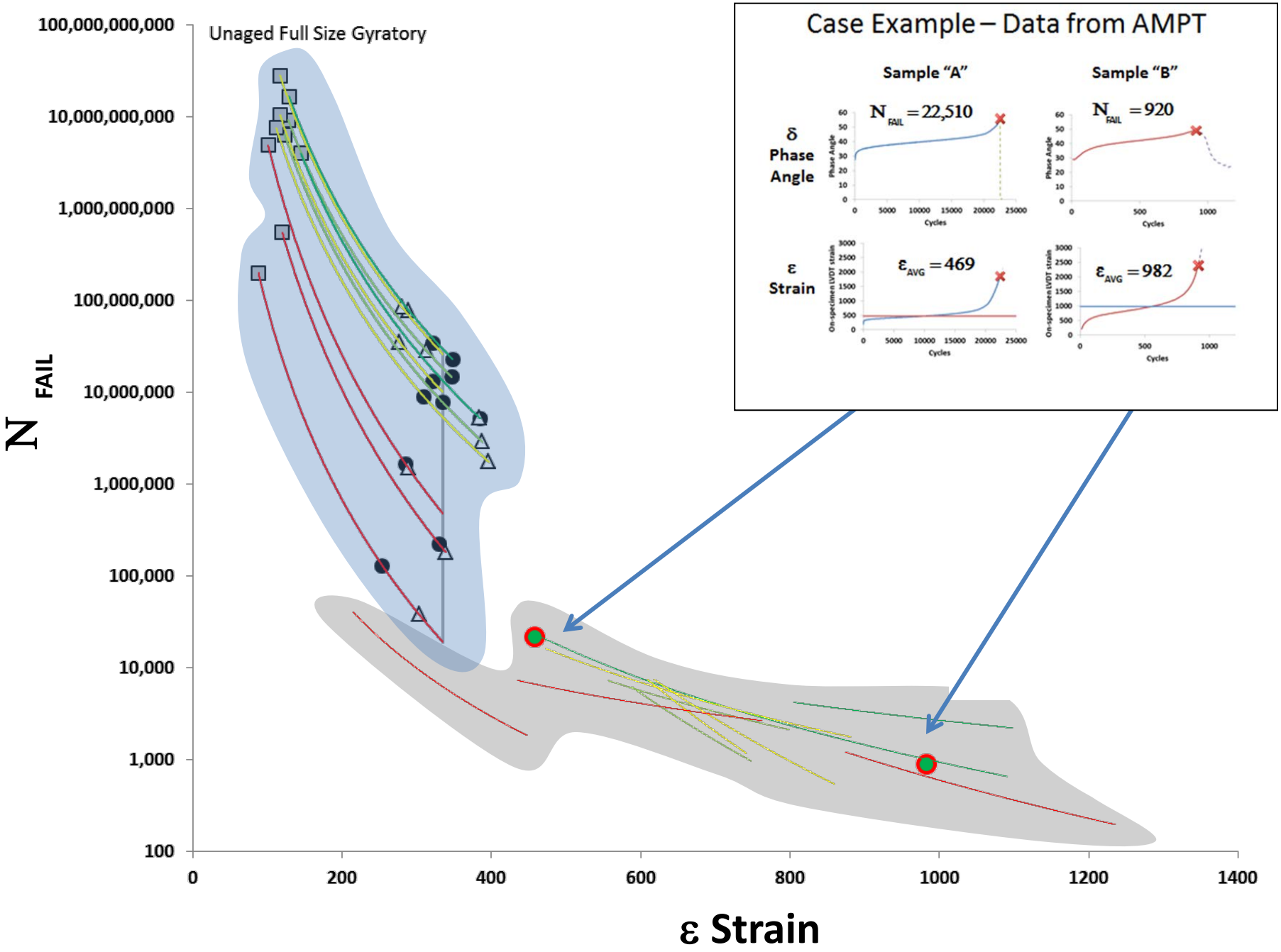


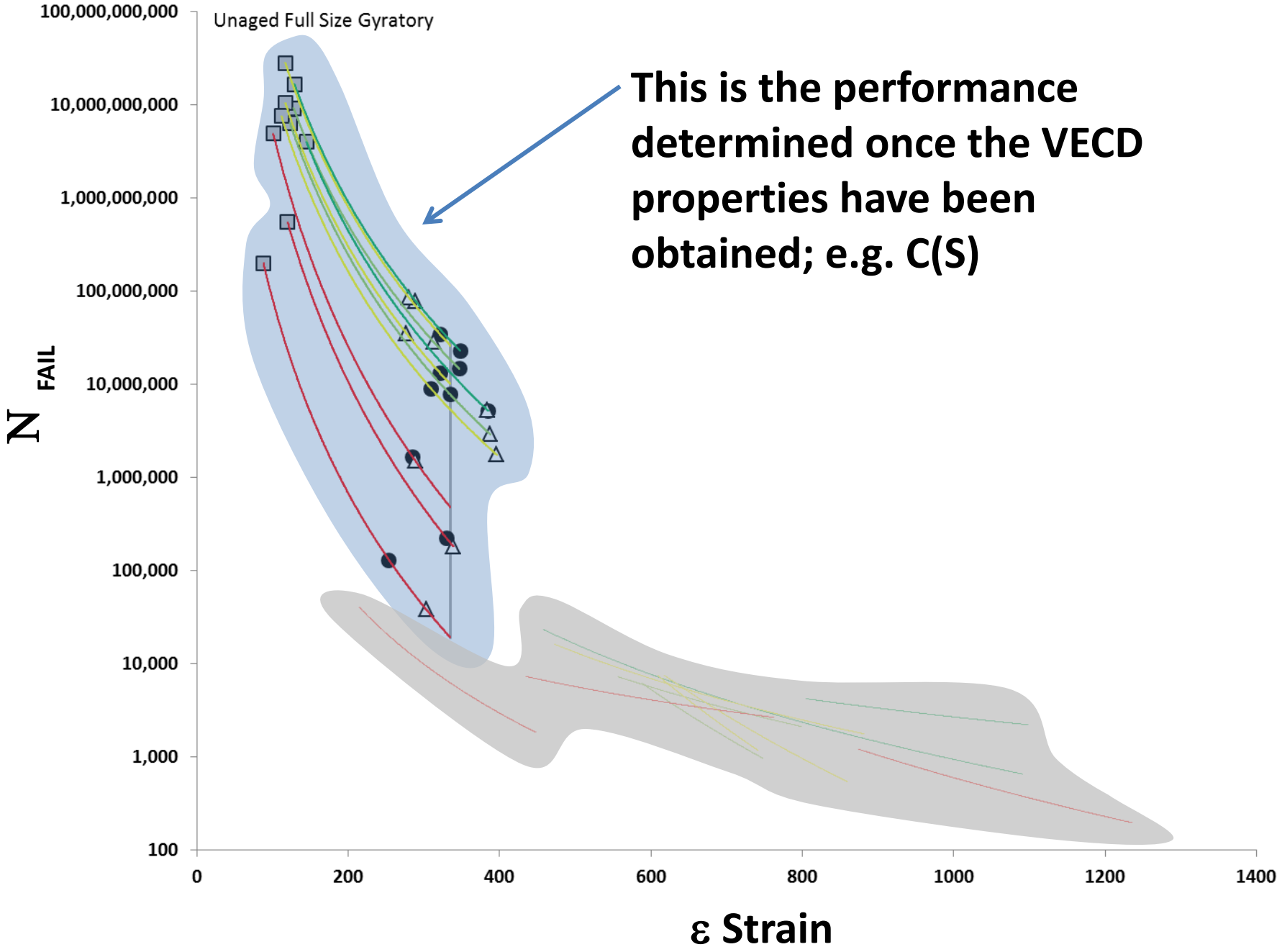


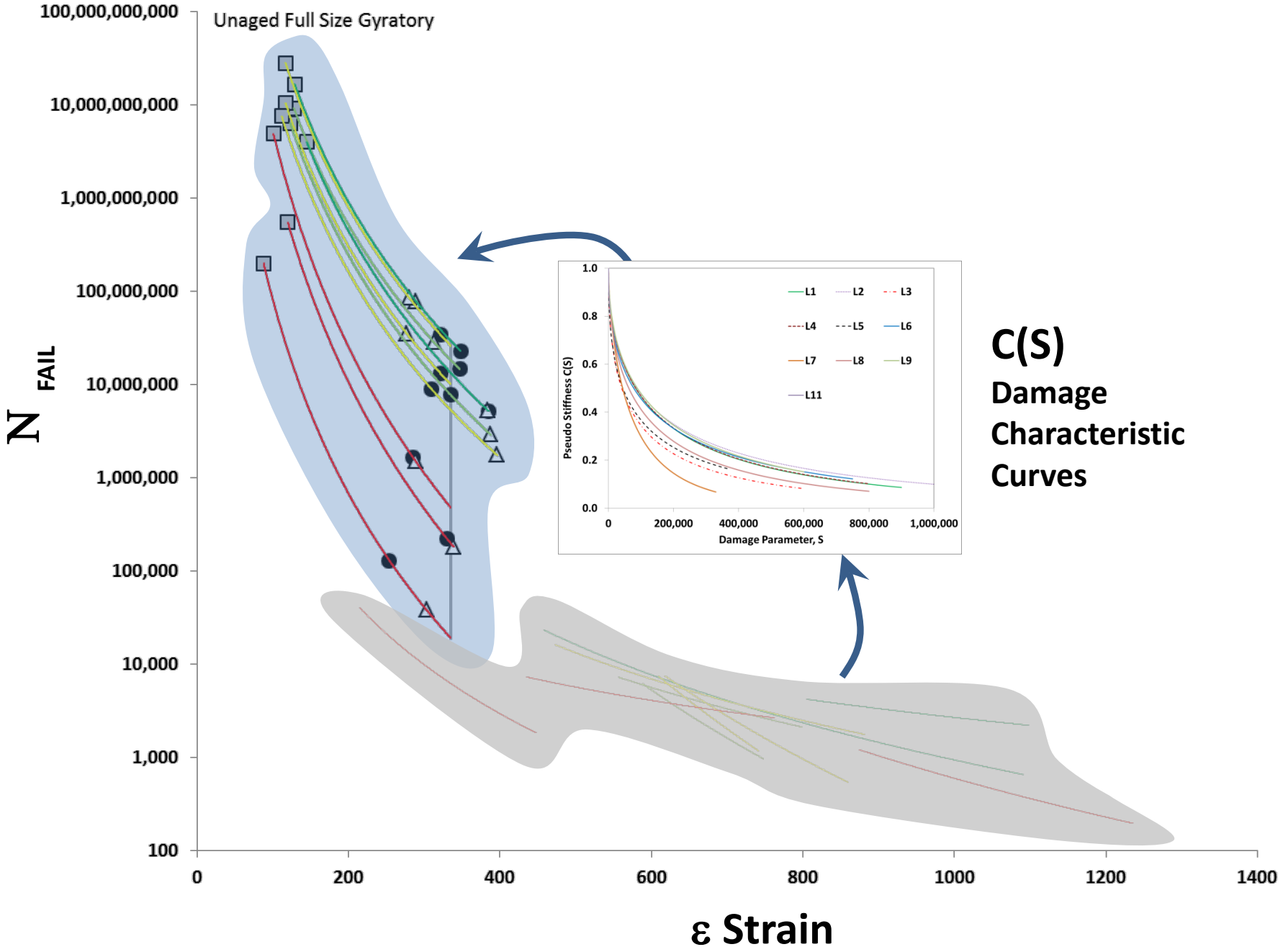
ε Strain

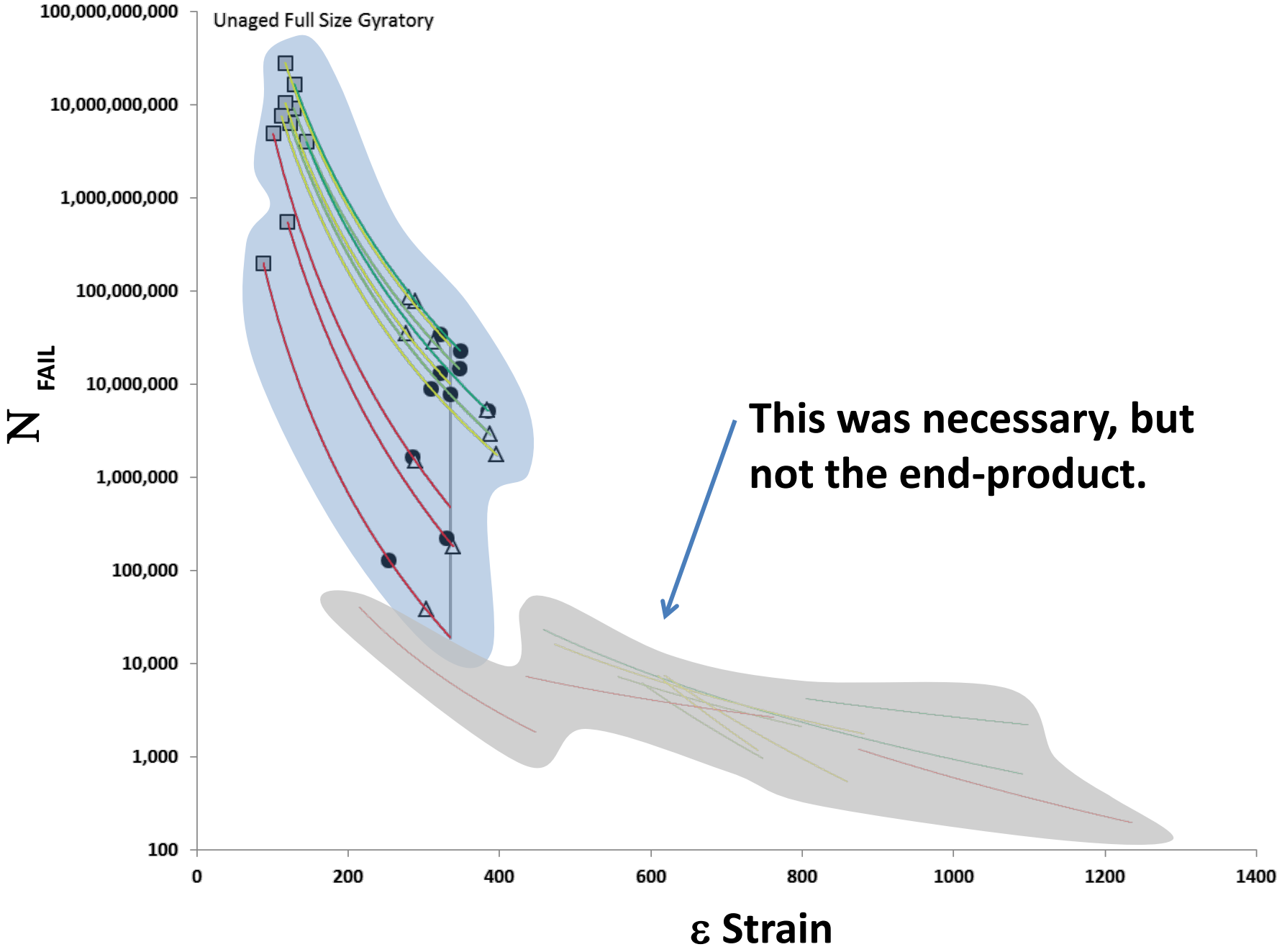


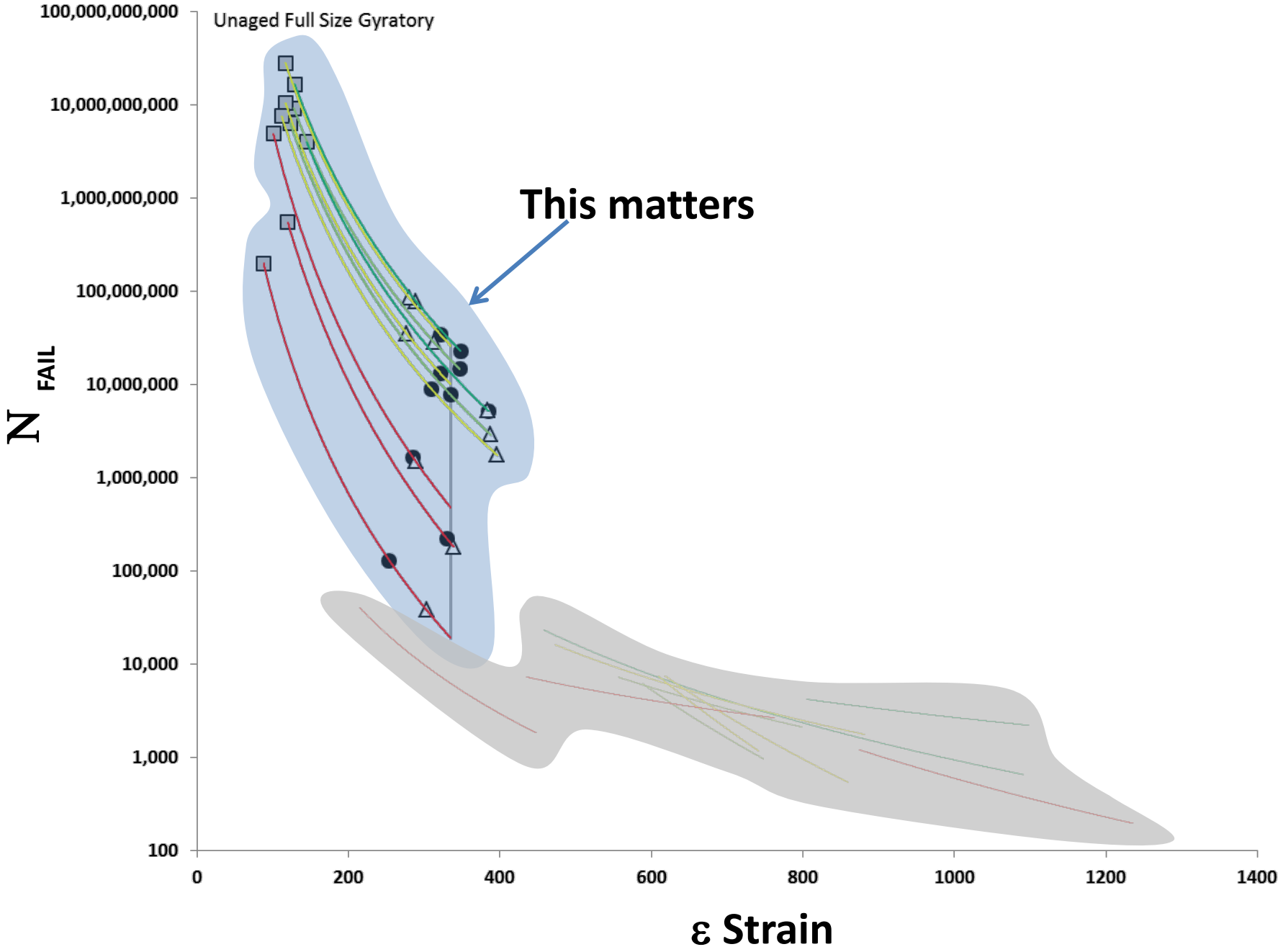


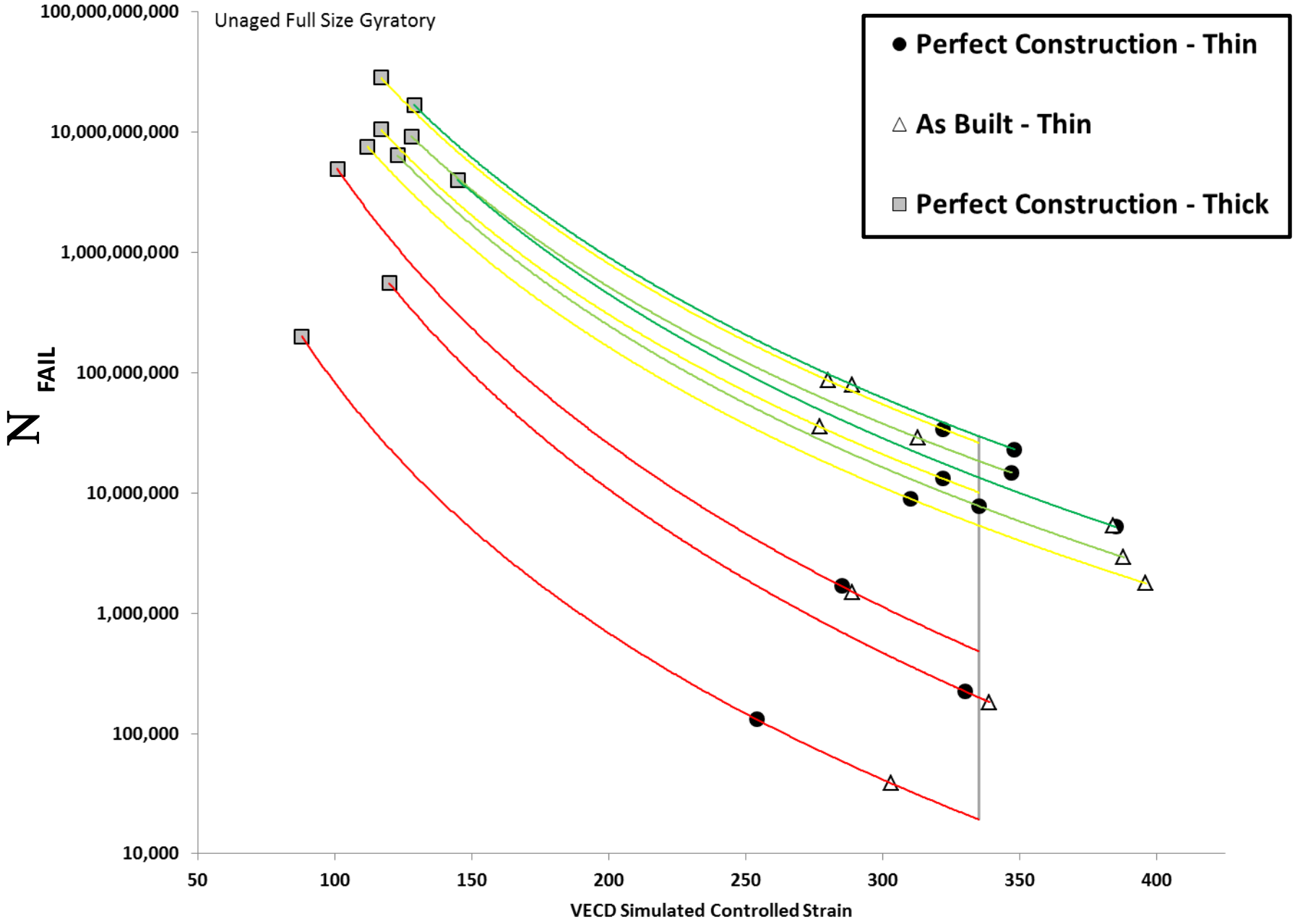

Unaged Full Size Gyratory
Case Example – Data from AMPT
Sample "A"
Sample "B"
δ Phase Angle
ε Strain
$N_{FAIL} = 22{,}510$
$N_{FAIL} = 920$
$\varepsilon_{AVG} = 469$
$\varepsilon_{AVG} = 982$
Phase Angle
On-specimen LVDT strain
Cycles
100,000,000,000
10,000,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
0
200
400
600
800
1000
1200
1400
N FAIL
ε Strain


Unaged Full Size Gyratory
This is the performance determined once the VECD properties have been obtained; e.g. C(S)
100,000,000,000
10,000,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
N FAIL
0
200
400
600
800
1000
1200
1400
ε Strain


Unaged Full Size Gyratory
100,000,000,000
10,000,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
N FAIL
0
200
400
600
800
1000
1200
1400
ε Strain
Pseudo Stiffness C(S)
1.0
0.8
0.6
0.4
0.2
0.0
0
200,000
400,000
600,000
800,000
1,000,000
Damage Parameter, S
L1
L2
L3
L4
L5
L6
L7
L8
L9
L11
C(S)
Damage
Characteristic
Curves

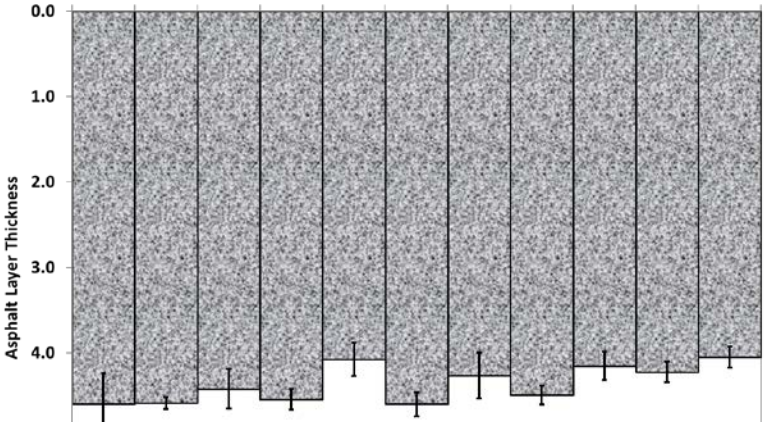

Unaged Full Size Gyratory
100,000,000,000
10,000,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
N FAIL
0
200
400
600
800
1000
1200
1400
ε Strain
This was necessary, but not the end-product.

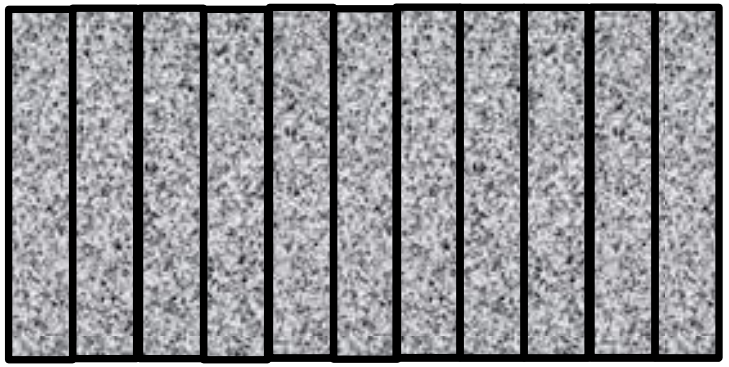

Unaged Full Size Gyratory
This matters
100,000,000,000
10,000,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
1,000
100
N FAIL
0
200
400
600
800
1000
1200
1400
ε Strain


Unaged Full Size Gyratory
Perfect Construction - Thin
As Built - Thin
Perfect Construction - Thick
N FAIL
100,000,000,000
10,000,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
50
100
150
200
250
300
350
400
VECD Simulated Controlled Strain

As-Built vs. Perfect Construction (thin)

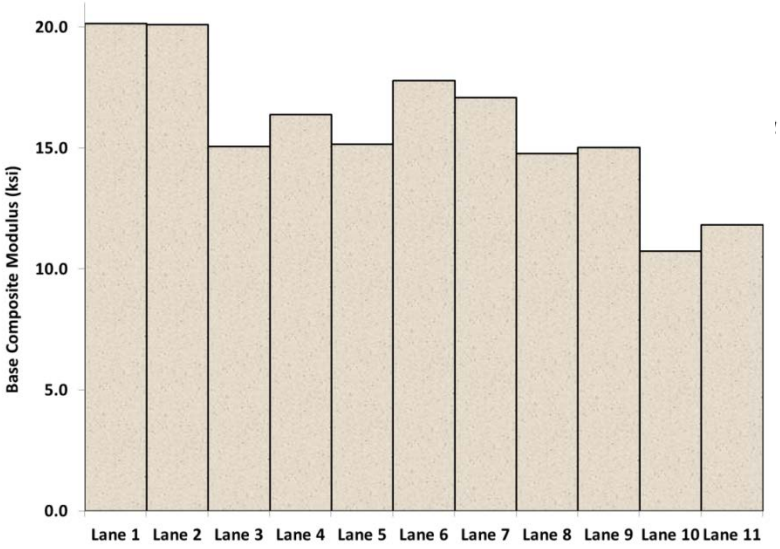
Asphalt Thickness

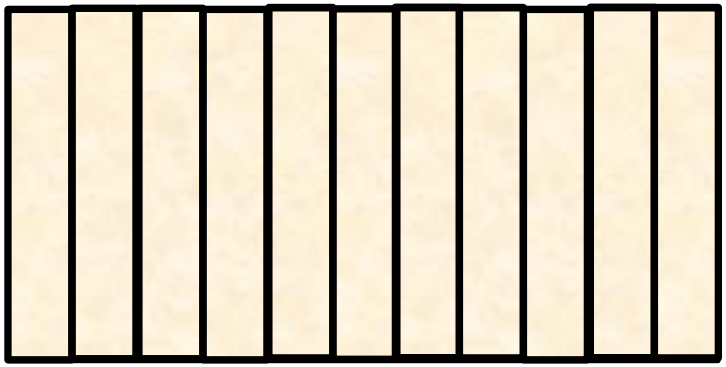


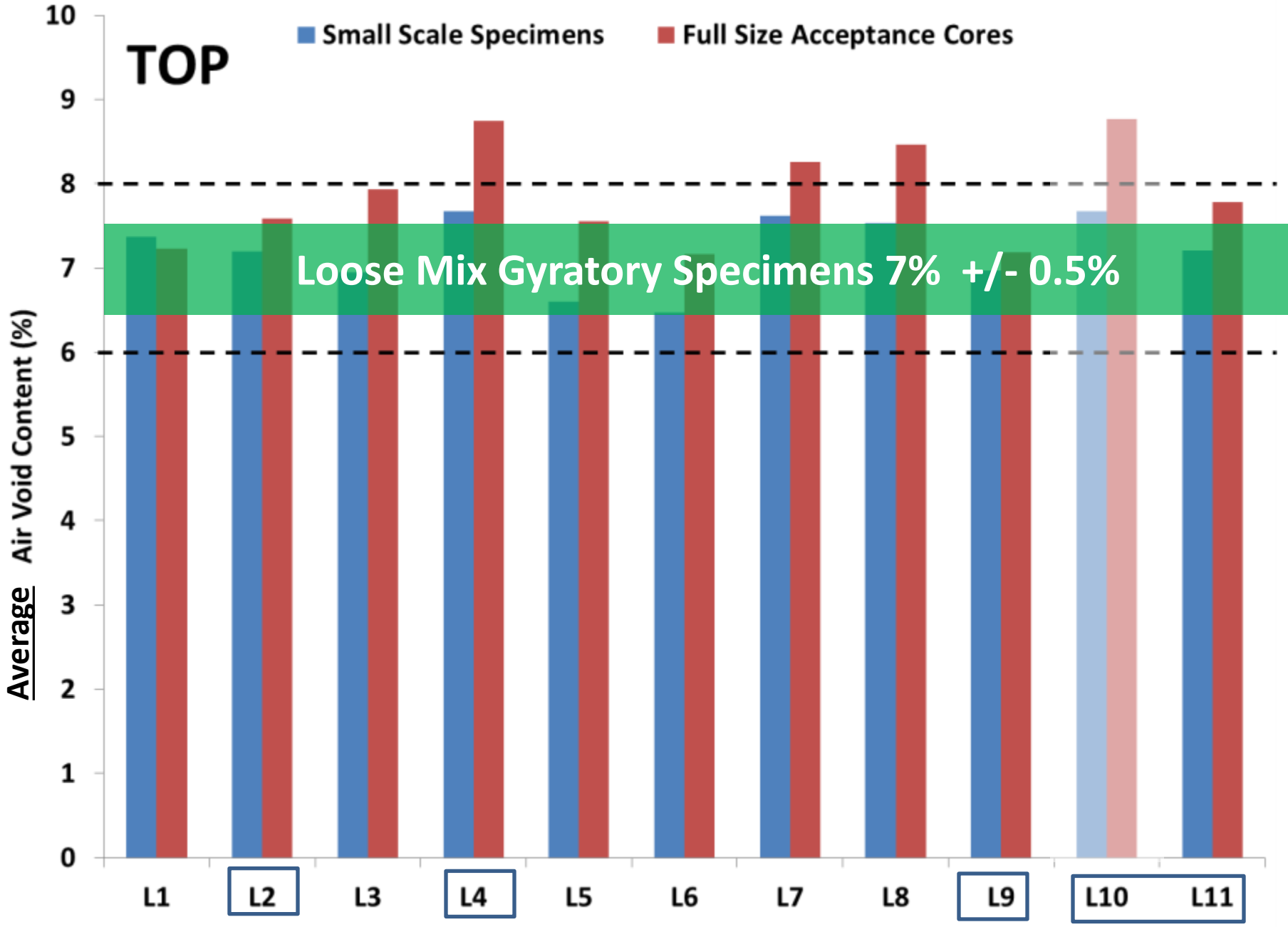


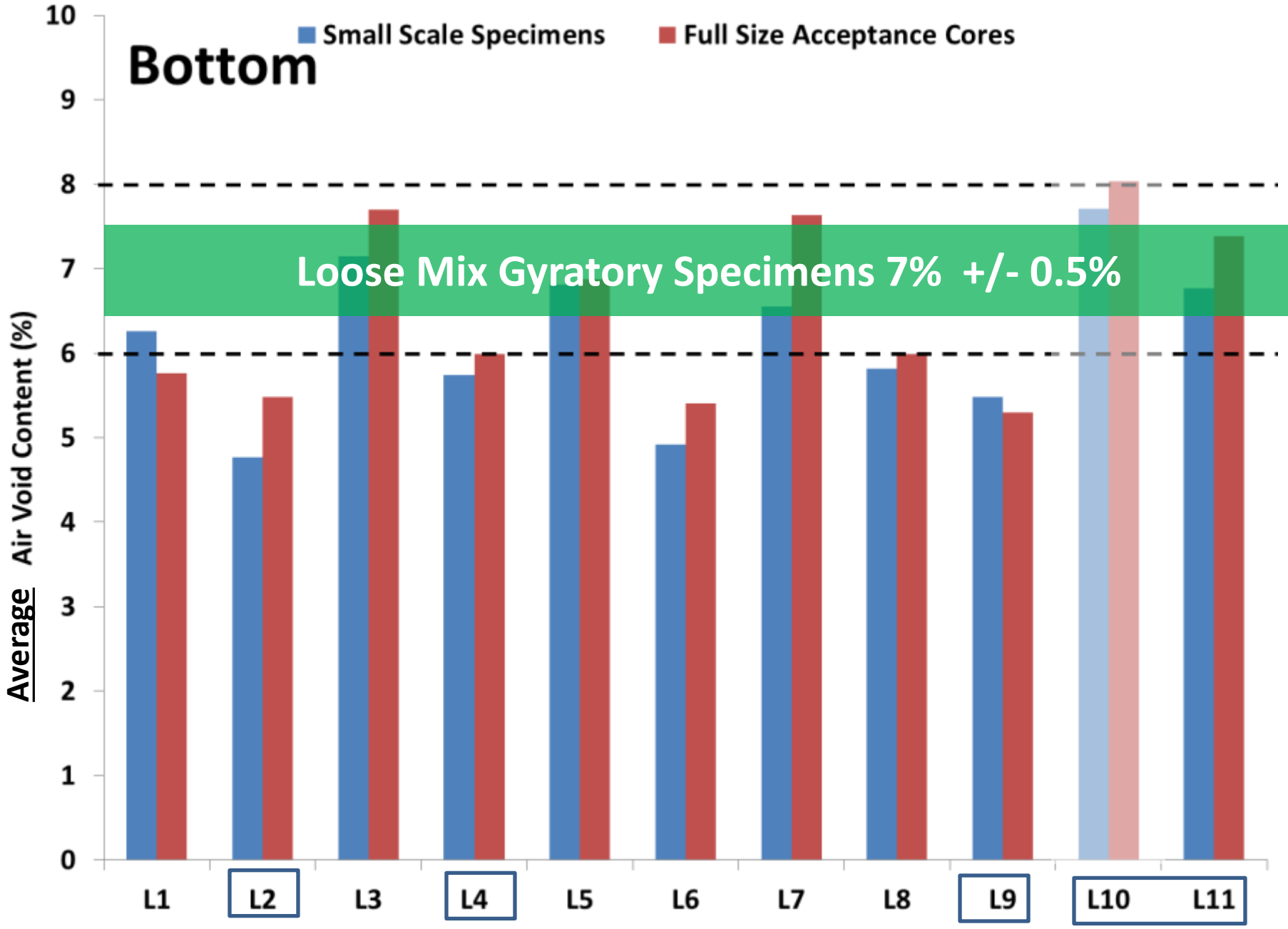
Average = “Perfect”

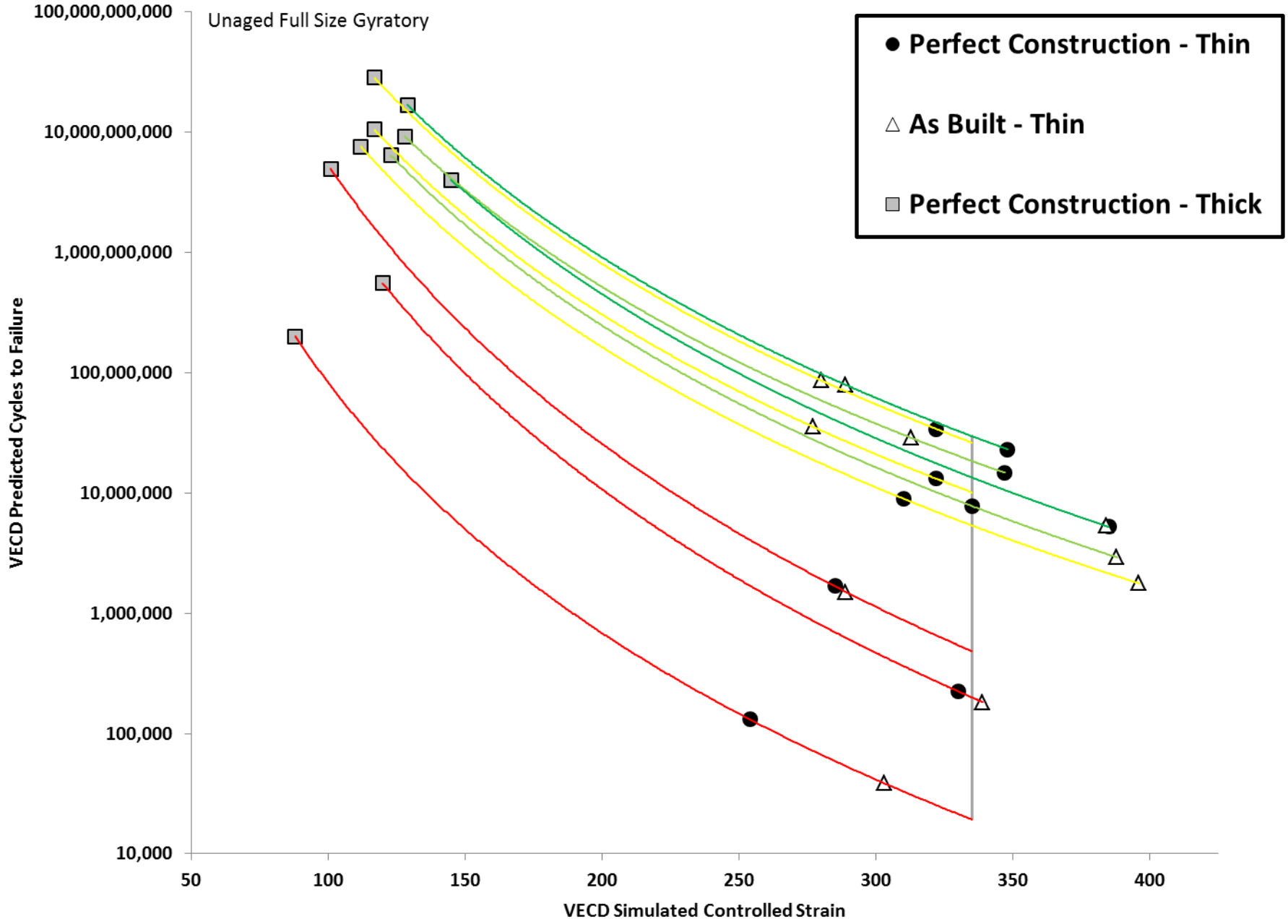
Base Stiffness






TOP
Small Scale Specimens
Full Size Acceptance Cores
Loose Mix Gyratory Specimens 7% +/- 0.5%
Average Air Void Content (%)
10
9
8
7
6
5
4
3
2
1
0
L1
L2
L3
L4
L5
L6
L7
L8
L9
L10
L11


Bottom
Small Scale Specimens
Full Size Acceptance Cores
Loose Mix Gyratory Specimens 7% +/- 0.5%
Average Air Void Content (%)
10
9
8
7
6
5
4
3
2
1
0
L1
L2
L3
L4
L5
L6
L7
L8
L9
L10
L11


Unaged Full Size Gyratory
Perfect Construction - Thin
As Built - Thin
Perfect Construction - Thick
VECD Predicted Cycles to Failure
100,000,000,000
10,000,000,000
1,000,000,000
100,000,000
10,000,000
1,000,000
100,000
10,000
50
100
150
200
250
300
350
400
VECD Simulated Controlled Strain

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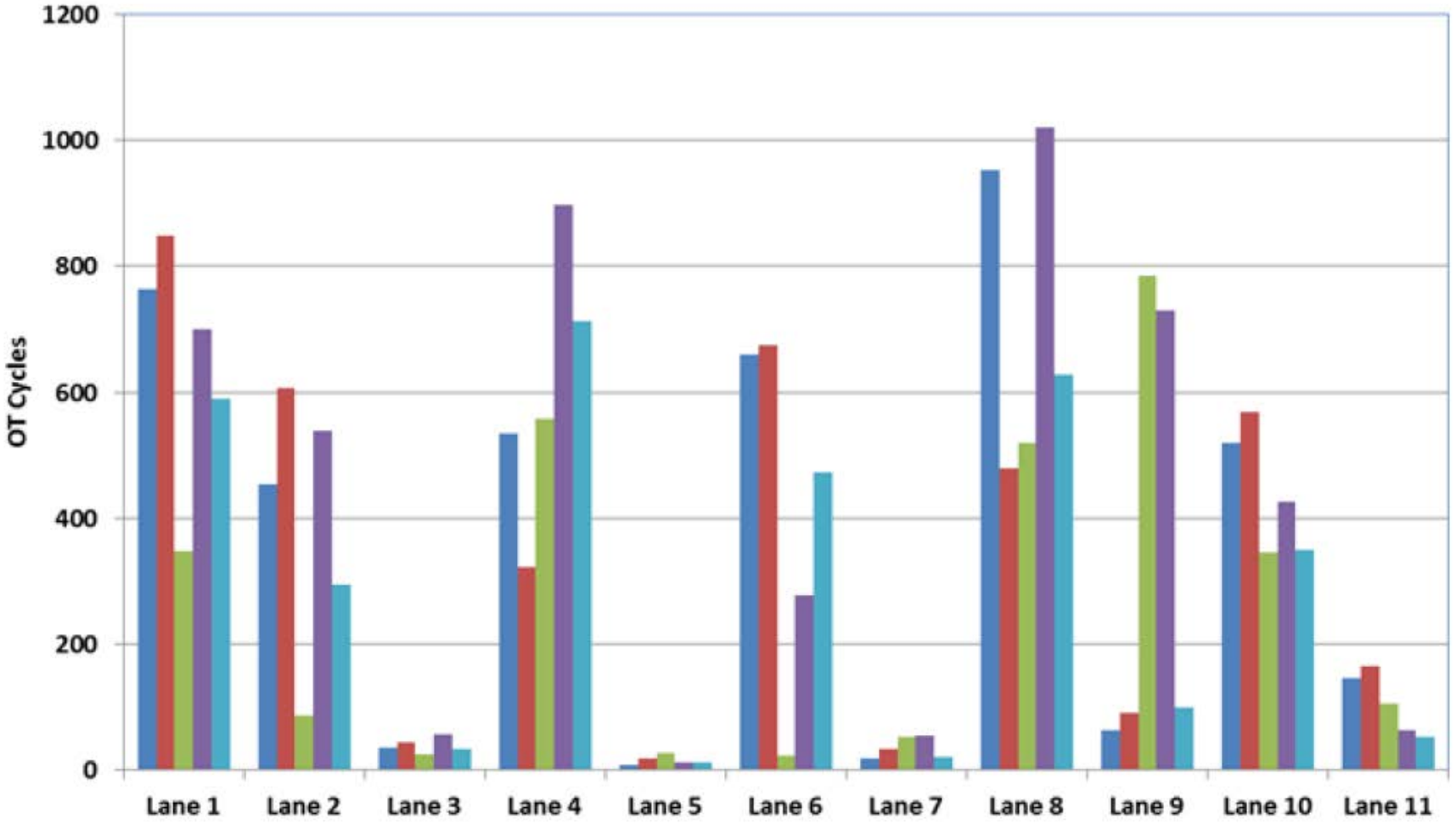
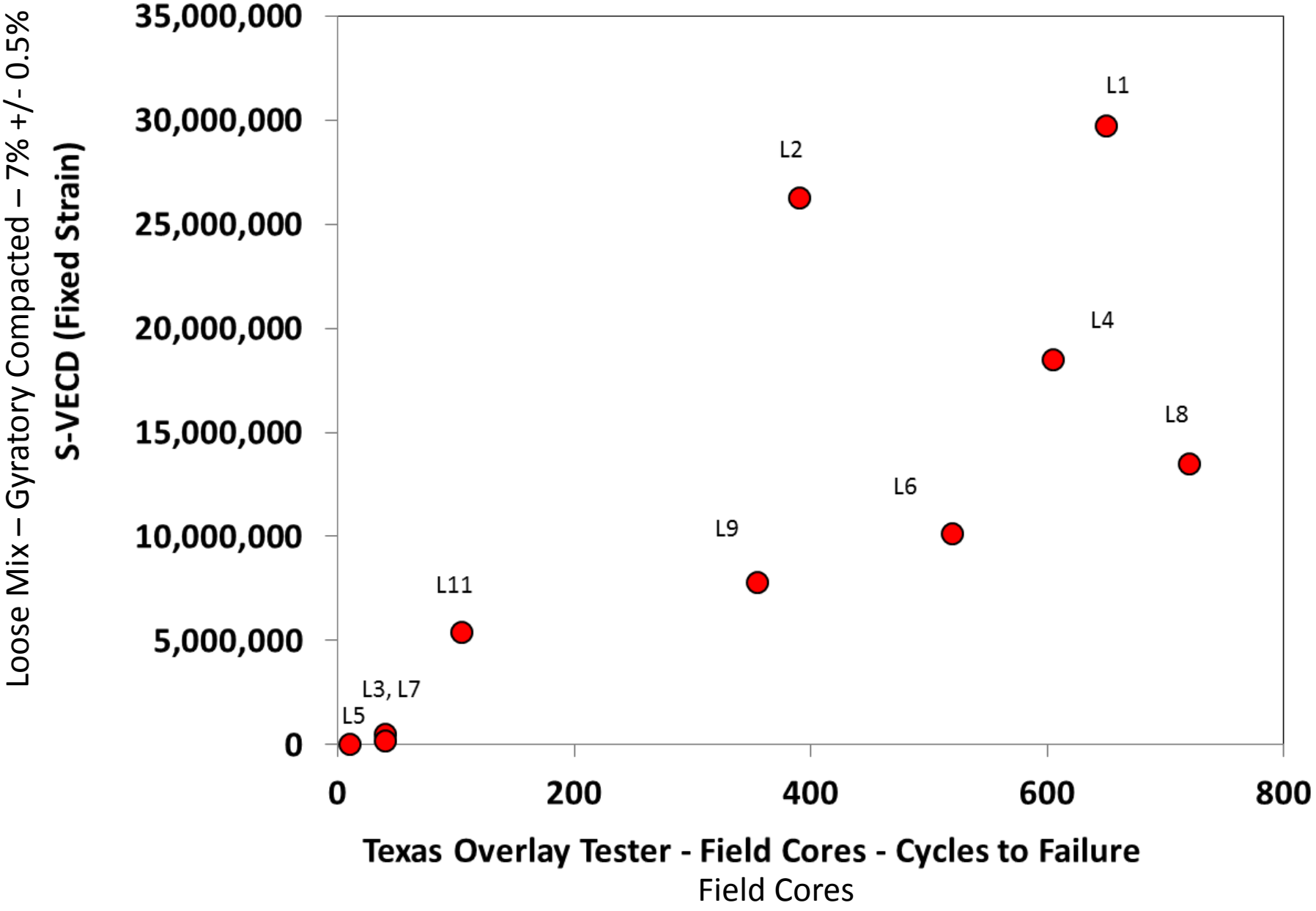
Texas Overlay Tester

- FHWA cored & trimmed the bottom surface
- Cores shipped to TTI
- TTI split cores into Top Lift & Bottom Lift
- 5 replicates
- Tested at: 20^{o}C

  0.020 inch displacement

  (0.5 mm)


Texas Overlay Test: 20C and 0.020 inch opening displacement
OT Cycles
1200
1000
800
600
400
200
0
Lane 1
Lane 2
Lane 3
Lane 4
Lane 5
Lane 6
Lane 7
Lane 8
Lane 9
Lane 10
Lane 11


Loose Mix – Gyratory Compacted – 7% +/- 0.5%
S-VECD (Fixed Strain)
35,000,000
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
0
0
200
400
600
800
L1
L2
L4
L8
L6
L9
L11
L3, L7
L5
Texas Overlay Tester - Field Cores - Cycles to Failure
Field Cores

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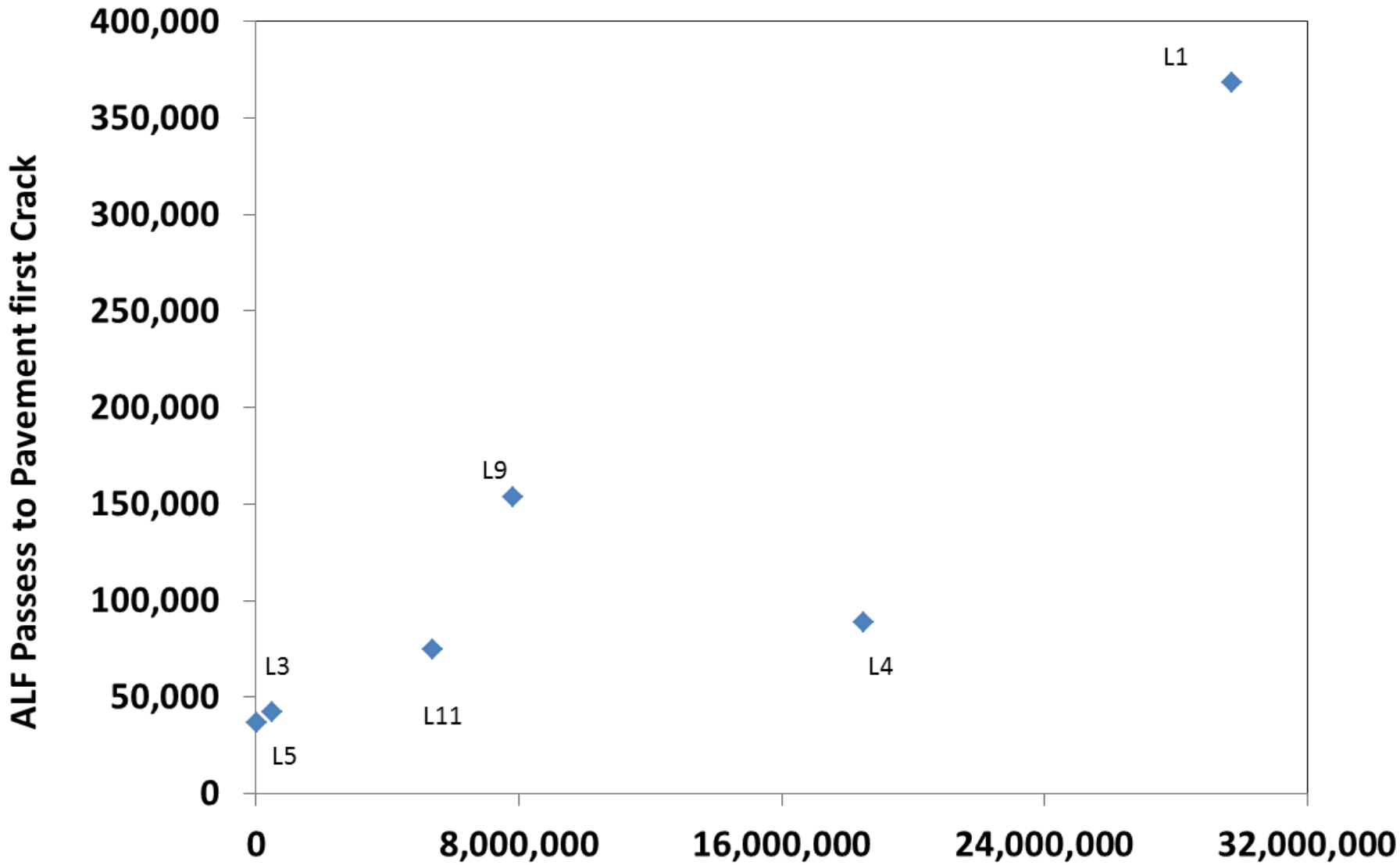
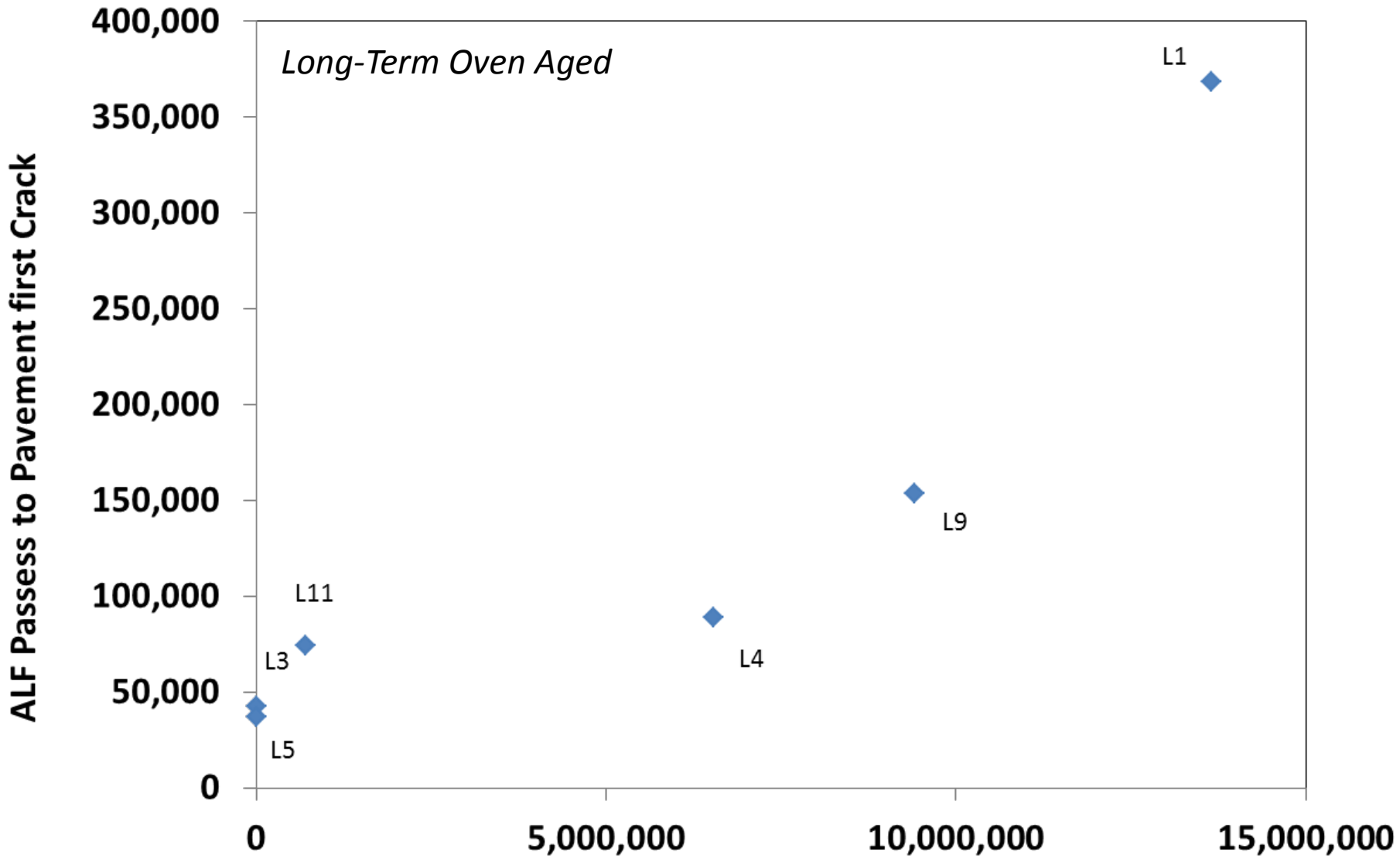
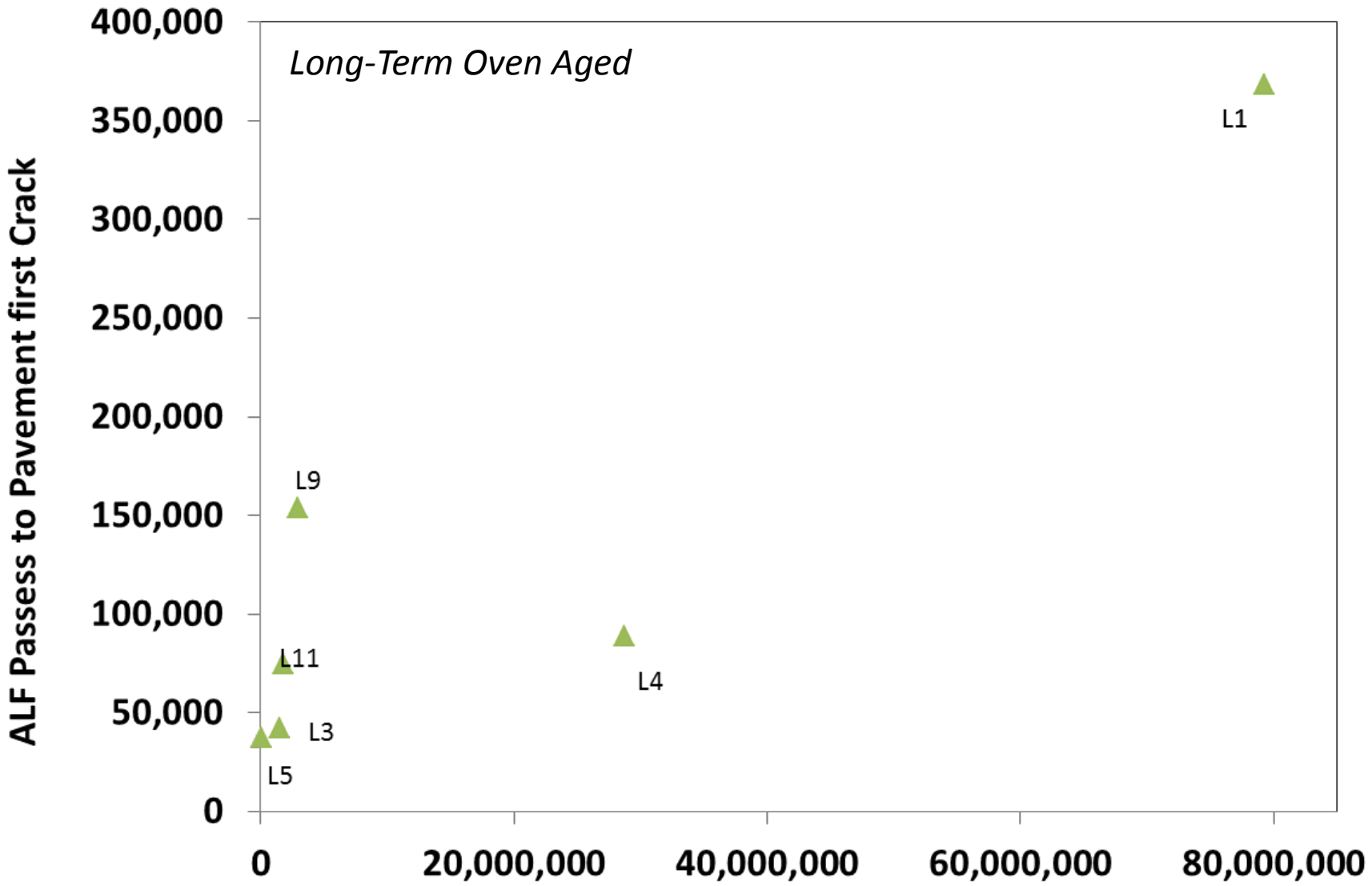


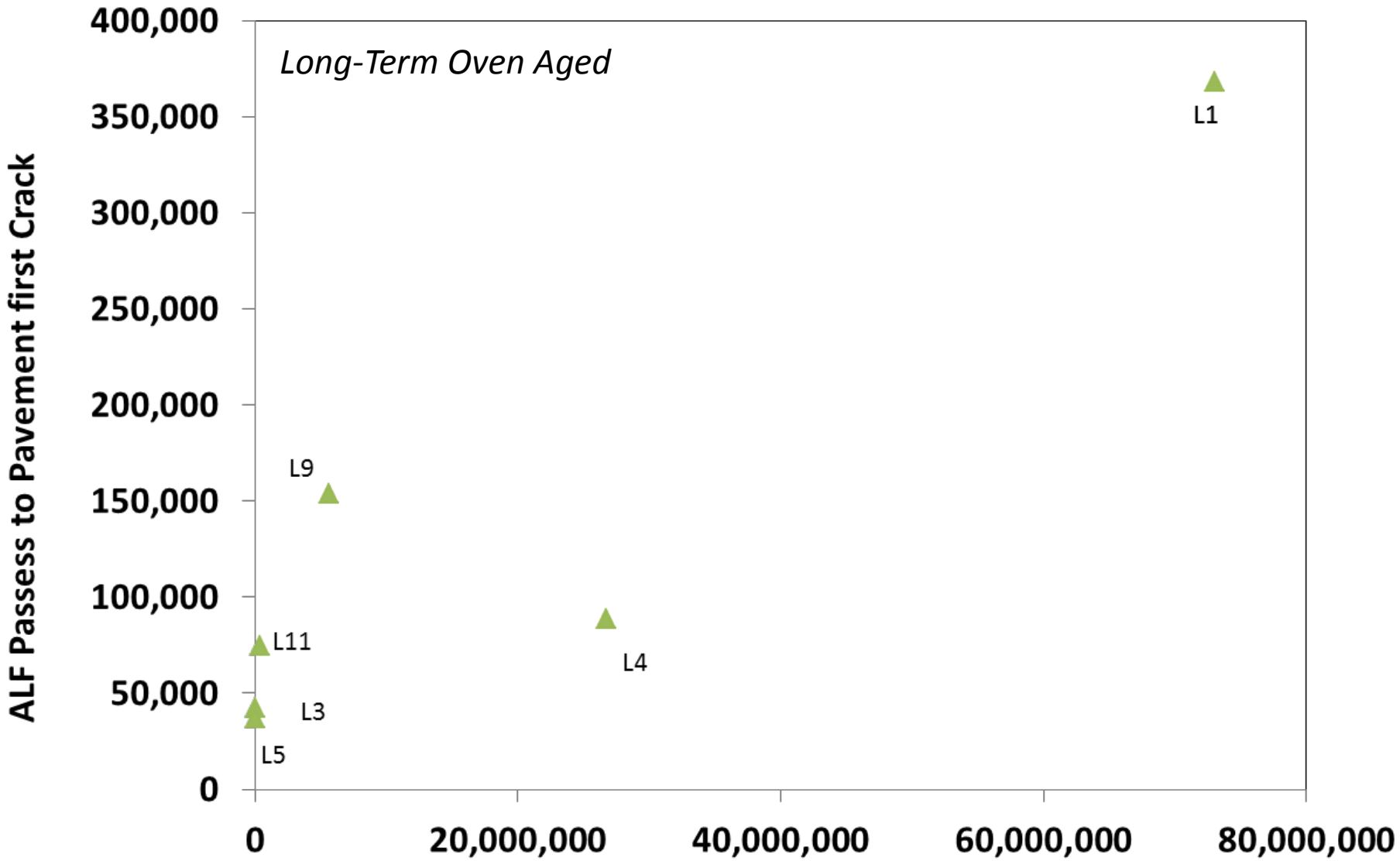
Loose Mix – Gyratory Compacted – 7% +/- 0.5%



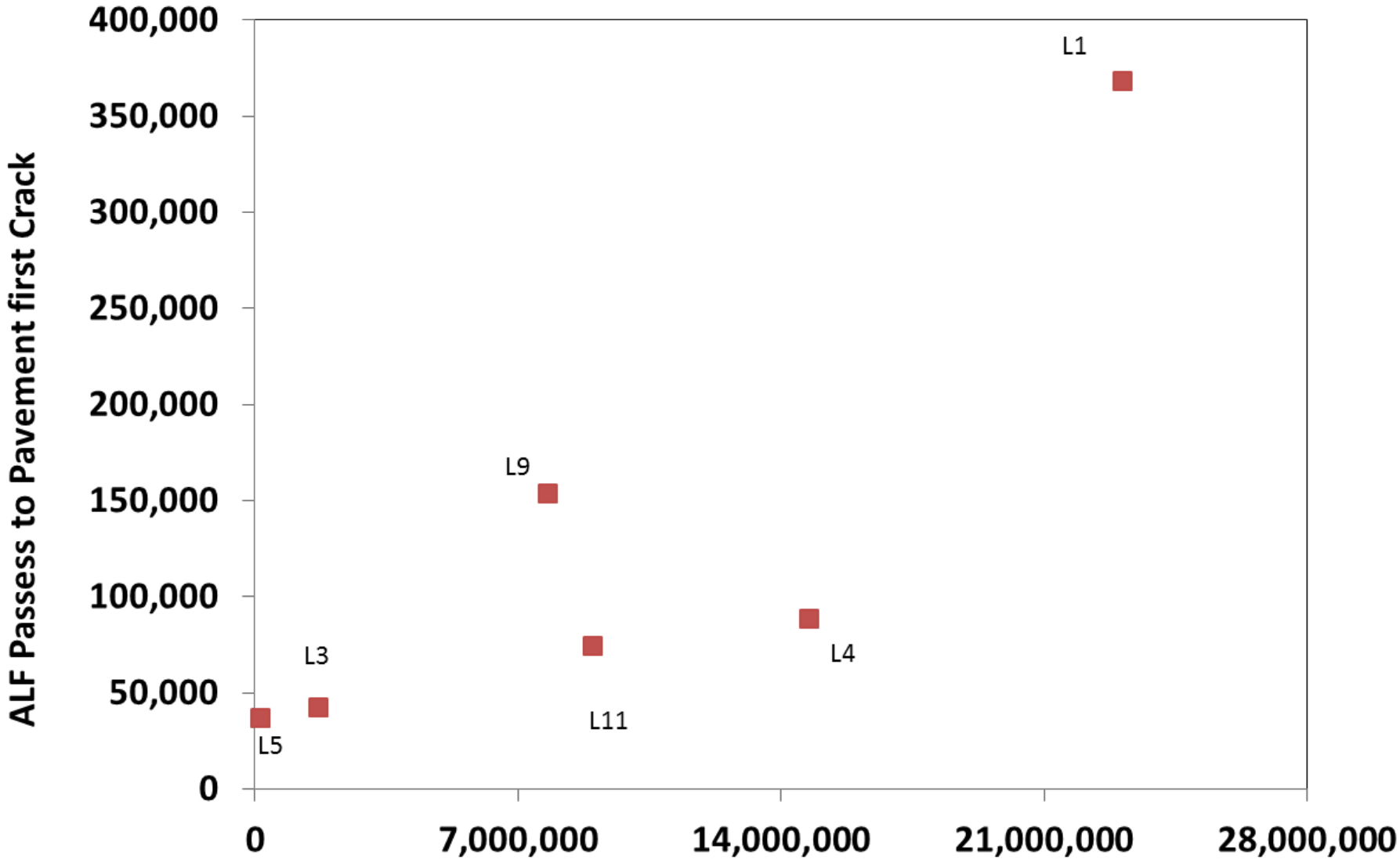
Loose Mix – Gyratory Compacted – 7% +/- 0.5%



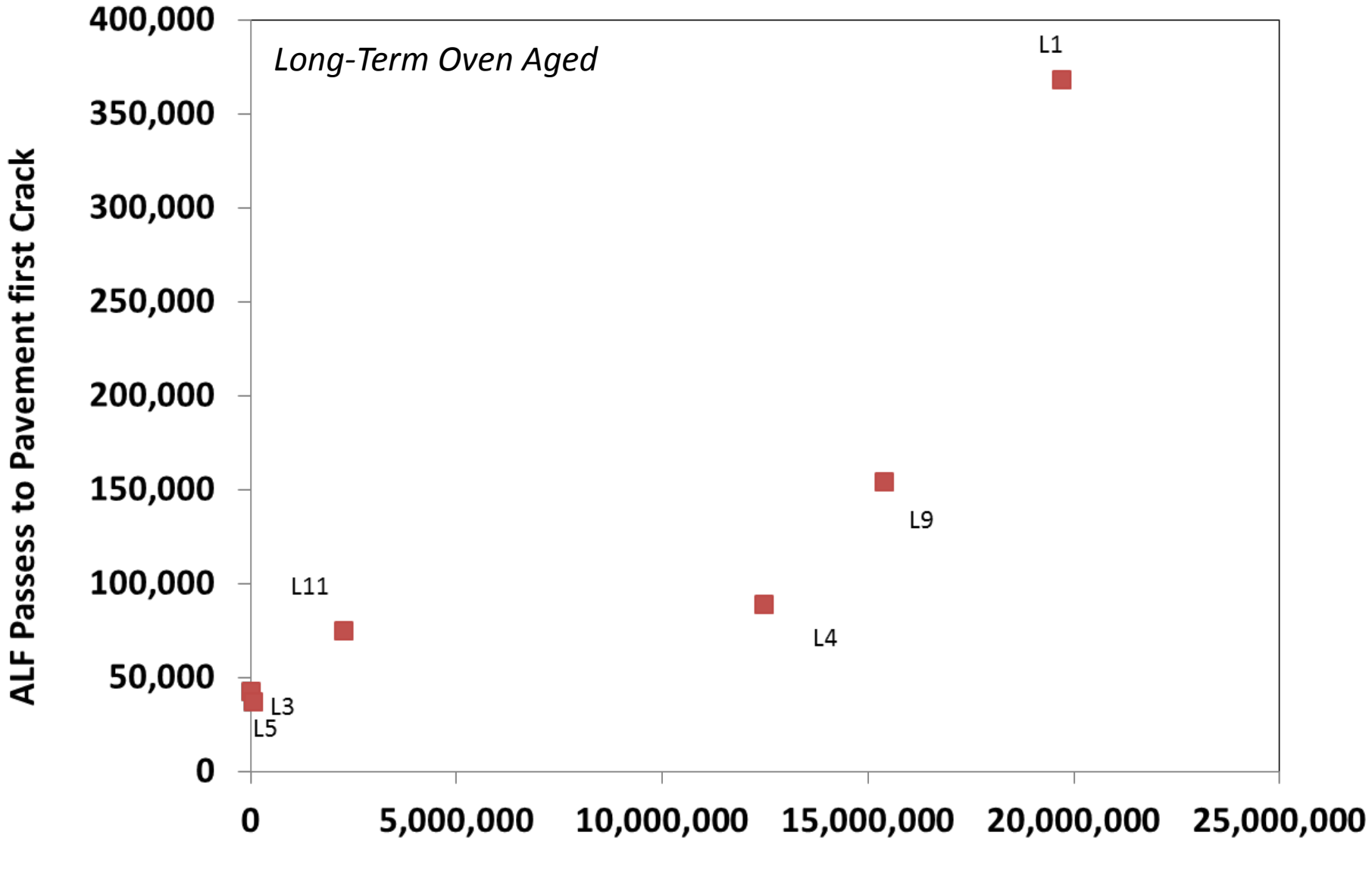
Loose Mix – Gyratory Compacted – 7% +/- 0.5%

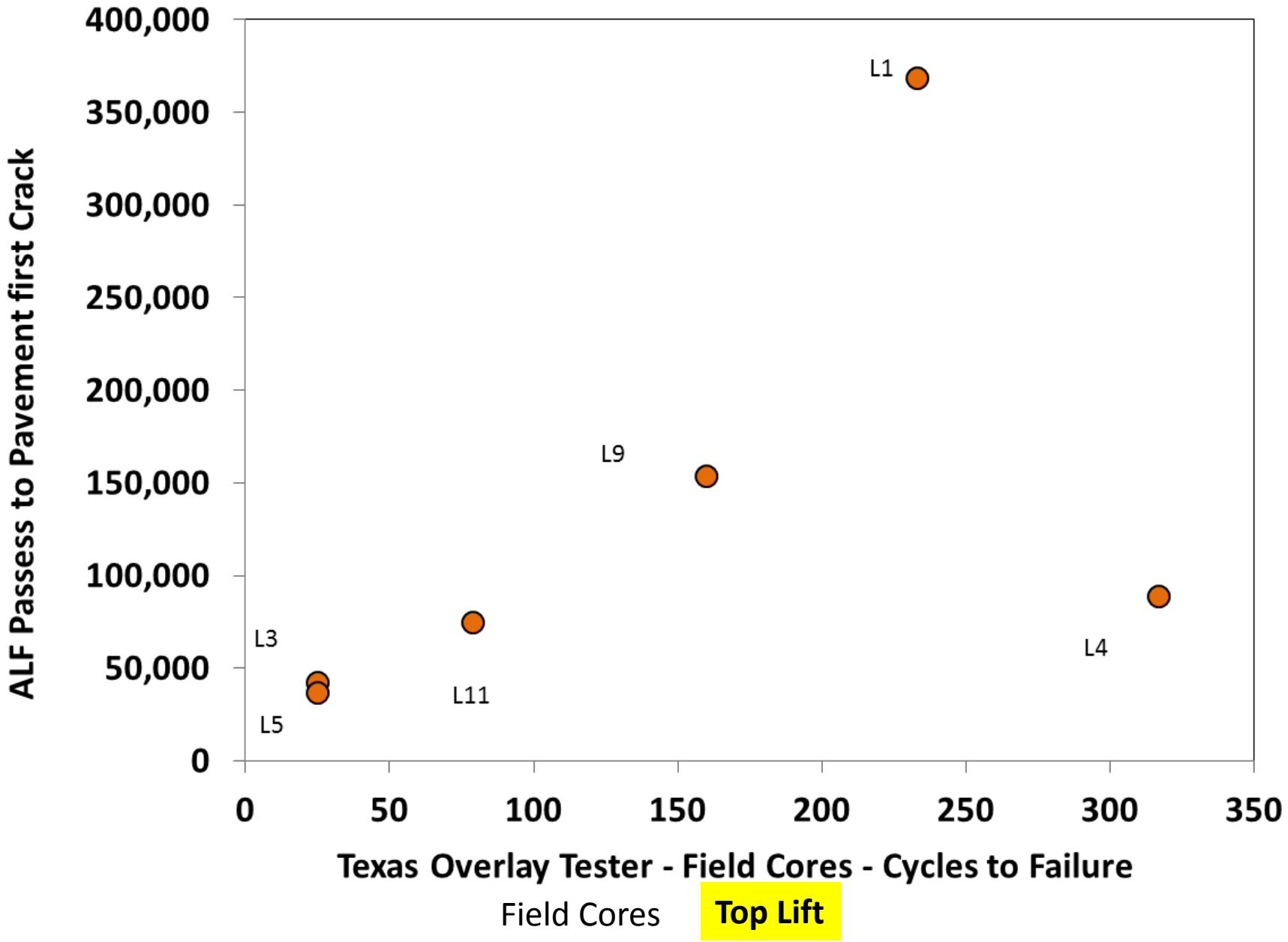


Loose Mix – Gyratory Compacted – 7% +/- 0.5%

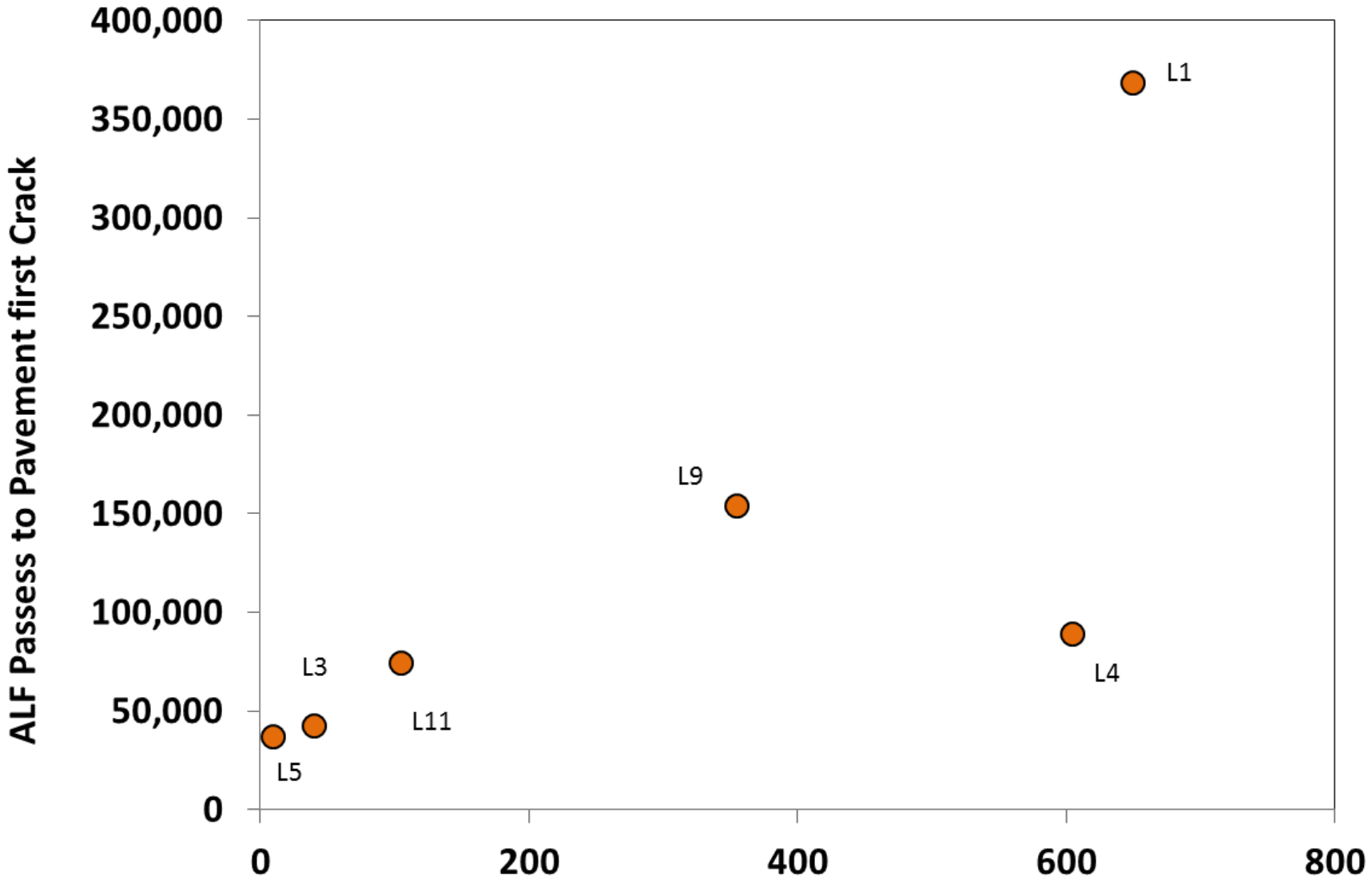


Loose Mix – Gyratory Compacted – 7% +/- 0.5%

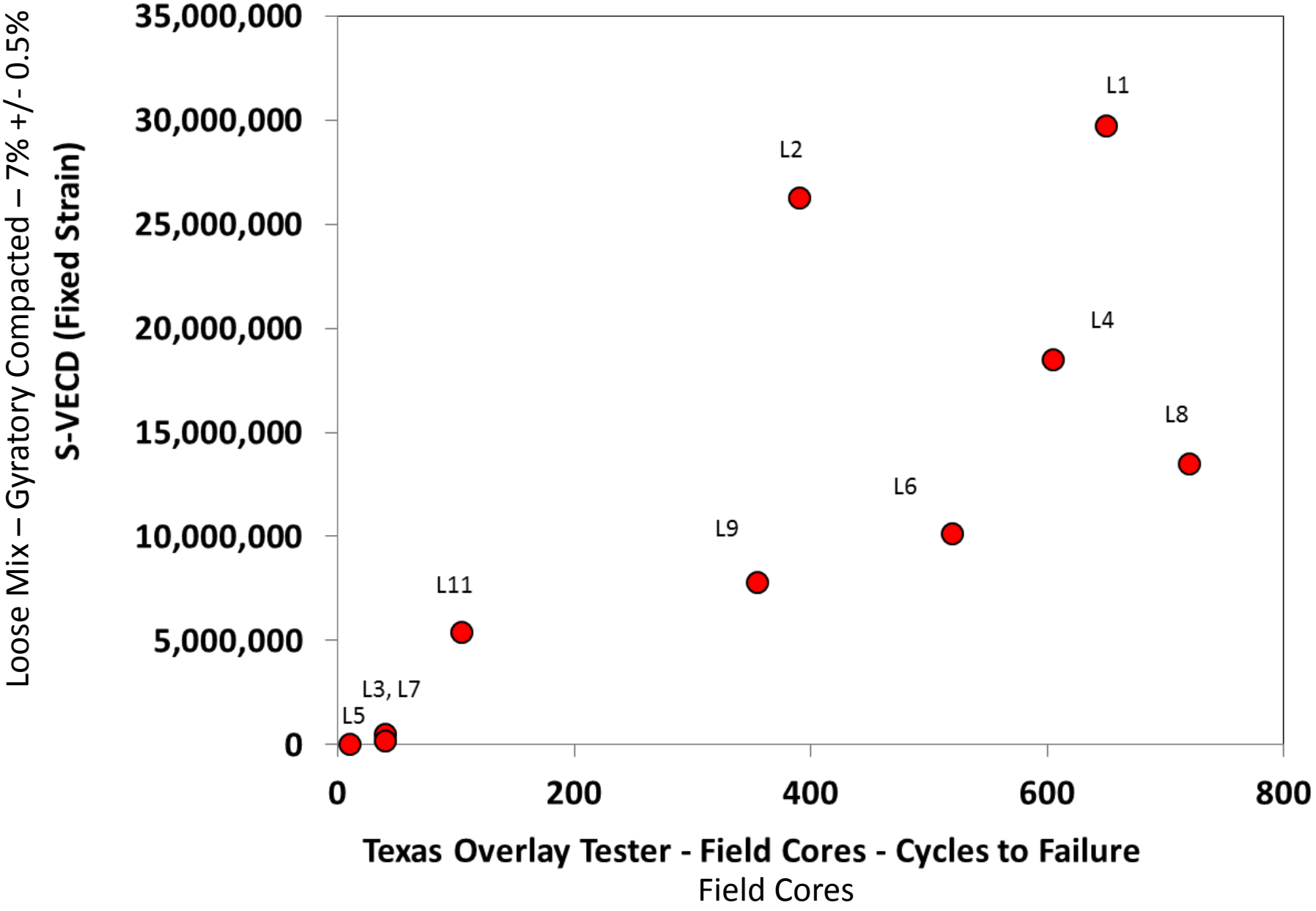

Long-Term Oven Aged
ALF Passess to Pavement first Crack
400,000
350,000
300,000
250,000
200,000
150,000
100,000
50,000
0
L1
L9
L11
L4
L3
L5
0
5,000,000
10,000,000
15,000,000
20,000,000
25,000,000
Laboratory Cycles to Failure, S-VECD (PERFECT CONSTRUCTION)
Loose Mix – Gyratory Compacted – 7% +/- 0.5%

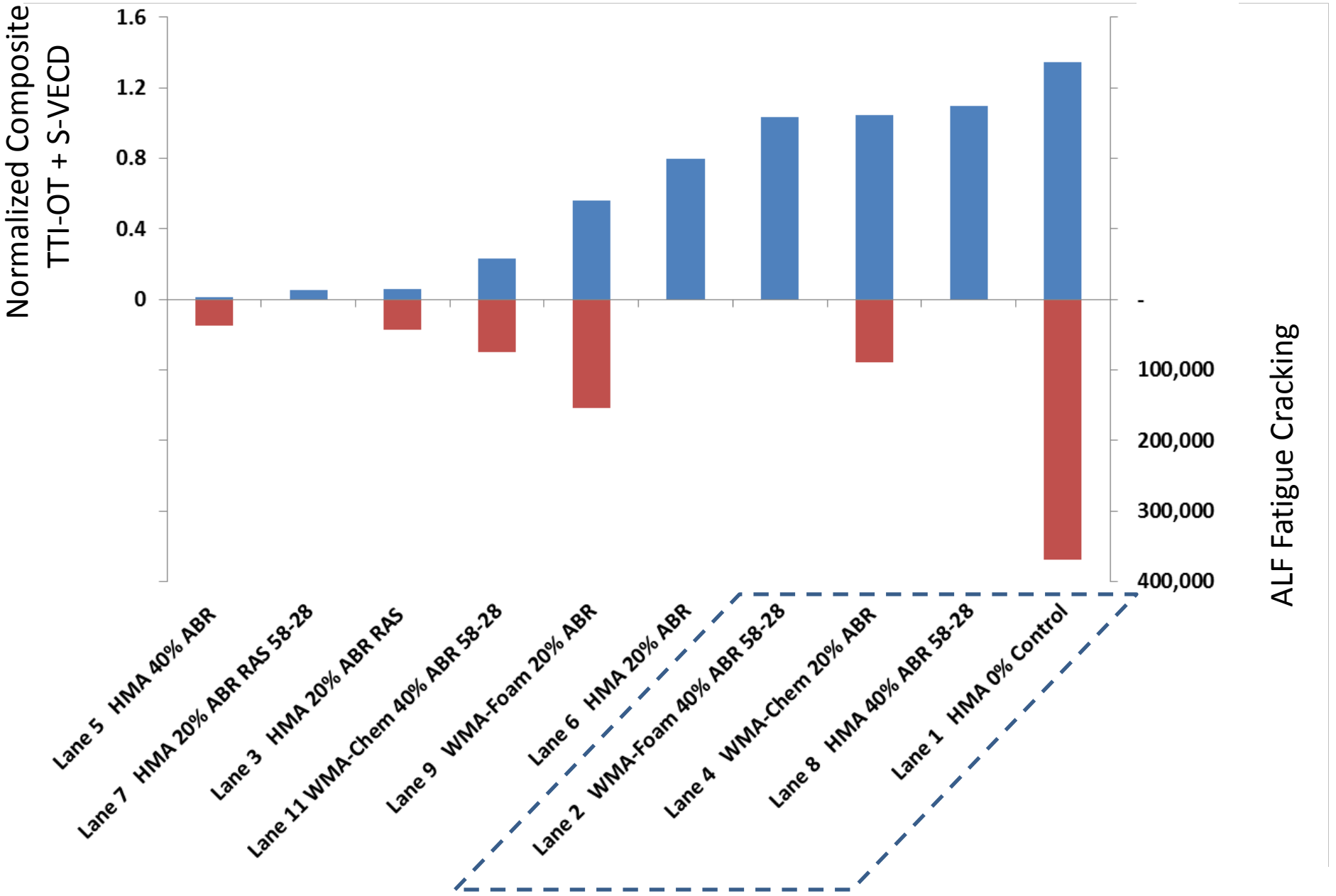


Field Cores **Top Lift**



Field Cores **Bottom Lift**


Loose Mix – Gyratory Compacted – 7% +/- 0.5%
S-VECD (Fixed Strain)
35,000,000
30,000,000
25,000,000
20,000,000
15,000,000
10,000,000
5,000,000
0
0
200
400
600
800
L1
L2
L4
L8
L6
L9
L11
L3, L7
L5
Texas Overlay Tester - Field Cores - Cycles to Failure
Field Cores


Normalized Composite
TTI-OT + S-VECD
1.6
1.2
0.8
0.4
0
-
100,000
200,000
300,000
400,000
ALF Fatigue Cracking
Lane 5 HMA 40% ABR
Lane 7 HMA 20% ABR RAS 58-28
Lane 3 HMA 20% ABR RAS
Lane 11 WMA-Chem 40% ABR 58-28
Lane 9 WMA-Foam 20% ABR
Lane 6 HMA 20% ABR
Lane 2 WMA-Foam 40% ABR 58-28
Lane 4 WMA-Chem 20% ABR
Lane 8 HMA 40% ABR 58-28
Lane 1 HMA 0% Control

Outline

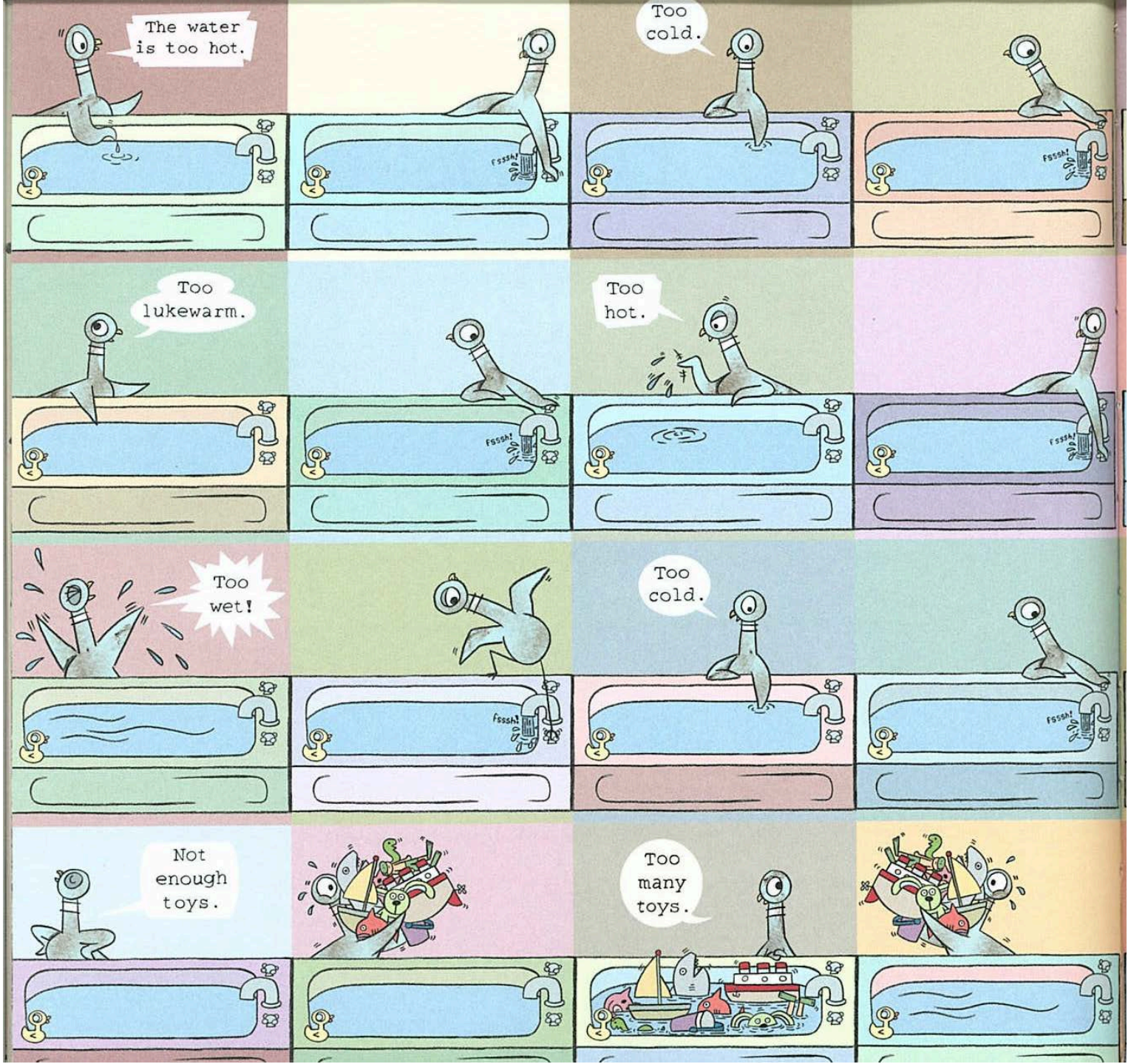
- Experimental Design – Refresher
- ALF Loading Status
- Laboratory Test Results
  - S-VECD – *Loose Mix/Gyratory Unaged and Aged*
  - Texas Overlay Tester - *Cores* - iRLPD SCB
- Comparison of Lab Cracking Tests vs. Field
- Future Steps

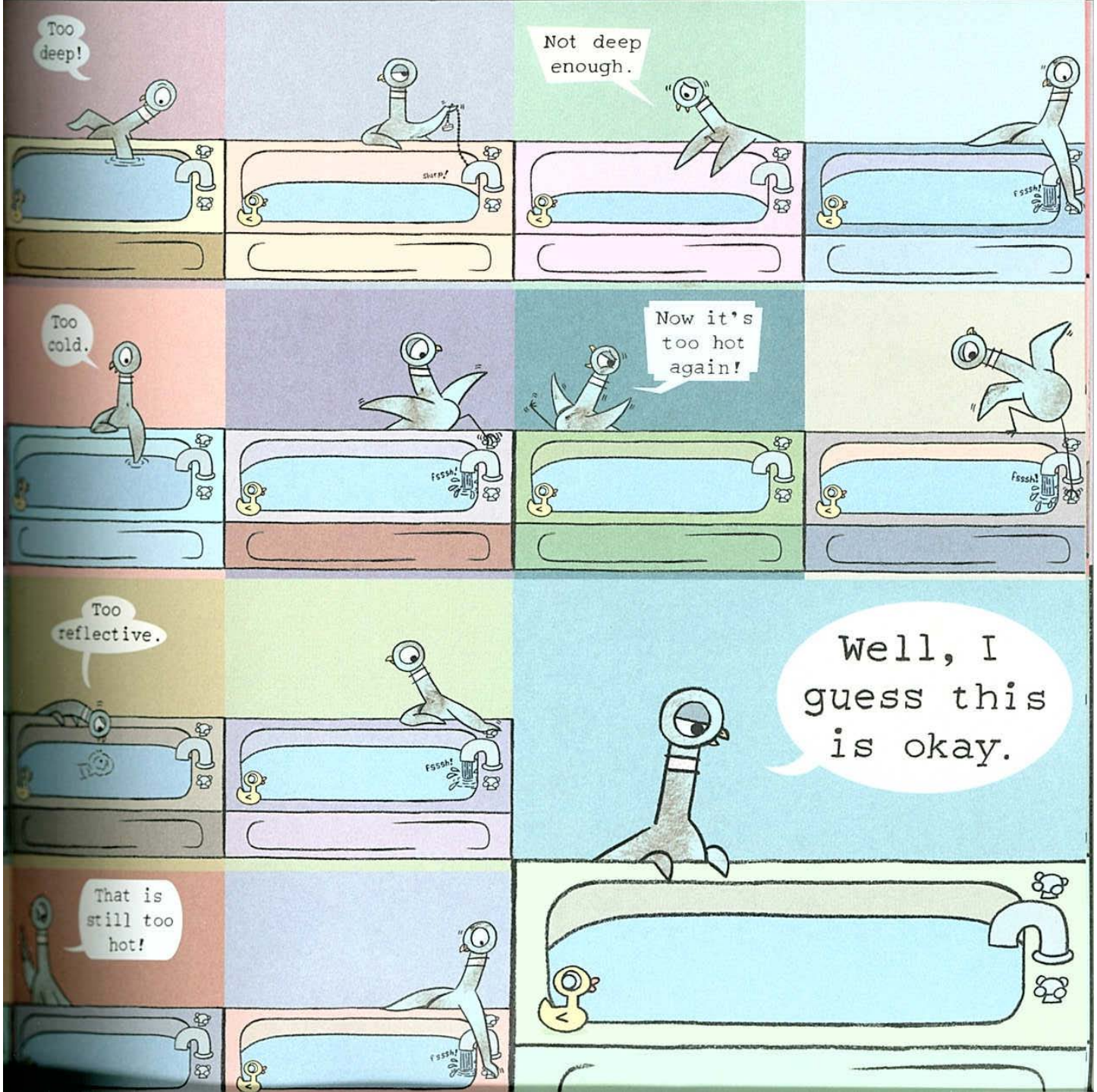
Upcoming Efforts

- ***Identify the Recycled Binder Ratio (aka ABR) which provides Equivalent Performance*****
  - ***Equivalent to 0% RAP PG64-22 ??***
    20% RAP PG64-22 ??
  - ***Lab-batched mixes***
  - ***Add more virgin binder***
  - ***Conduct this only on 40% RAP ABR PG58-28***
    20% RAS ABR PG58-28

- Long Term Aging vs. Field Aging
- Extraction & Recovery – Large Quantities
- Variability in Lab Crack Test
- Collaborative Testing
  - Beam Fatigue @ AAT
  - SCB @ LaDOTD
  - IDT @ WSU
  - OT*, SCB, Cantaboro, IDT @ NCAT

The Pigeon Needs a Bath!


The water is too hot.
Too cold.
Too lukewarm.
Too hot.
Too wet!
Too cold.
Not enough toys.
Too many toys.


Too deep!
Slurp!
Not deep enough.
Fssssh!
Too cold.
Fssssh!
Now it's too hot again!
Fssssh!
Too reflective.
Fssssh!
Well, I guess this is okay.
That is still too hot!
Fssssh!

The **Pavement Engineer** Needs a

Cracking Test !

http://circuitoftheamericas.com/articles/cota-completes-track-pavement-with-success

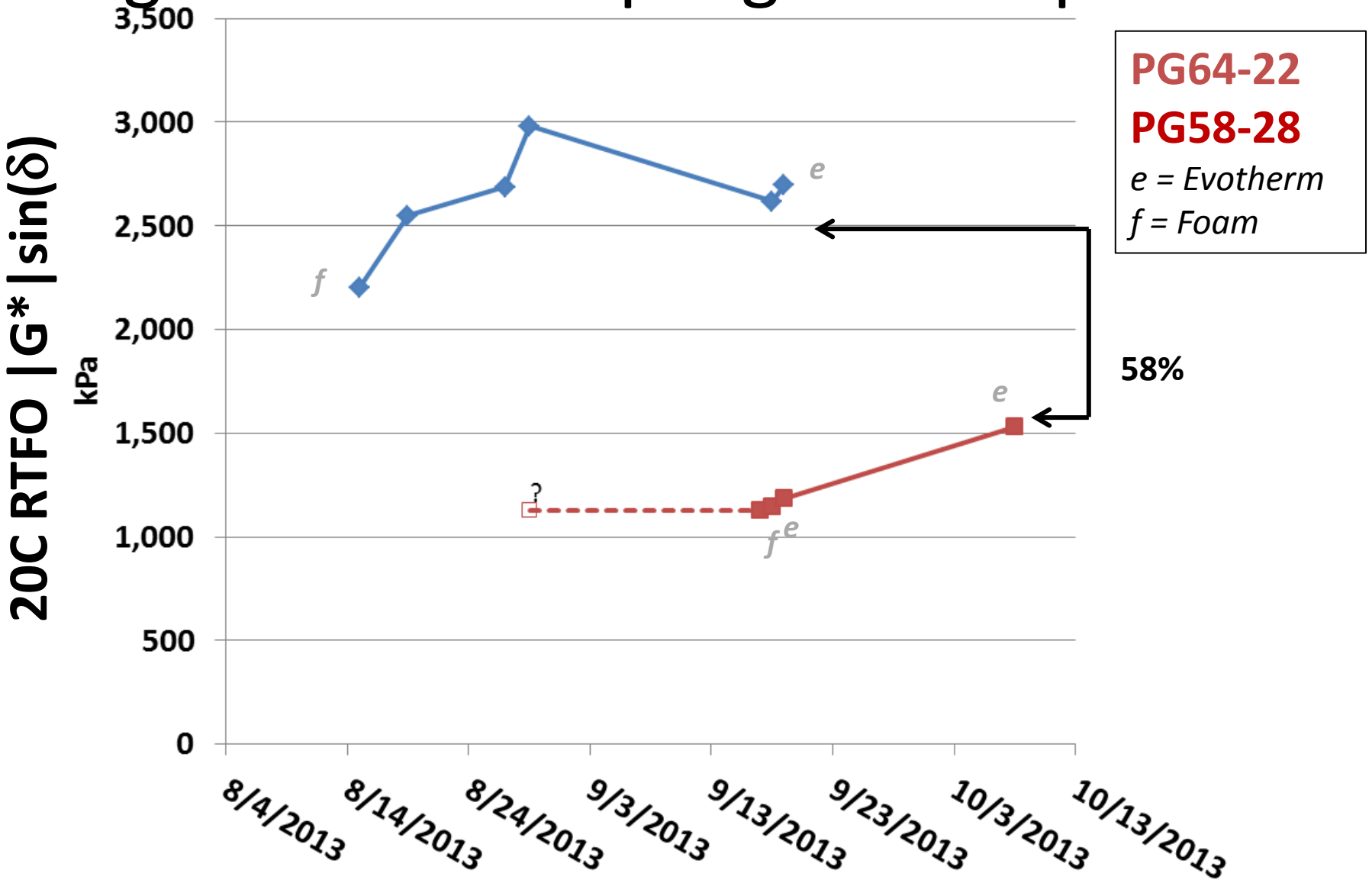
Thank You.

Questions?
Comments?
Concerns?

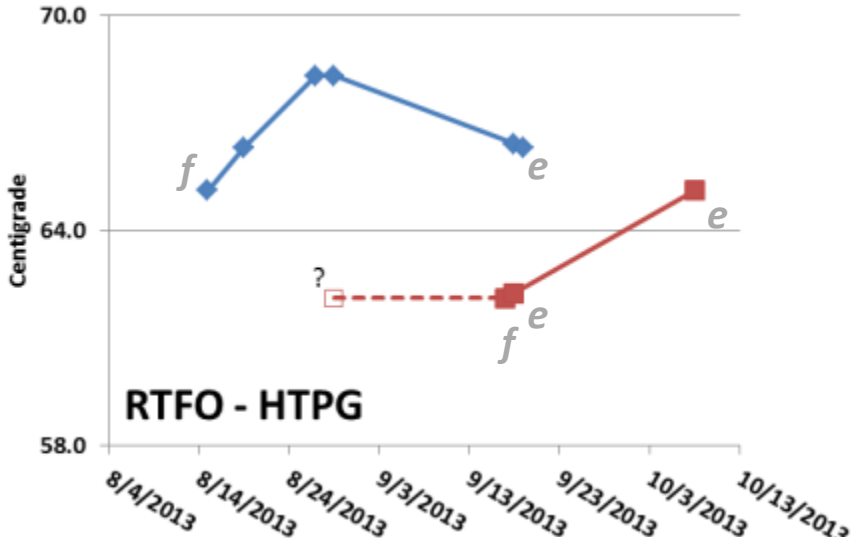
Virgin Binder Sampling and Properties

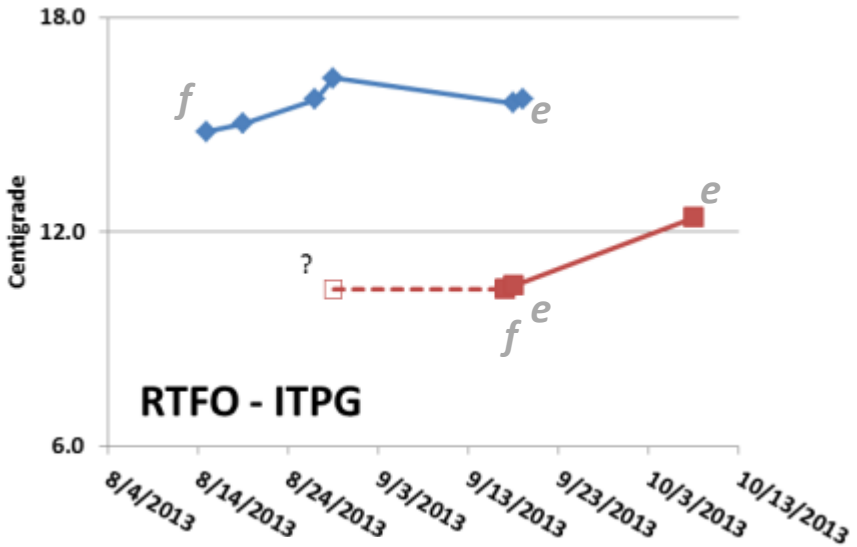
- **In-line sampling port just before entering the drum**
- **One gallon on each day of production**

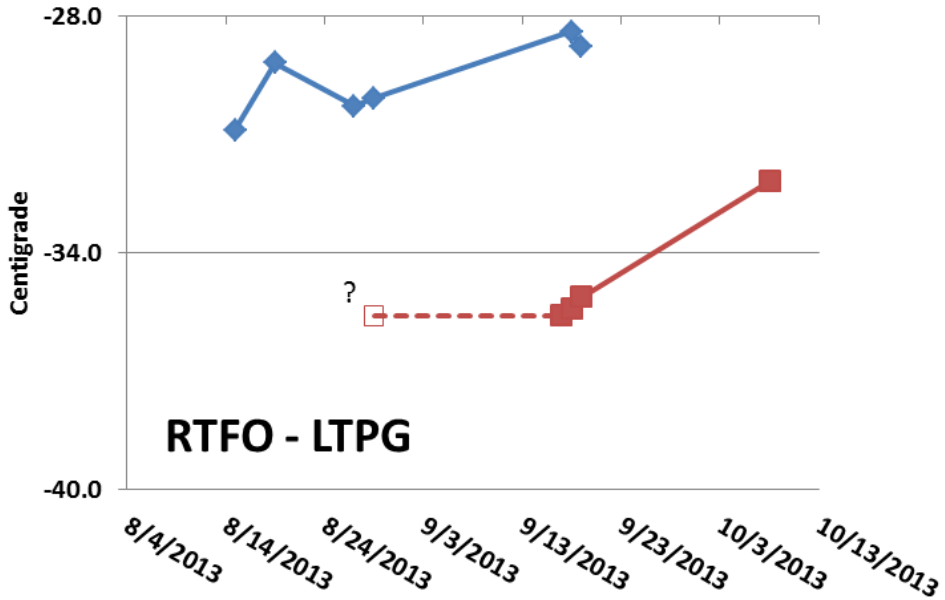
Virgin Binder Sampling and Properties



Virgin Binder Sampling and Properties





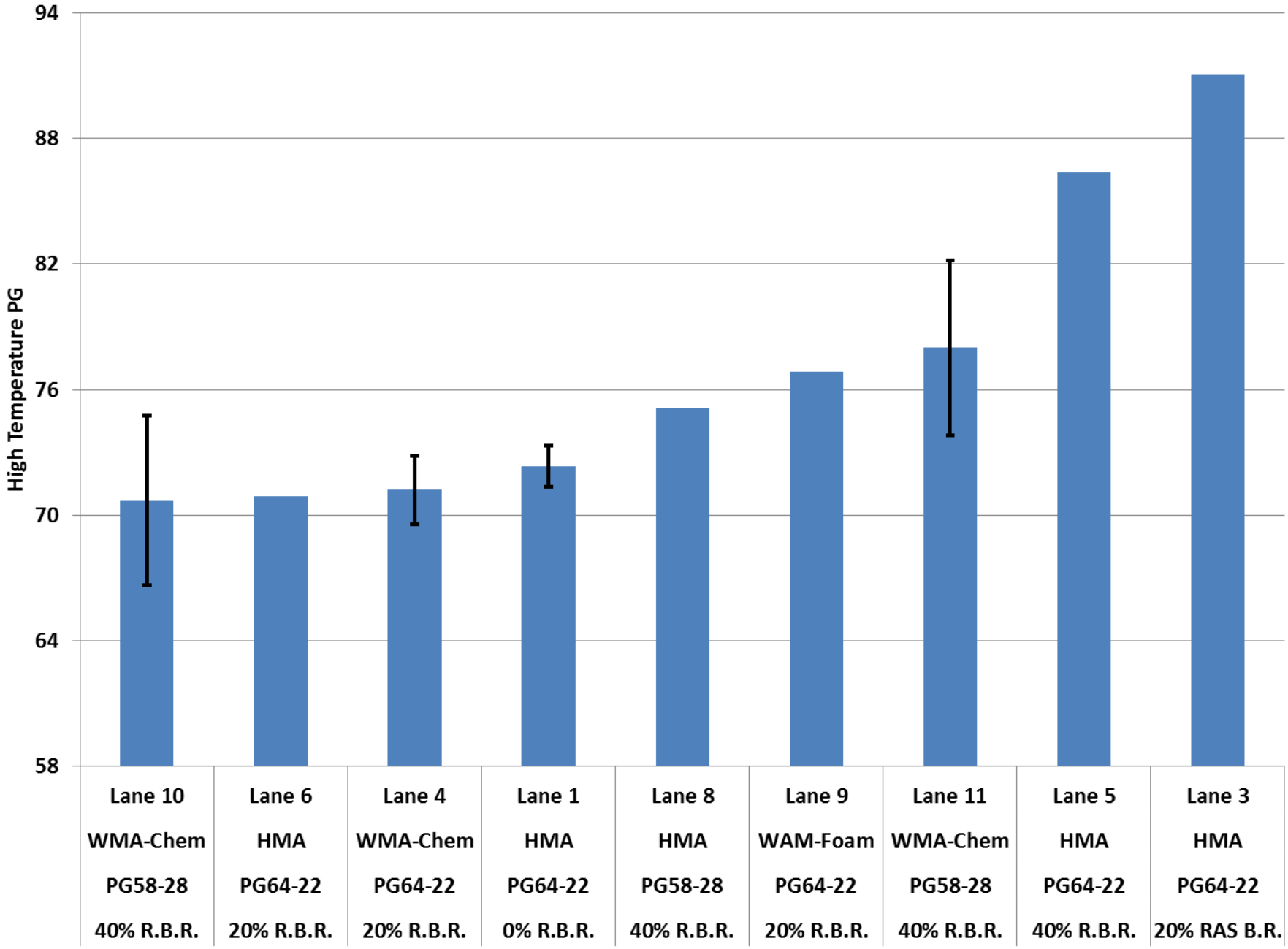


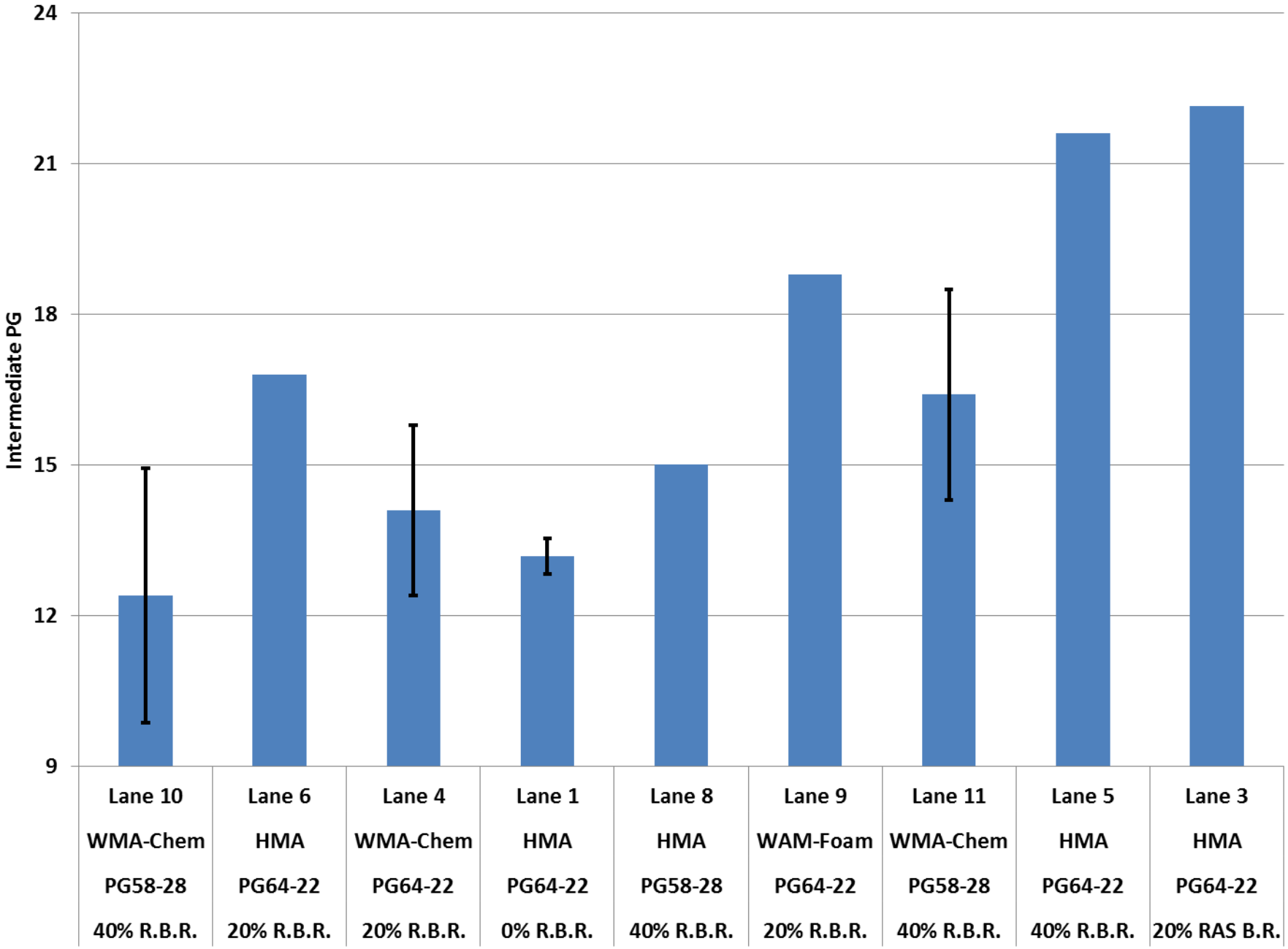
PG64-22

PG58-28

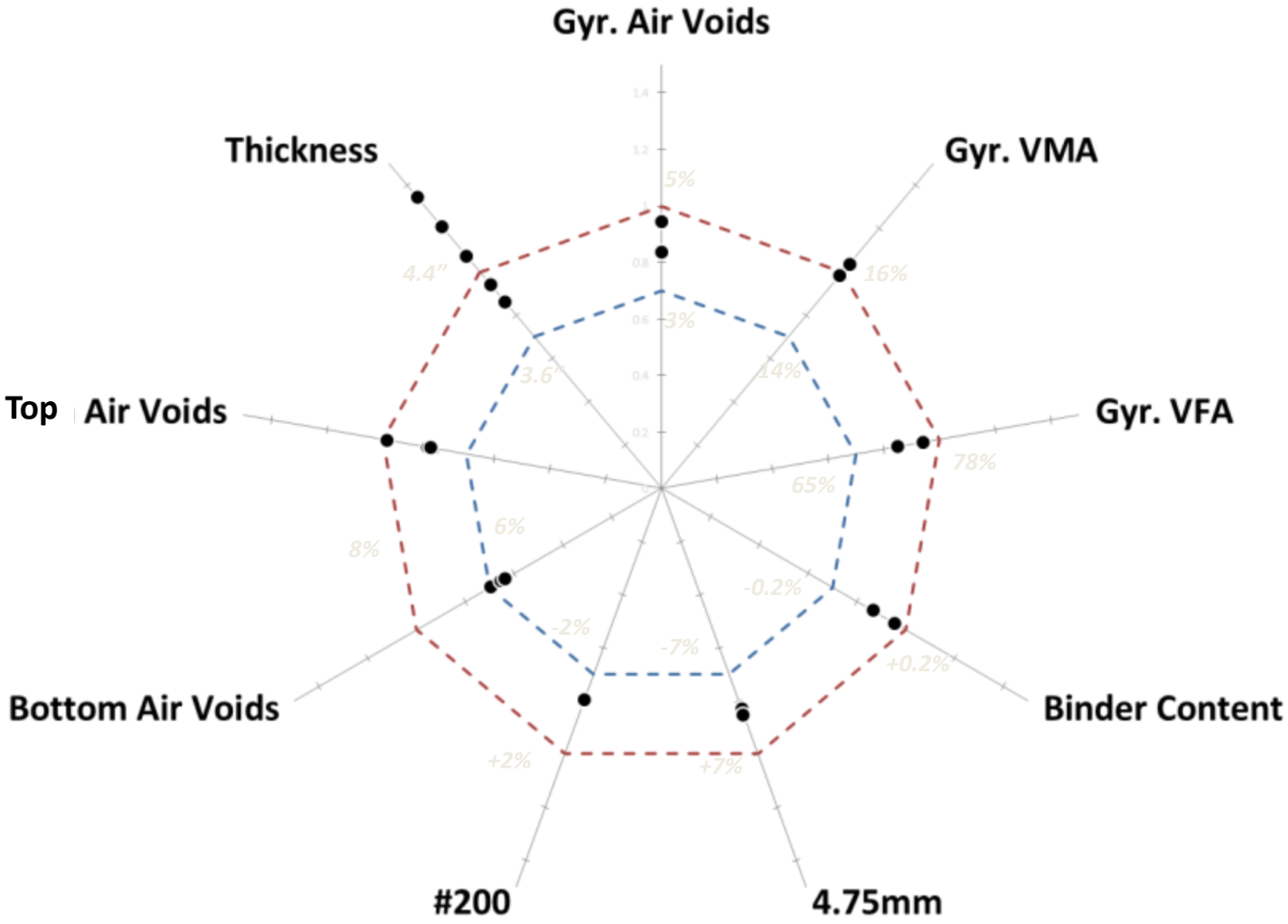
e = Evotherm

f = Foam

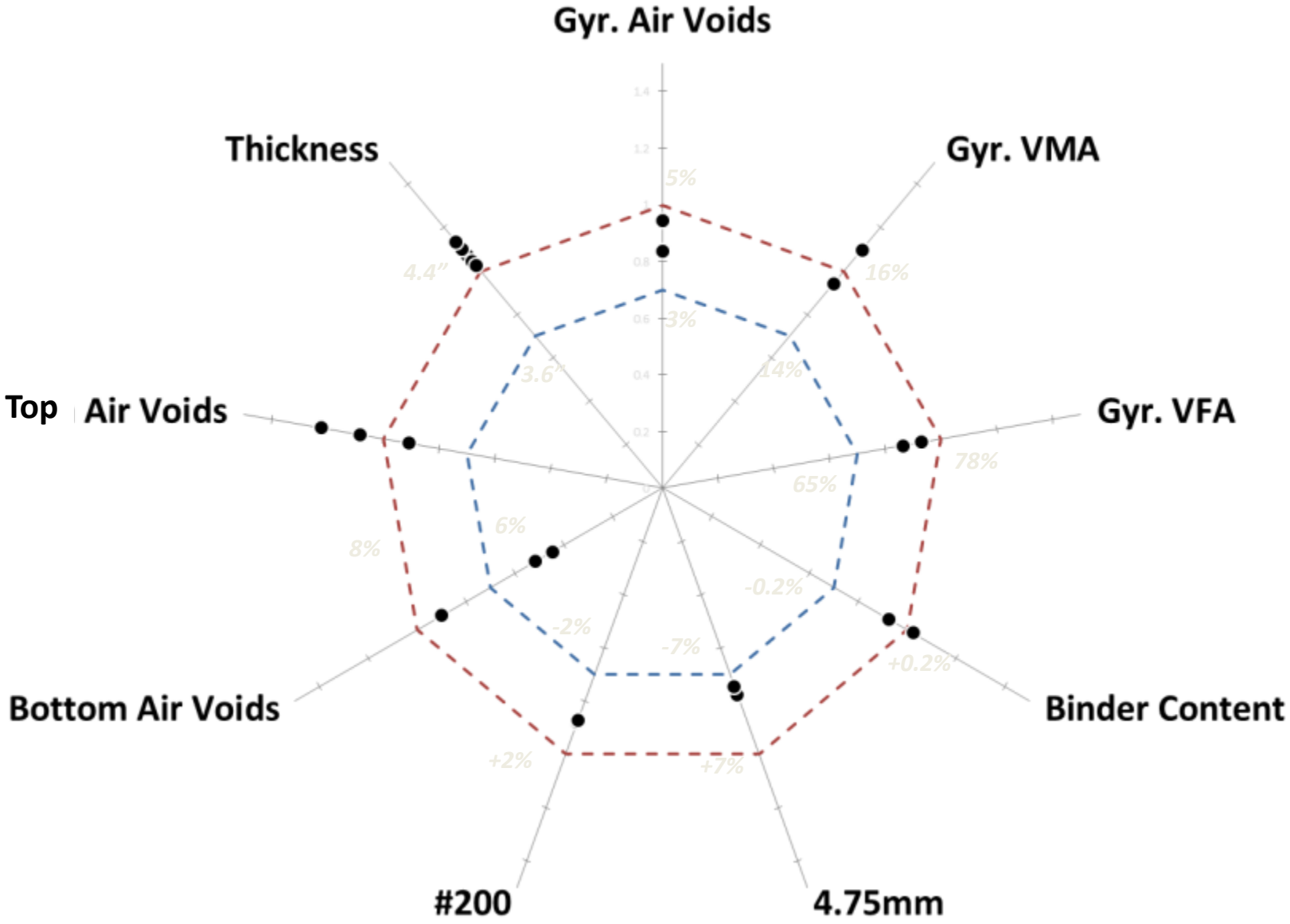

94
88
82
76
70
64
58
High Temperature PG
Lane 10
WMA-Chem
PG58-28
40% R.B.R.
Lane 6
HMA
PG64-22
20% R.B.R.
Lane 4
WMA-Chem
PG64-22
20% R.B.R.
Lane 1
HMA
PG64-22
0% R.B.R.
Lane 8
HMA
PG58-28
40% R.B.R.
Lane 9
WAM-Foam
PG64-22
20% R.B.R.
Lane 11
WMA-Chem
PG58-28
40% R.B.R.
Lane 5
HMA
PG64-22
40% R.B.R.
Lane 3
HMA
PG64-22
20% RAS B.R.


24
21
18
15
12
9
Intermediate PG
Lane 10
WMA-Chem
PG58-28
40% R.B.R.
Lane 6
HMA
PG64-22
20% R.B.R.
Lane 4
WMA-Chem
PG64-22
20% R.B.R.
Lane 1
HMA
PG64-22
0% R.B.R.
Lane 8
HMA
PG58-28
40% R.B.R.
Lane 9
WAM-Foam
PG64-22
20% R.B.R.
Lane 11
WMA-Chem
PG58-28
40% R.B.R.
Lane 5
HMA
PG64-22
40% R.B.R.
Lane 3
HMA
PG64-22
20% RAS B.R.

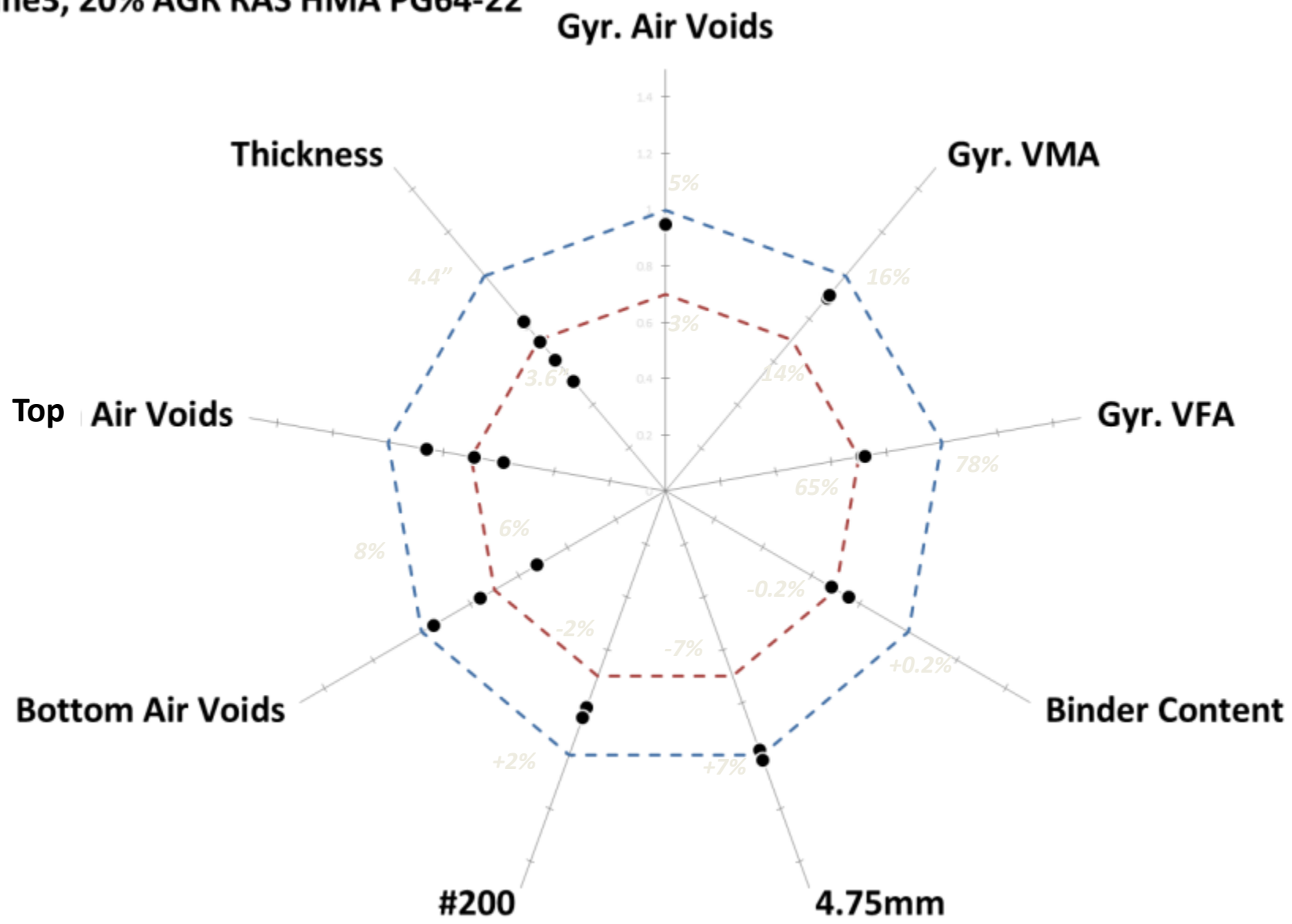
Lane1, 0% Recycle HMA PG64-22



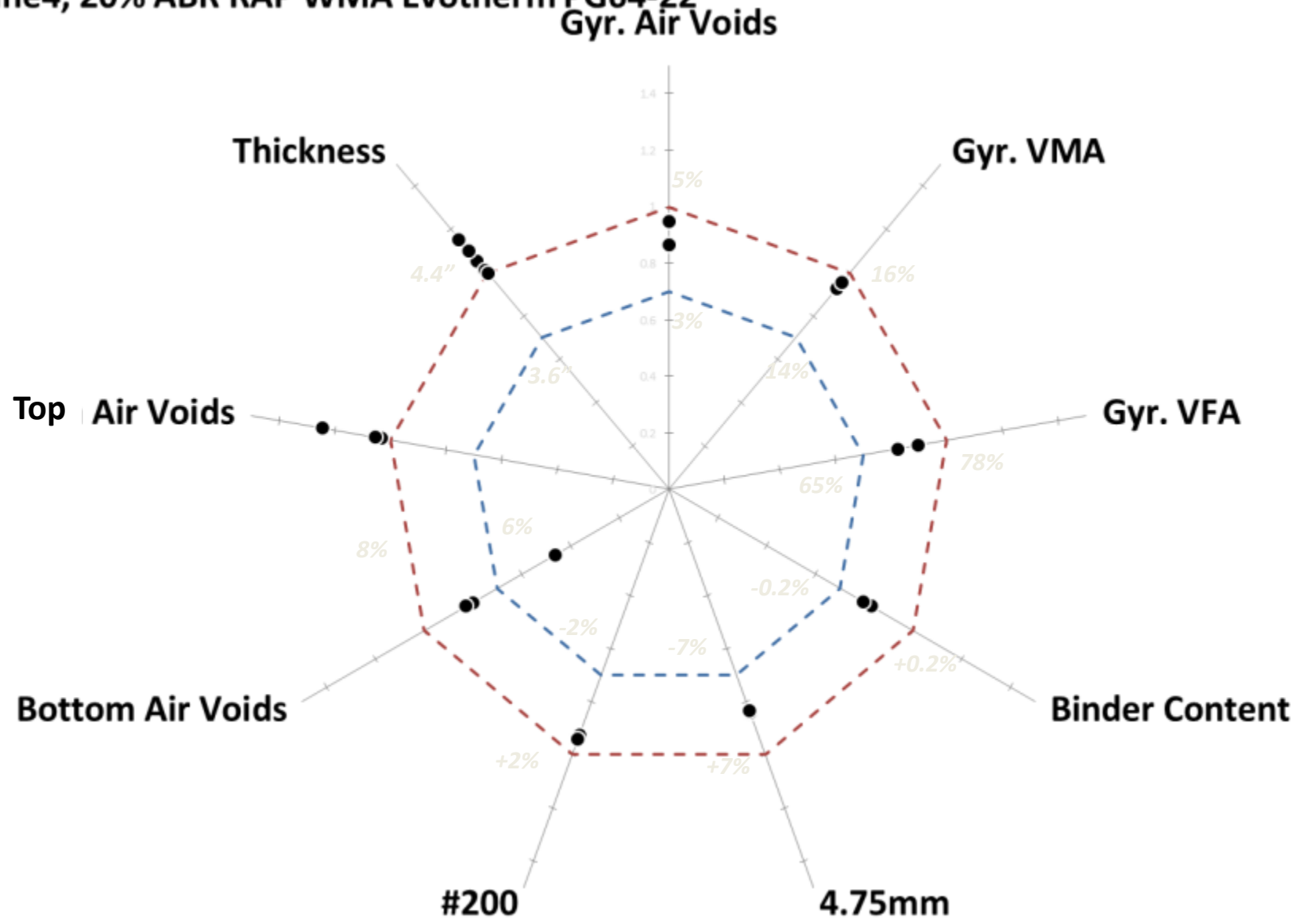
Lane2, 40% ABR RAP Foam PG58-28



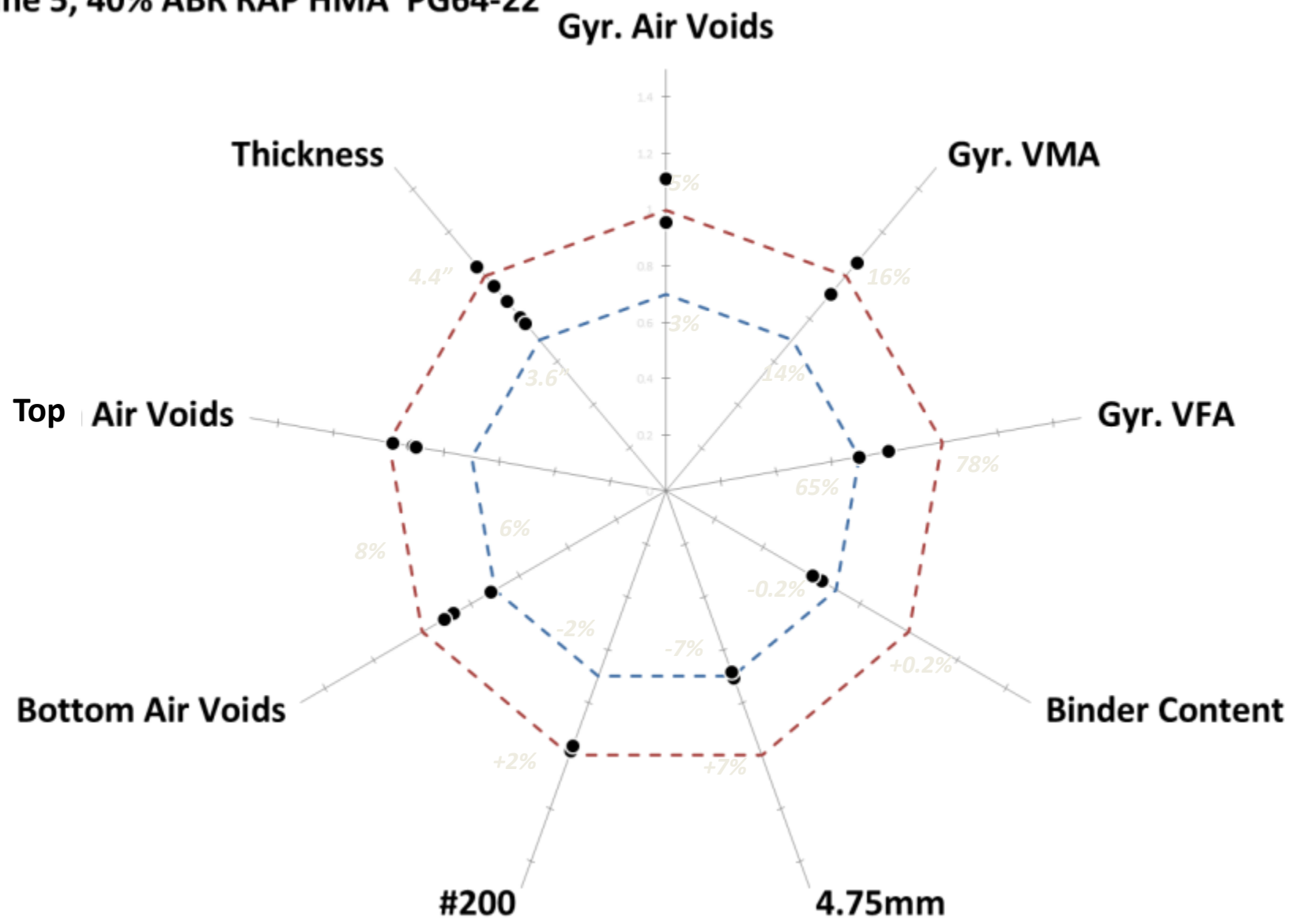
Lane3, 20% AGR RAS HMA PG64-22



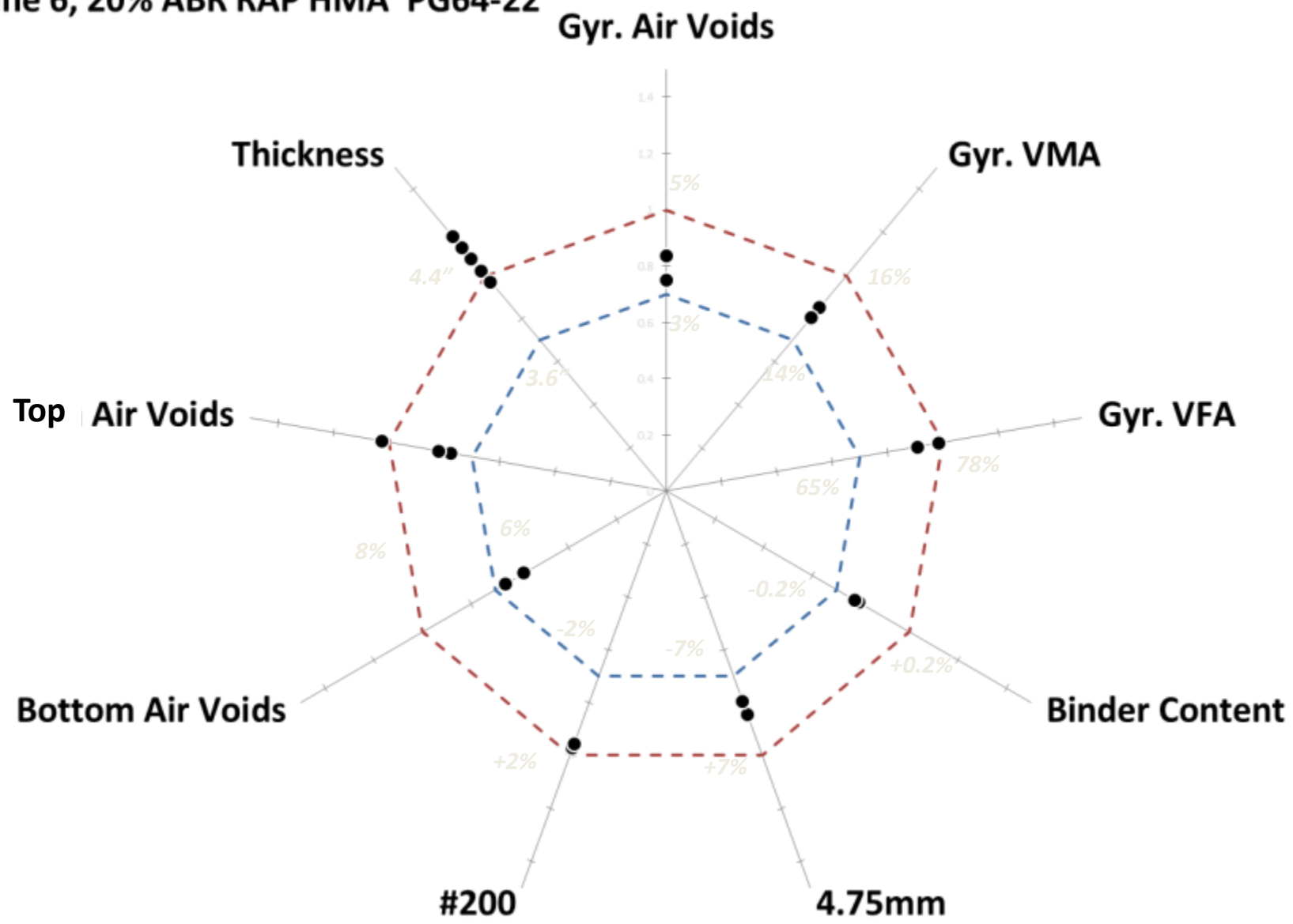
Lane4, 20% ABR RAP WMA Evotherm PG64-22



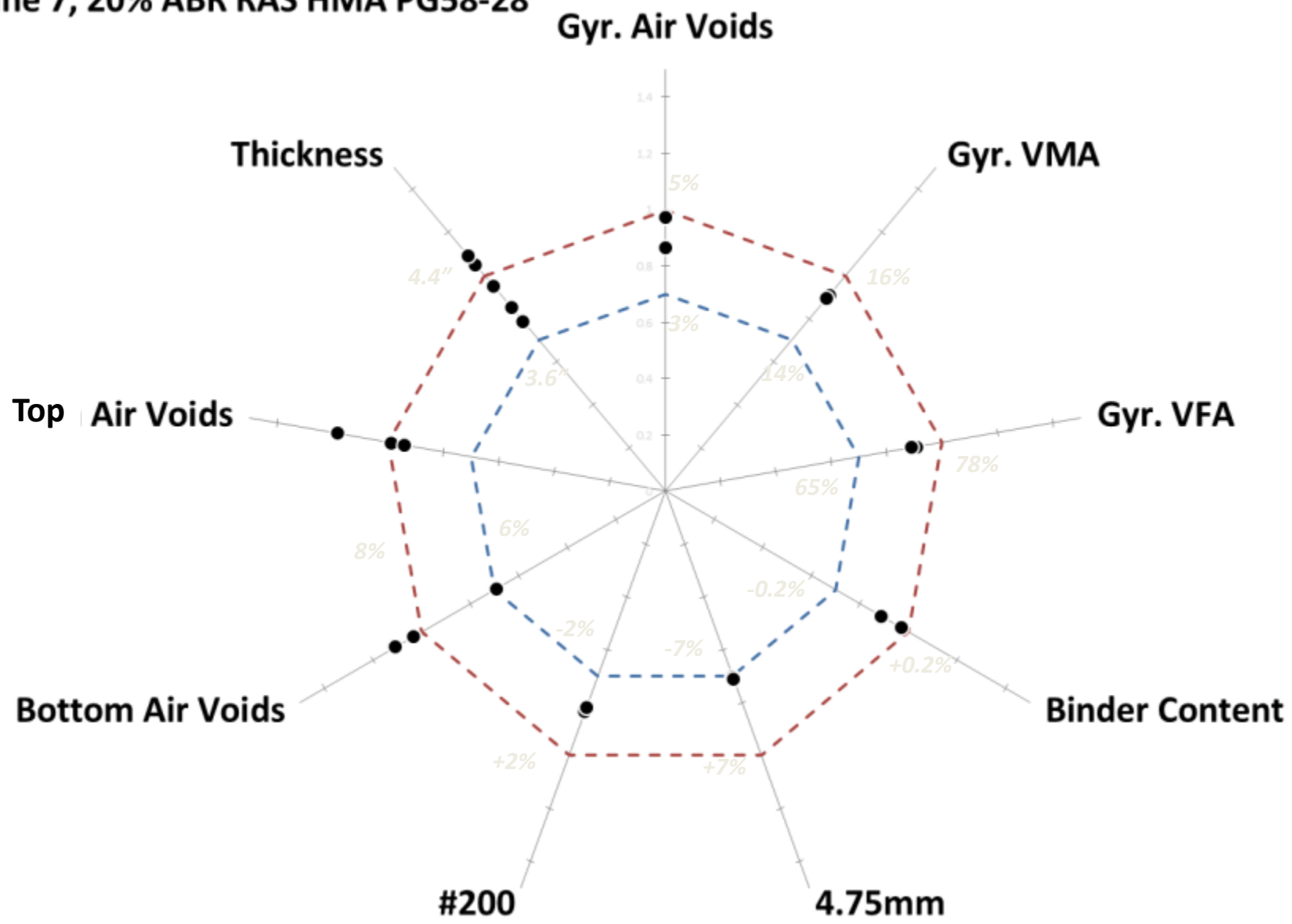
Lane 5, 40% ABR RAP HMA PG64-22



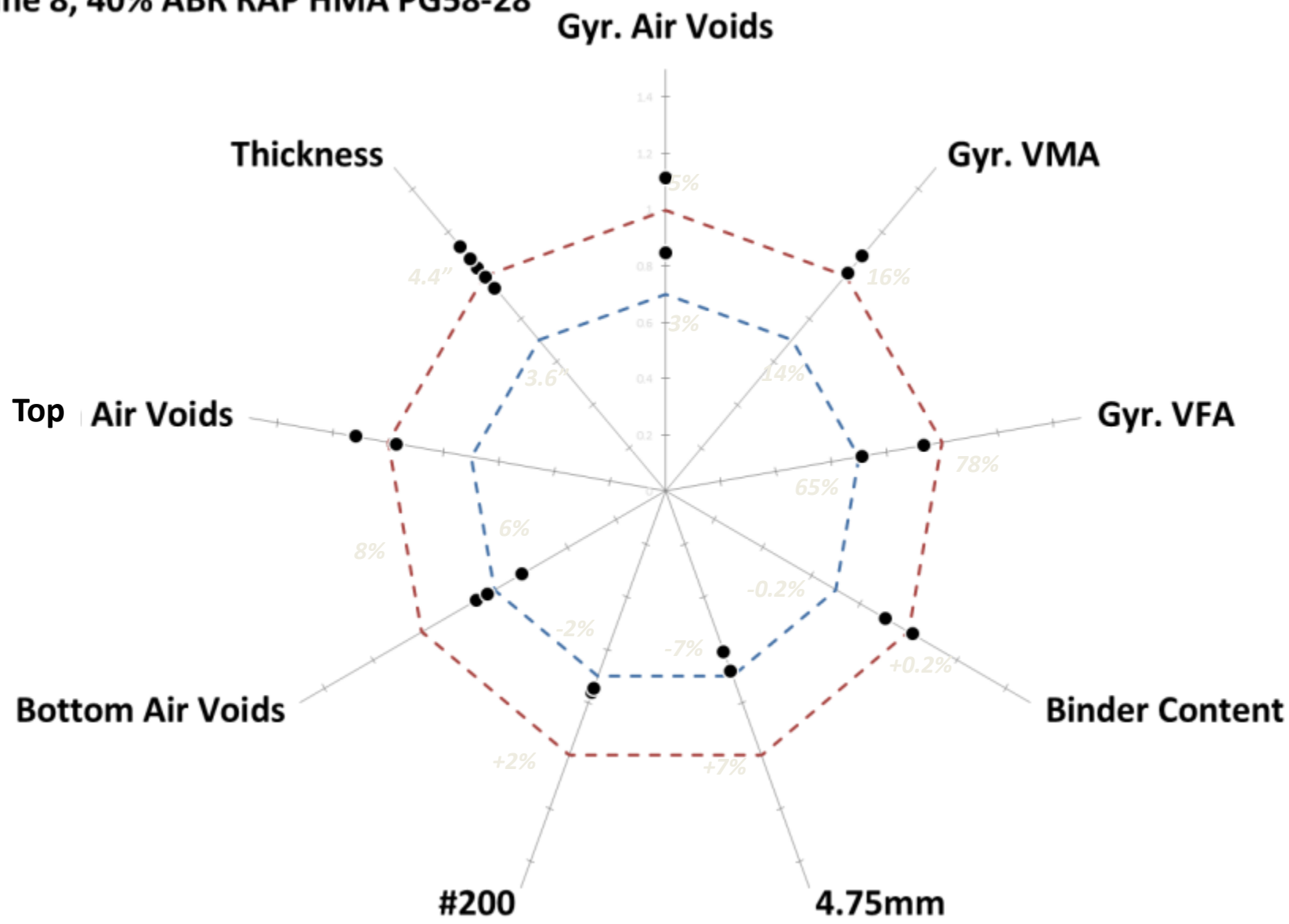
Lane 6, 20% ABR RAP HMA PG64-22



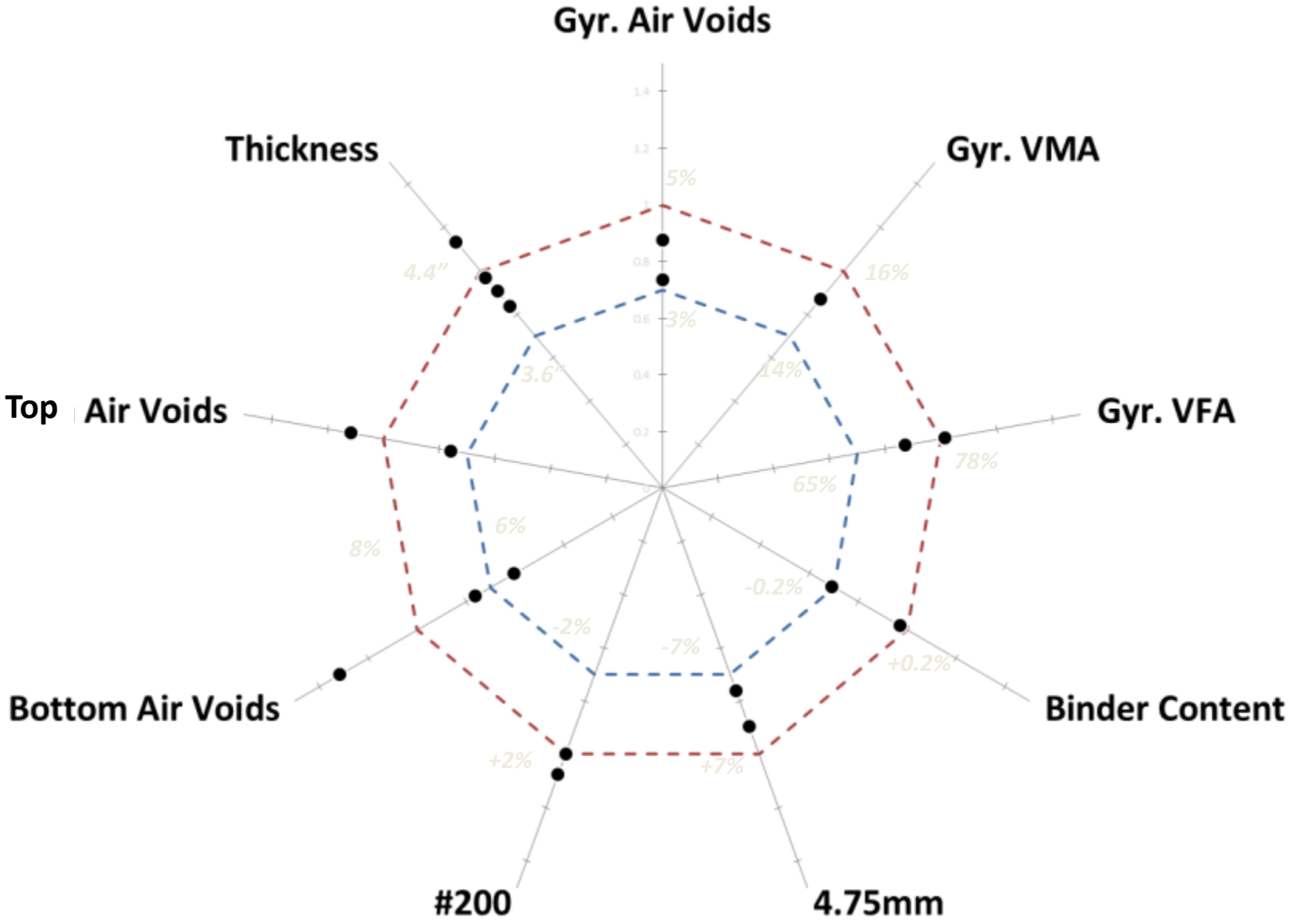
Lane 7, 20% ABR RAS HMA PG58-28



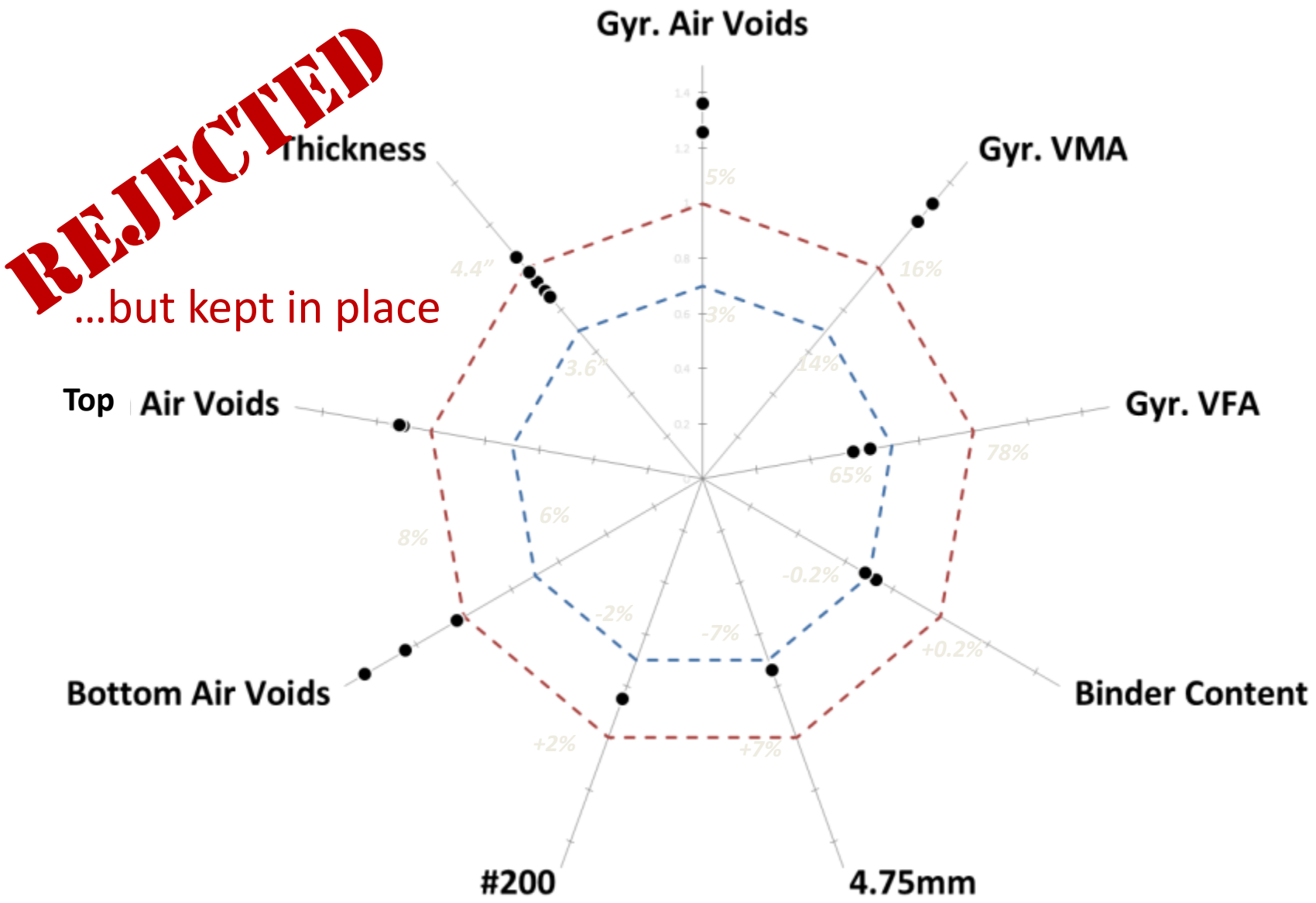
Lane 8, 40% ABR RAP HMA PG58-28



Lane9, 20% ABR RAP WMA Foam PG64-22



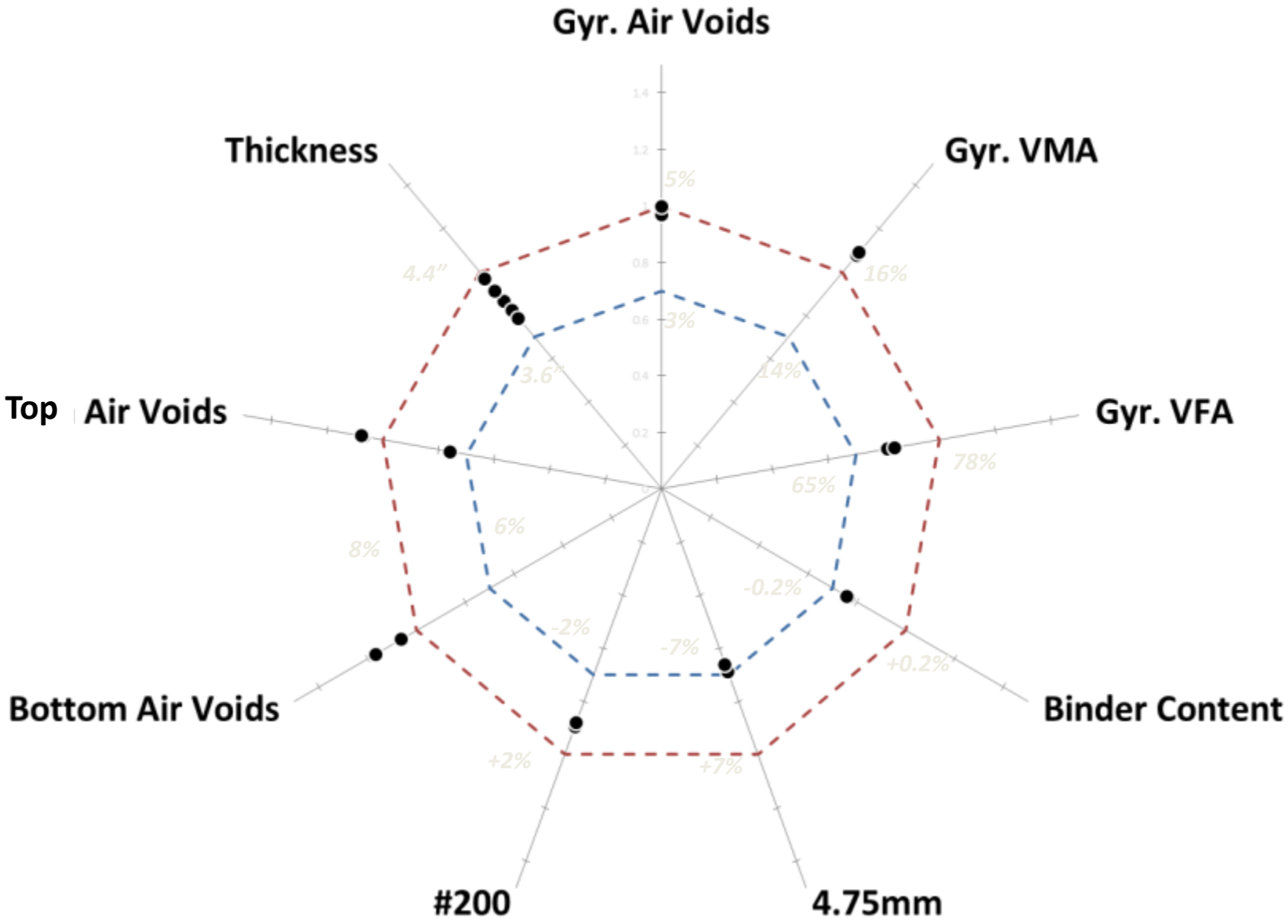
Lane 10, 40% ABR RAP WMA Evotherm PG58-28



REJECTED

…but kept in place

Lane 11, 40% ABR RAP WMA Evotherm PG58-28 (#2)



Characteristics of Recycled Asphalt Materials

RAP

- 13 samples taken as stockpile was built
- 4.7% average AC content by solvent
  - 0.2% std. dev. AC
- TCE Recovered PG
  - PG89.4-21.7
  - ITPG 29.1C

RAS

- Tear-Offs
- 99.4% Passing ½" sieve
- 85.2% Passing #4 sieve
- 20.9% AC by solvent
- High Temp >>> PG140

Dedicated RAP and RAS stockpiles for the Project