U.S. Department of Transportation
Federal Highway Administration

# AMPT – Small Scale Specimens

Asphalt Mixture ETG – April 2015

# Outline

- TP 79-15 Appendix X3
  - Jeff Withee
- ALF Experience
  - Nelson Gibson
- NCHRP IDEA Project
  - Richard Kim

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# TP 79-15 Appendix X3

X3.1 Small Test Specimens

Test specimens smaller than the standard AMPT geometry can be obtained from constructed pavement layers to measure the dynamic modulus for use in applications such as forensic investigations and field monitoring of test sections. **38-mm diameter specimens** can be cored horizontally from within the bounds **of construction lifts that are at least 50 mm thick**. The ends of the core are then trimmed to create a specimen with a recommended **height of 110 mm**. **No precision statements** have been developed for these sample sizes as yet.

# TP 79-15 Appendix X3

X3.1 Small Test Specimens (continued)

The **same** gauge points, same gauge length, same type of friction reducers, same specimen extensometers and same AMPT software and inputs are used. The top and bottom platens used with standard size geometry should not be used, and **smaller platens with smaller friction reducers are recommended**. Reduced-size sample geometry is only intended for **unconfined dynamic modulus** characterization. **Prismatic specimens 25 mm x 50 mm x 100 mm** have also been evaluated for thinner construction lifts; calculate the rectangular cross-sectional area and then calculate the effective circular diameter that yields the same cross-sectional area to be entered in to the AMPT test control software.

# TP 79-15 Appendix X3

X3.2 Data quality indicators for small test specimens

**Data quality indicators** identified in TP 79, Table 1 are applicable for **19 mm and smaller** nominal maximum aggregate size (NMAS) mixtures for small cylindrical 38 mm x 100 mm specimens. Data quality indicators for small-size samples require **careful review for temperatures higher than 38°C and/or larger NMAS**. (See Li, X. and N. Gibson, "Using Small Specimens for AMPT Dynamic Modulus and Fatigue Tests", Asphalt Paving Technology, Journal of the Association of Asphalt Paving Technologists, pp. 579-615, Vol 82, 2013).

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# Why?

- Although APT = *accelerated* , the experiment will last about 2 years; November 2013 to December 2015
- Quantify how laboratory-measured dynamic modulus (and fatigue) change with time & with depth.
- To what degree does WMA, RAS, HighRAP affect relative aging?


*Time Lapse Video of ALF(s) Testing From Lane to Lane*

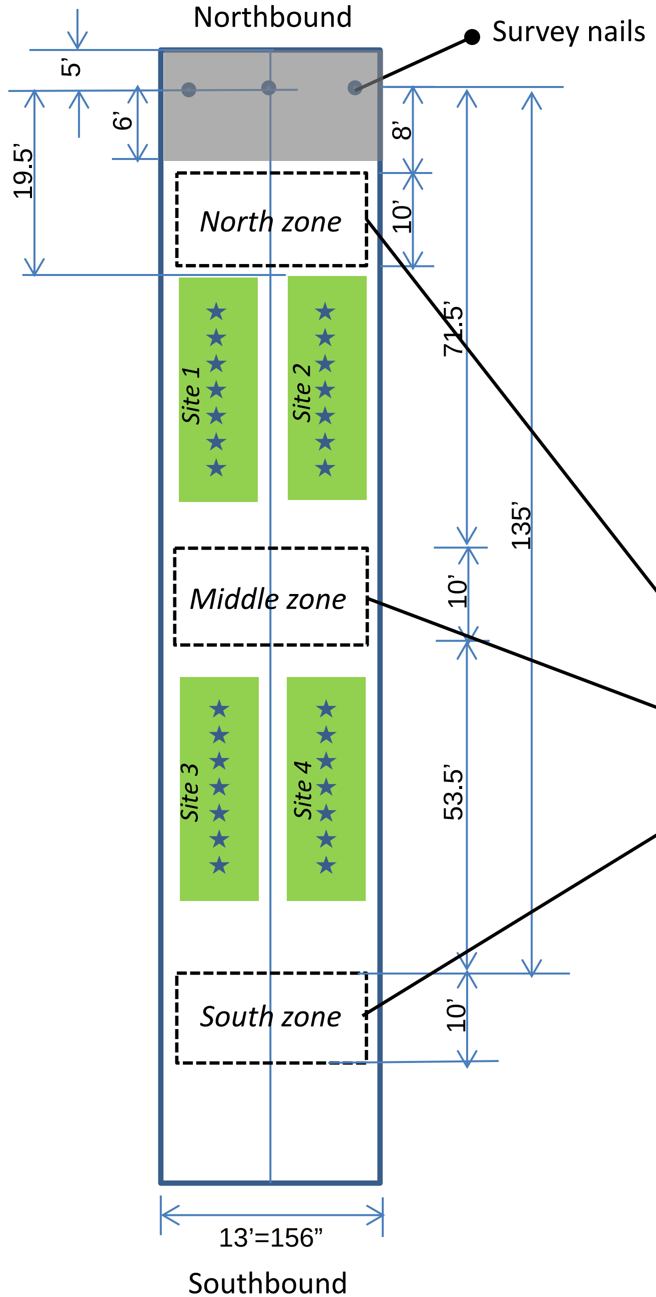
# Core Sampling Timeline

2013 2014 2015 2016

JFMAMJJASOND JFMAMJJASOND JFMAMJJASOND JFMAMJJASOND

| | t = 0m | t = 6m | t = 12m | t = 18m | t = 24m | t = 30m | t = 36m |
|---|---|---|---|---|---|---|---|
| | Top<br>Bottom | Top | Top<br>Bottom | Top | Top<br>Bottom | Top | Top<br>Bottom |
| Cores Taken | ✓ | ✓ | ✓ | ⌛ | | | |
| Data Analyzed | ✓ | ✓ | ⌛ | | | | |

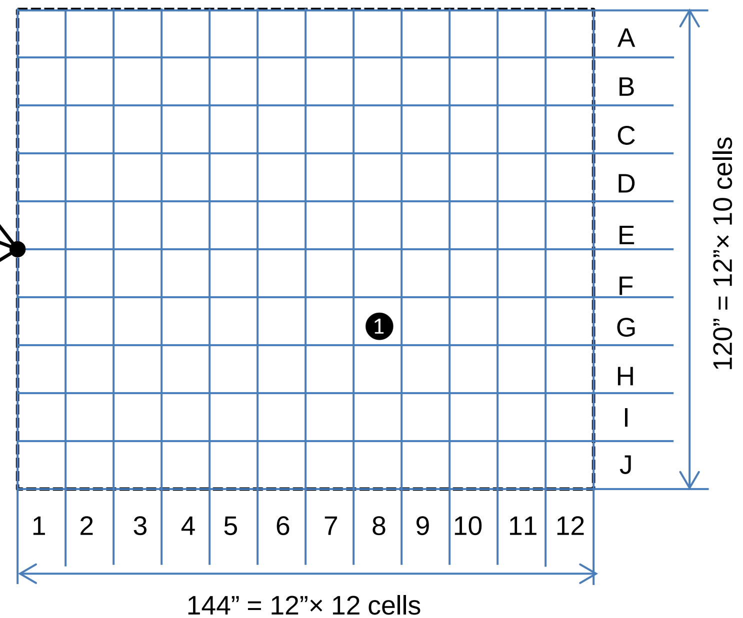
# Grid for core collection zones

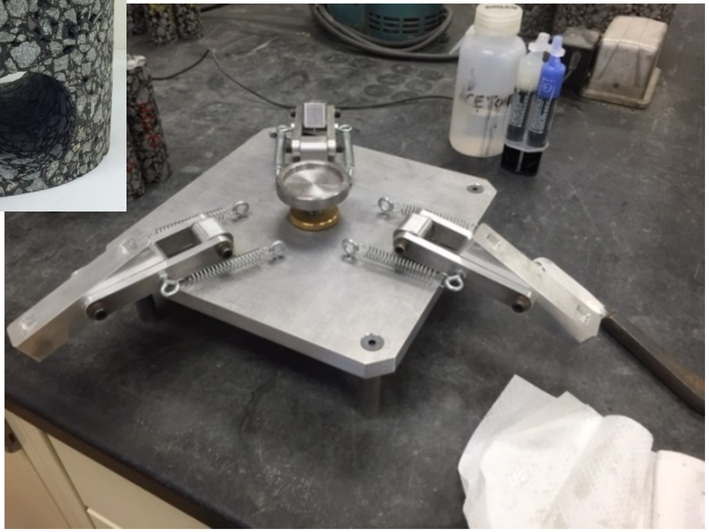


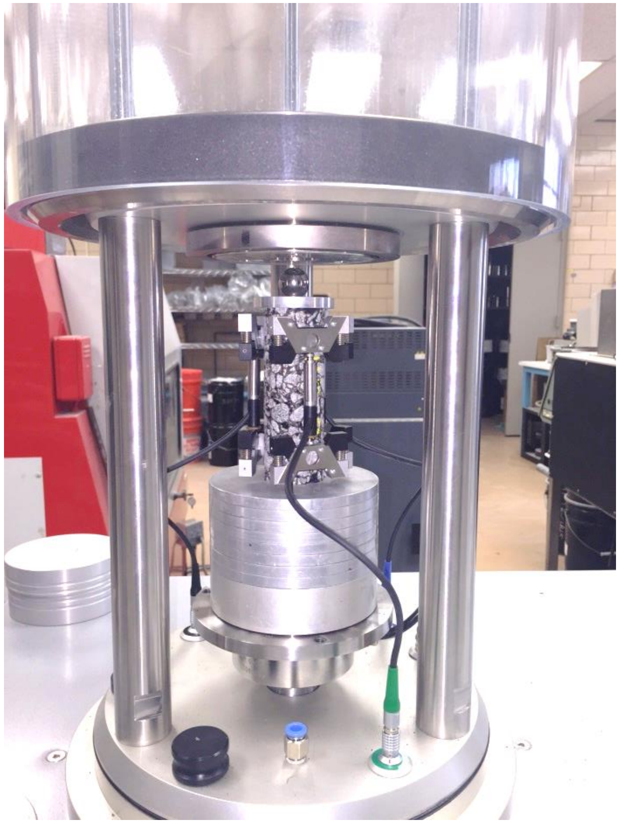

***Core Identification***

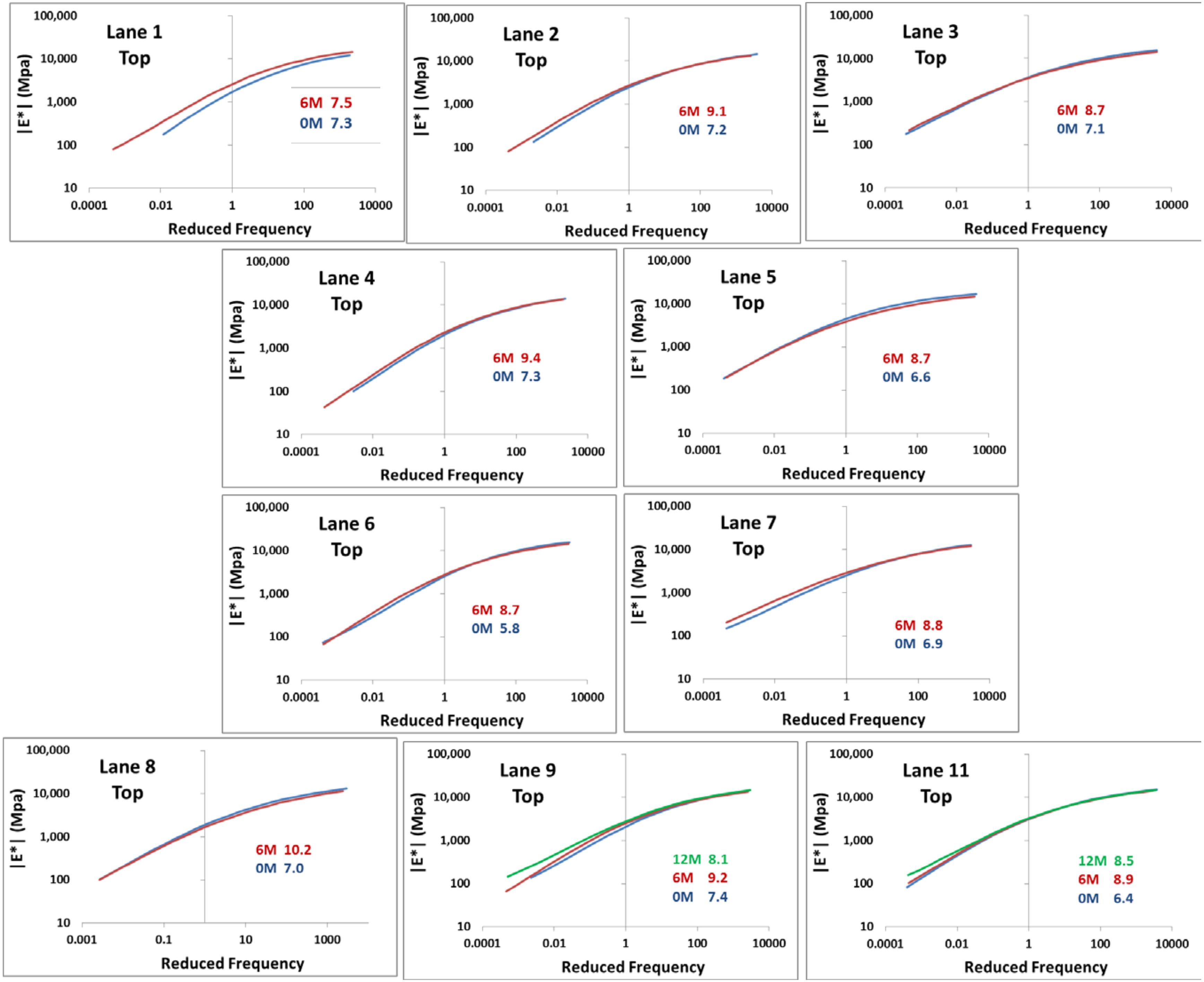
***Lane #_Coring Zone_Trans. Cell #_Long. Cell letter***
**(1~10)_(N or C or S)_(1~12)_(A~J)**

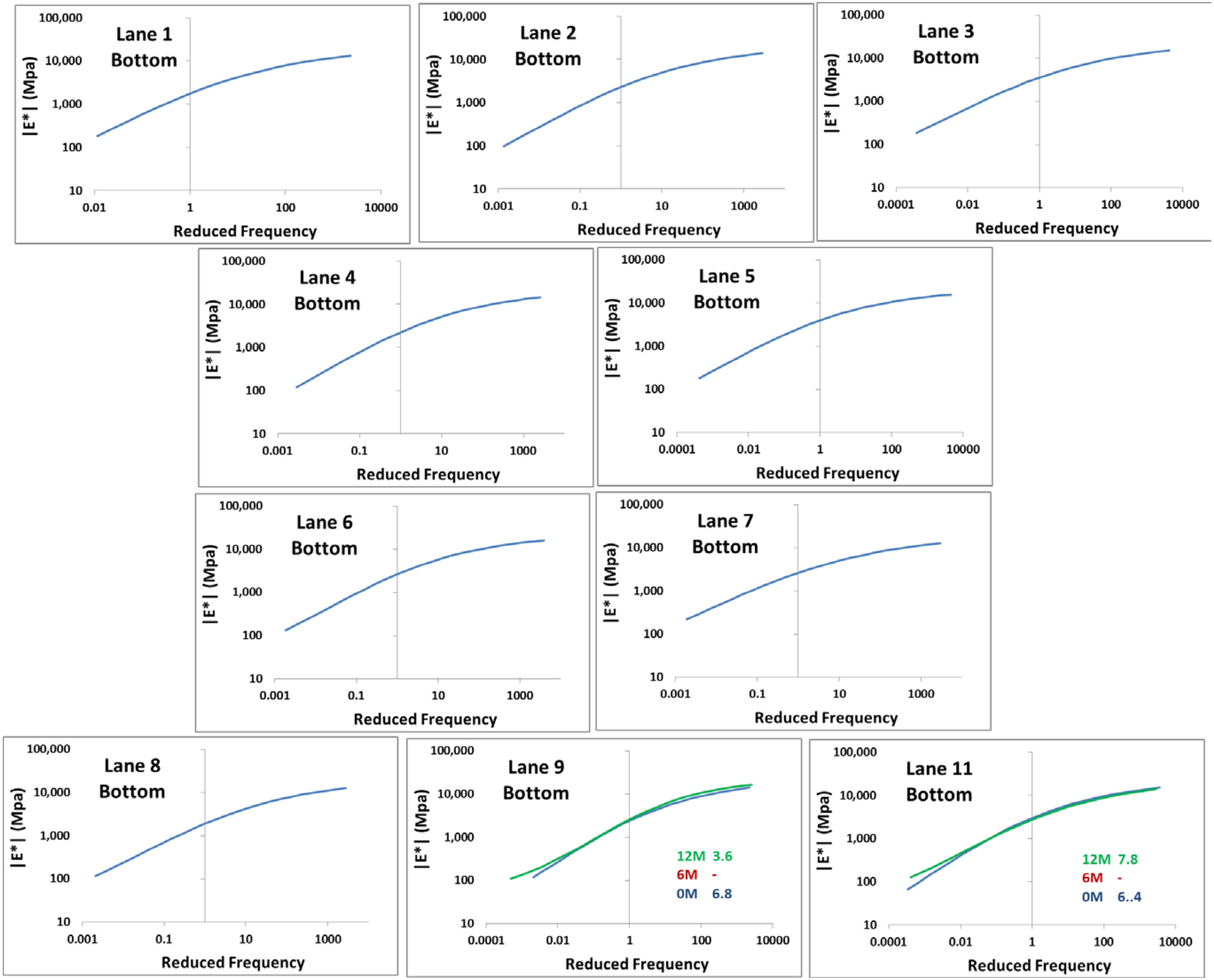
*Example* ❶: ***2_N_8_G*** (*if this is from the north zone of lane 2*)








Lane 1
Top
6M 7.5
0M 7.3
Lane 2
Top
6M 9.1
0M 7.2
Lane 3
Top
6M 8.7
0M 7.1
Lane 4
Top
6M 9.4
0M 7.3
Lane 5
Top
6M 8.7
0M 6.6
Lane 6
Top
6M 8.7
0M 5.8
Lane 7
Top
6M 8.8
0M 6.9
Lane 8
Top
6M 10.2
0M 7.0
Lane 9
Top
12M 8.1
6M 9.2
0M 7.4
Lane 11
Top
12M 8.5
6M 8.9
0M 6.4
|E*| (Mpa)
100,000
10,000
1,000
100
10
Reduced Frequency
0.0001
0.001
0.01
0.1
1
10
100
1000
10000



Lane 1 Bottom
Lane 2 Bottom
Lane 3 Bottom
Lane 4 Bottom
Lane 5 Bottom
Lane 6 Bottom
Lane 7 Bottom
Lane 8 Bottom
Lane 9 Bottom
Lane 11 Bottom
|E*| (Mpa)
Reduced Frequency
100,000
10,000
1,000
100
10
0.0001
0.001
0.01
0.1
1
10
100
1000
10000
12M 3.6
6M -
0M 6.8
12M 7.8
6M -
0M 6..4

# Comments

- This is still preliminary
- More time is needed to analyze the data
- There are air void differences at different times of sampling (and location)

- Future Activities:
  - Address air void effects
  - Incorporate metrics such as ***Degree-Days***
  - Collect more feedback from the ETG & Others.

# How much do engineering properties vary depending on density?

**Witczack |E*| Predictive Model**

$$\log_{10}E^* = -0.349 + 0.754(|G_b^*|^{-0.0052}) \times \Big(6.65 - 0.032\rho_{200} + 0.0027\rho_{200}^2 + 0.011\rho_4 - 0.0001\rho_4^2 + 0.006\rho_{38} - 0.00014\rho_{38}^2 - 0.08V_a - 1.06\left(\frac{V_{beff}}{V_a + V_{beff}}\right)\Big) + \frac{2.56 + 0.03V_a + 0.71\left(\frac{V_{beff}}{V_a+V_{beff}}\right) + 0.012\rho_{38} - 0.0001\rho_{38}^2 - 0.01\rho_{34}}{1 + e^{(-0.7814-0.5785\log|G_b^*|+0.8834\log\delta_b)}}$$

**Hirsch |E*| Predictive Model**

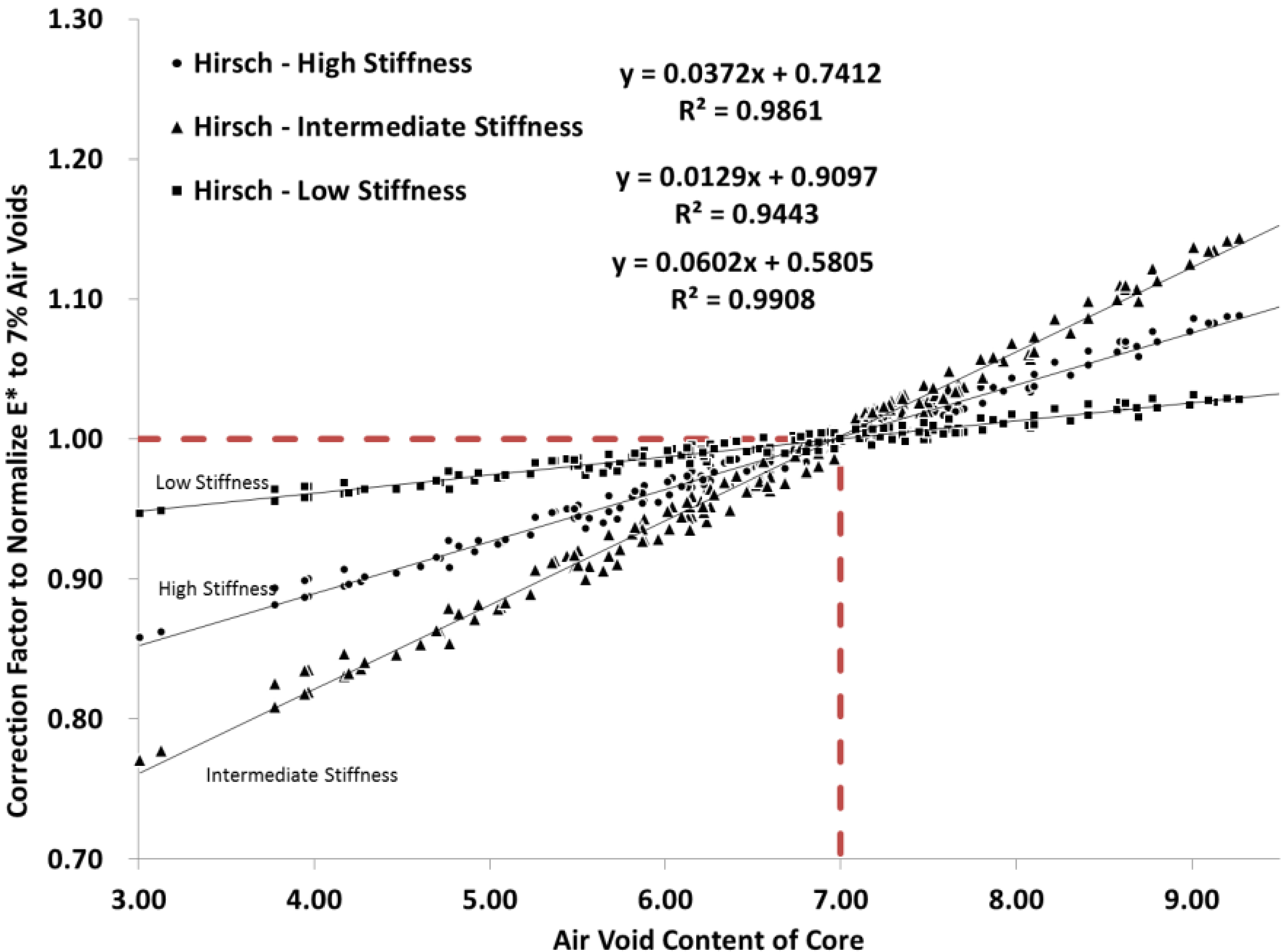
$$|E^*|_{mix} = Pc \times \left[4200000 \times \left(1 - \frac{VMA}{100}\right) + 3 \times |G^*|_{binder}\left(\frac{VFA \times VMA}{10000}\right)\right] + (1 - Pc) \times \left[\frac{1 - \frac{VMA}{100}}{4200000} + \frac{VMA}{3 \times VFA \times |G^*|_{binder}}\right]^{-1}$$

$$Pc = \frac{\left(20 + \frac{VFA\times3\times|G^*|_{binder}}{VMA}\right)^{0.58}}{650 + \left(\frac{VFA\times3\times|G^*|_{binder}}{VMA}\right)^{0.58}}$$

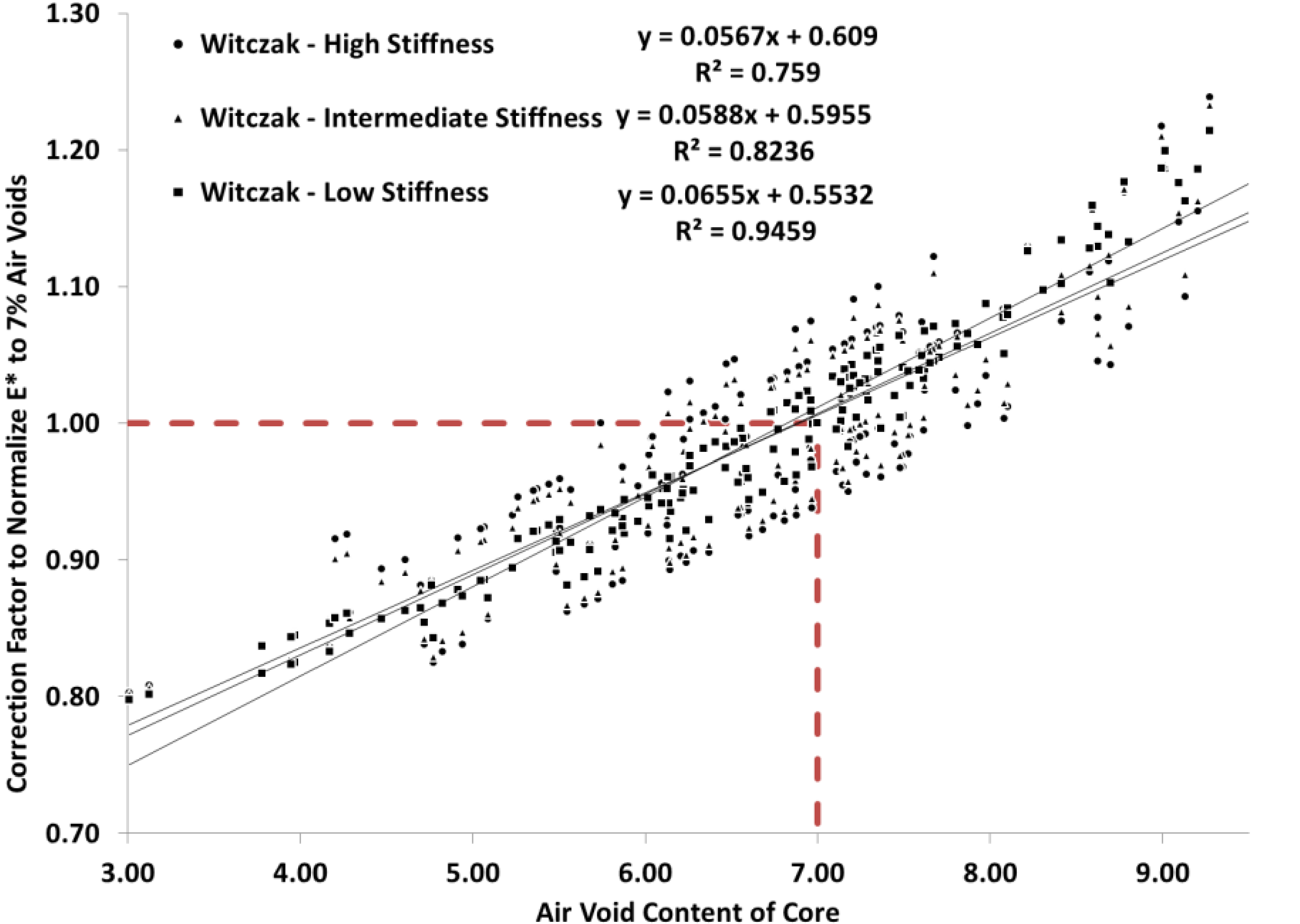
# How much do engineering properties vary depending on density?

- |E*| Normalization Approach:

$$\frac{Predicted\ |E*|\ @\ Target\ 7\%\ Air\ Voids}{Predicted\ |E*|\ @\ in-place\ Volumetrics}$$

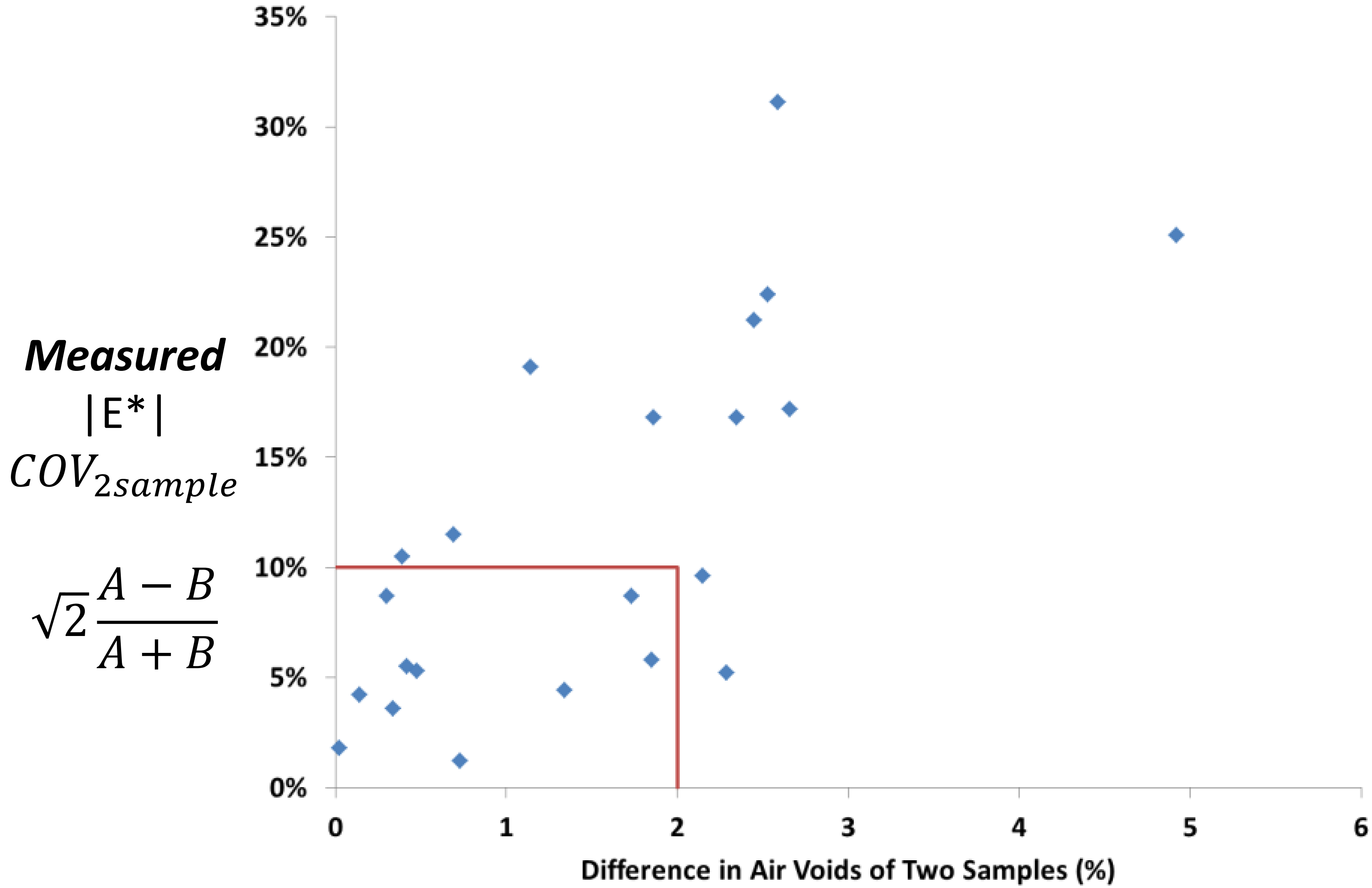


Hirsch - High Stiffness
Hirsch - Intermediate Stiffness
Hirsch - Low Stiffness
y = 0.0372x + 0.7412
R² = 0.9861
y = 0.0129x + 0.9097
R² = 0.9443
y = 0.0602x + 0.5805
R² = 0.9908
Low Stiffness
High Stiffness
Intermediate Stiffness
Correction Factor to Normalize E* to 7% Air Voids
Air Void Content of Core
1.30
1.20
1.10
1.00
0.90
0.80
0.70
3.00
4.00
5.00
6.00
7.00
8.00
9.00



Witczak - High Stiffness
Witczak - Intermediate Stiffness
Witczak - Low Stiffness
y = 0.0567x + 0.609
R² = 0.759
y = 0.0588x + 0.5955
R² = 0.8236
y = 0.0655x + 0.5532
R² = 0.9459
Correction Factor to Normalize E* to 7% Air Voids
Air Void Content of Core
1.30
1.20
1.10
1.00
0.90
0.80
0.70
3.00
4.00
5.00
6.00
7.00
8.00
9.00

Based on ***predictive equations*** … it seems that about every 1% change in air void content (and associated VMA, VFA changes) there is about a 5% change in |E*|



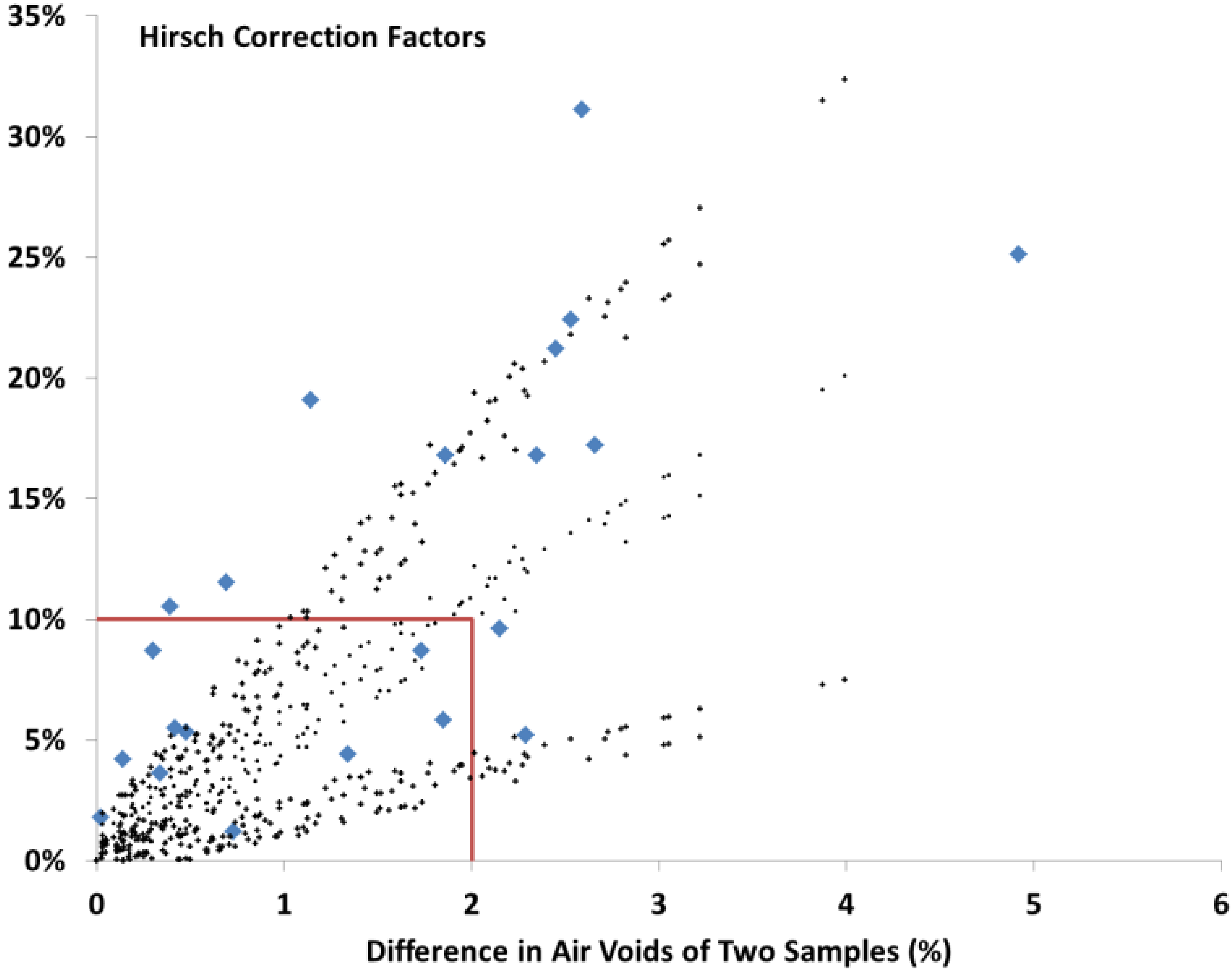
Measured
|E*|
$COV_{2sample}$
$\sqrt{2}\frac{A-B}{A+B}$
35%
30%
25%
20%
15%
10%
5%
0%
0
1
2
3
4
5
6
Difference in Air Voids of Two Samples (%)

**Measured**

|E*|

$COV_{2sample}$

$$\sqrt{2}\frac{A-B}{A+B}$$

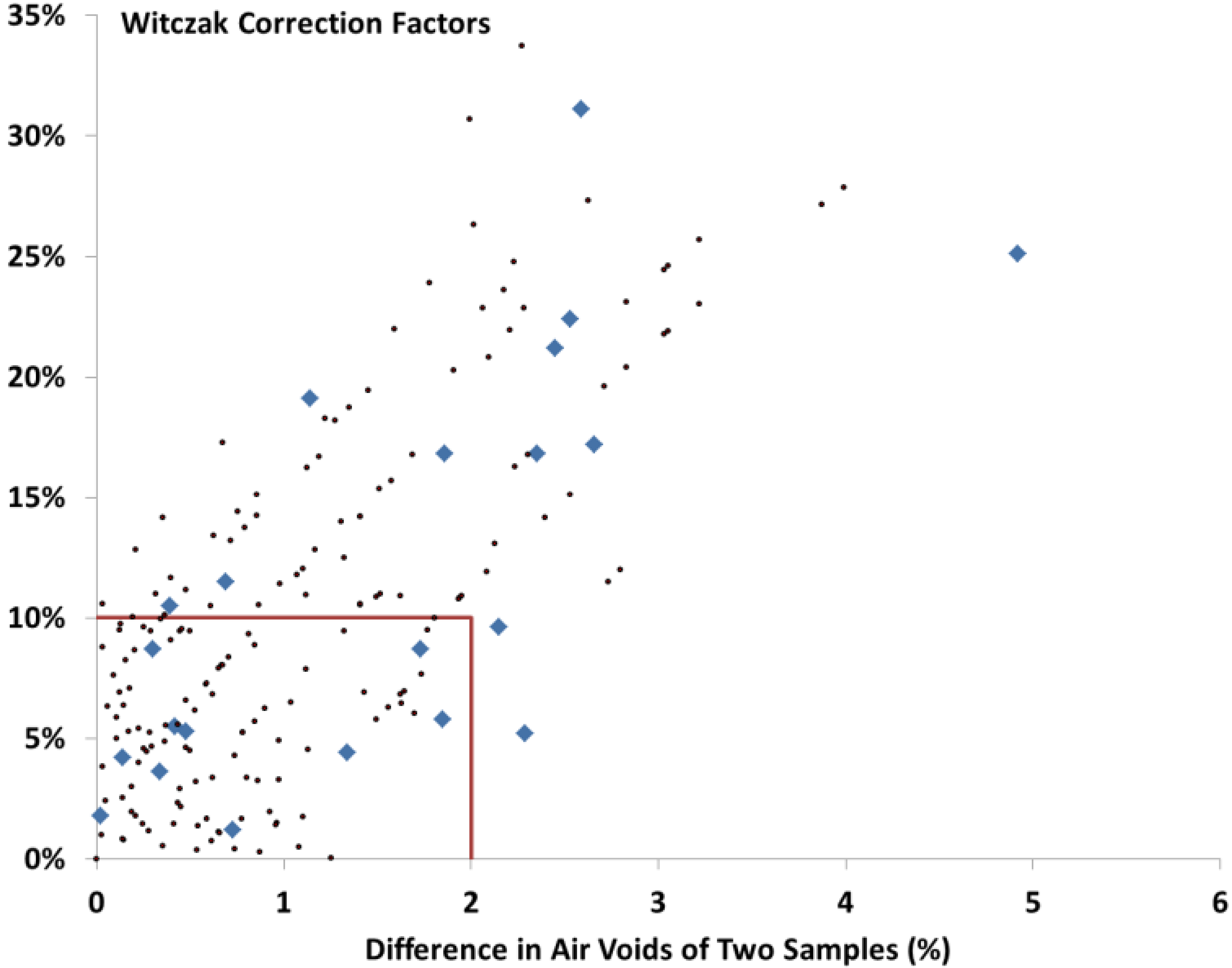


***Measured***

|E*|

$$COV_{2sample}$$

$$\sqrt{2}\,\frac{A-B}{A+B}$$



Data from:

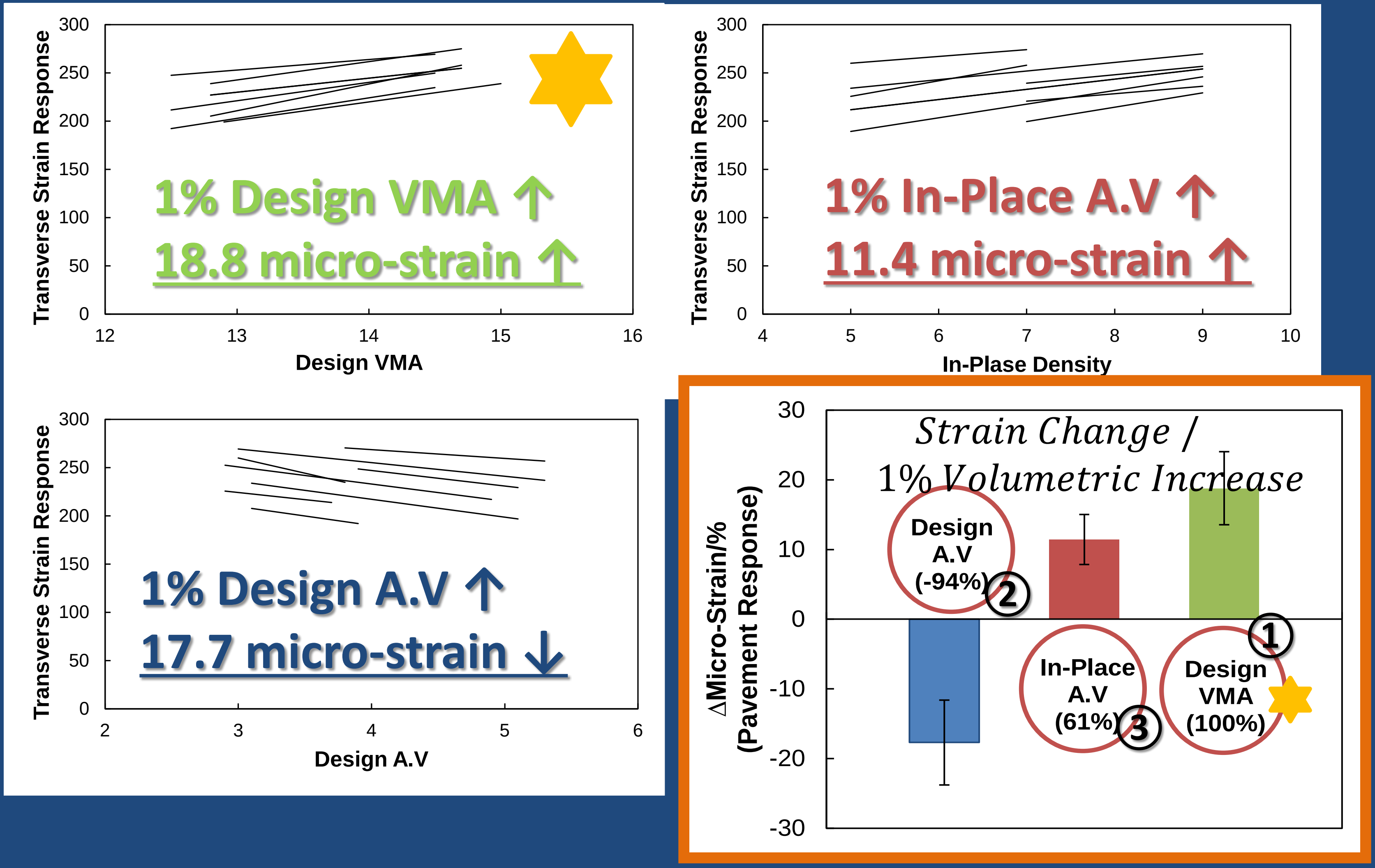
Lee, Gibson, & Kim (TRB 2015) *Investigation of Effects of Asphalt Mix Design Targets and Compaction on Fatigue Performance of Asphalt Mixtures Using Mechanistic Models*

# Final Mix Designs and Compaction Levels

- Design AVs: Binder Content (±0.3~0.4%)
- In-Place AVs: Gyratory Specimen Height (±4~5mm)

| (%) | 100% CA LUW (VMA 15) | | | 95% LUW CA (VMA 14) | | | 88% LUW CA (VMA 13) | | |
|---|---|---|---|---|---|---|---|---|---|
| **Design VMA** | 15 | 14.5 | 14.7 | 14.1 | 13.5 | 13.7 | 12.9 | 12.5 | 12.8 |
| **Design A.V** | 5.3 | 3.8 | 3.0 | 4.9 | 3.7 | 2.9 | 5.1 | 3.9 | 3.1 |
| **Binder Content** | 4.2 | 4.5 | 4.9 | 3.8 | 4.1 | 4.4 | 3.2 | 3.6 | 3.9 |
| **VFA** | 64.7 | 73.8 | 79.6 | 65.2 | 72.6 | 78.7 | 60.5 | 68.8 | 75.8 |
| **Compacted Specimen A.V (In-Place A.V)** | - | 5% **C** | 5% **F** | - | 5% **J** | 5% **M** | - | 5% **Q** | 5% **T** |
| | 7% **A** | 7% **D** | 7% **G** | 7% **H** | 7% **K** | 7% **N** | 7% **O** | 7% **R** | 7% **U** |
| | 9% **B** | 9% **E** | - | 9% **I** | 9% **L** | - | 9% **P** | 9% **S** | - |

# Mix Design Targets and Compaction Effect on LVE Pavement Response



| (%) | 100% CA LUW (VMA 15) | | | 95% LUW CA (VMA 14) | | | 88% LUW CA (VMA 13) | | |
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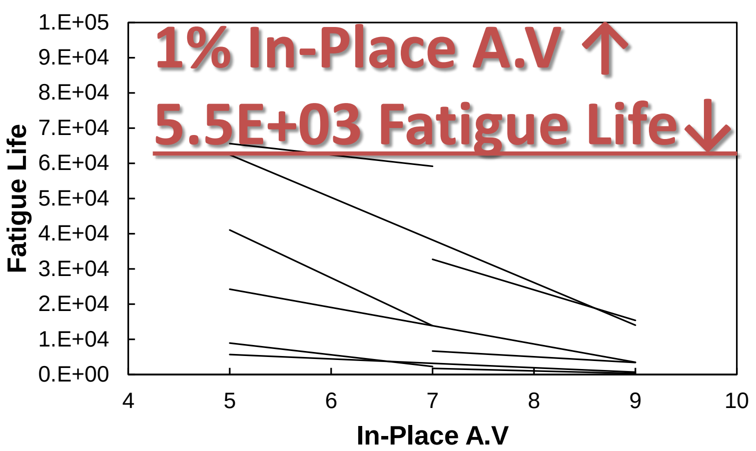
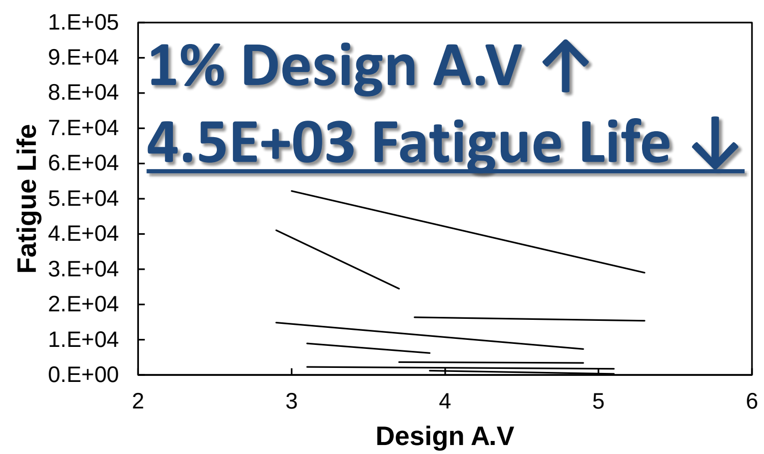
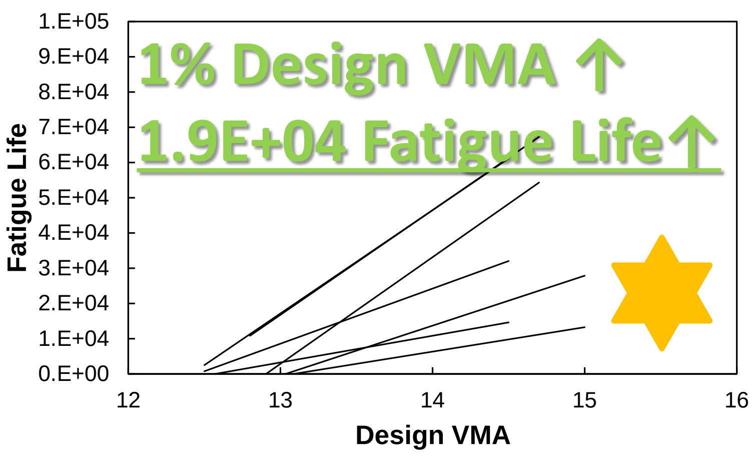
| | 7% **A** | 7% **D** | 7% **G** | 7% **H** | 7% **K** | 7% **N** | 7% **O** | 7% **R** | 7% **U** |
| | 9% **B** | 9% **E** | - | 9% **I** | 9% **L** | - | 9% **P** | 9% **S** | - |

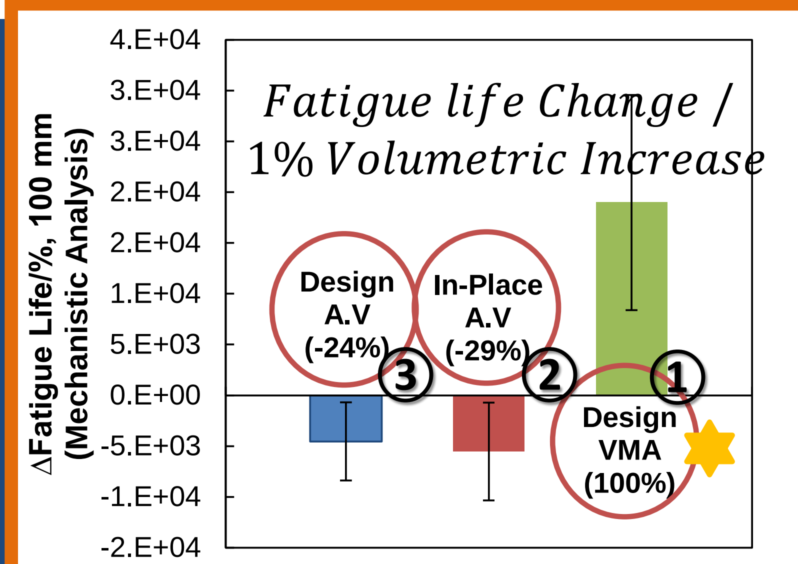
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **% Change in E* for 1% in Air Voids** | **4.2** | **4.3** | **3.4** | **3.8** | **5.4** | **8.4** | **8.1** | **7.2** | **8.1** |
| | **4.0** | | | **5.9** | | | **7.8** | | |
| | **5.9** | | | | | | | | |

# Mix Design Targets and Compaction Effect on Fatigue Life through M Analysis (100 mm Pavement)



| (%) | 100% CA LUW (VMA 15) | | | 95% LUW CA (VMA 14) | | | 88% LUW CA (VMA 13) | | |
|---|---|---|---|---|---|---|---|---|---|
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| Design A.V | 5.3 | 3.8 | 3.0 | 4.9 | 3.7 | 2.9 | 5.1 | 3.9 | 3.1 |
| Binder Content | 4.2 | 4.5 | 4.9 | 3.8 | 4.1 | 4.4 | 3.2 | 3.6 | 3.9 |
| VFA | 64.7 | 73.8 | 79.6 | 65.2 | 72.6 | 78.7 | 60.5 | 68.8 | 75.8 |
| Compacted Specimen A.V (In-Place A.V) | - | 5% C | 5% F | - | 5% J | 5% M | - | 5% Q | 5% T |
| | 7% A | 7% D | 7% G | 7% H | 7% K | 7% N | 7% O | 7% R | 7% U |
| | 9% B | 9% E | - | 9% I | 9% L | - | 9% P | 9% S | - |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| % Change in Fatigue Life for 1% A.V. | 26 | 19 | 4.9 | 25 | 21 | 33 | 40 | 20 | 37 |
| | 17 | | | 26 | | | 32 | | |
| | 25 | | | | | | | | |

# Outline

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# NCHRP IDEA Project
# Development of Small Specimen Geometry for Asphalt Mixture Performance Testing

*Jan. 1, 2015-June 30, 2016*

Cassie Castorena
Richard Kim
Kangjin Lee
Sonja Pape

# Motivation

- Small specimens
  - Enable performance testing individual layers of as-built pavements
  - Improve efficiency in fabrication and testing of laboratory compacted test specimens
    - ✓ Multiple small specimens per gyratory compacted sample
    - ✓ Ability to conduct monotonic tension tests in AMPT

# Project Overview

- Goals:
  - Develop ancillary devices for small specimen testing in AMPT (in partnership with Instrotek)
  - Determine if small cylindrical (38mm x 100mm) and/or prismatic (50mm x 25mm x 100mm) specimens give equivalent dynamic modulus and direct tension test results to full size specimens
    - ✓ Limitations on large NMAS mixes?
  - Establish number of test replicates required

# Experimental Plan

- Phase I: Development of Test Set-up and Resolution of Testing of Field Cores
  - Establish set-up for small specimen testing in the AMPT
  - Evaluate effects of specimen geometry for mixtures with varying NMAS
  - Compare dynamic modulus and direct tension test results of small and large specimens
    - ✓ Core all specimens vertically to eliminate anisotropy

| Factor | NMAS | | | | Geometry | | | Tests | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Level** | 25mm | 19mm | 12.5mm | 9.5mm | Full size | Small cylinder | Small prism | DMT | Monotonic (small only) | Cyclic Tension |

* Two binder types: PG 64-22, PG 76-22

# Experimental Plan

- Phase II: Resolution of Testing Small Specimens Extracted from Laboratory Gyratory Compacted Specimens
  - Evaluate anisotropy of laboratory fabricated specimens
  - Compare results of small specimens extracted horizontally and vertically
  - Same materials and experiments as Phase I
    - ✓ Core horizontally