# Evaluation of Laboratory Performance Tests for Cracking of Asphalt Pavements

50th Mid-Atlantic Quality Assurance Workshop

*2015 FHWA Cooperative Study at Asphalt Institute*

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# Greetings from Kentucky

Asphalt Institute Headquarters

Lexington, KY

# The Need for Performance Testing

# It all started in 1919

- Asphalt Association (later Asphalt Institute) was formed and hired Prevost Hubbard and Frederick Field as researchers
- Research led to the Hubbard-Field design method using rammers (like a Marshall hammer but with 2 size hammers) in mid 1920’s

AI Magazine article by Gerry Huber 2/15/2013

# Hubbard-Field Stability



Hubbard-Field Stability test at AI headquarters 8-2013

- Hubbard-Field Stability is the first known asphalt performance test.
- Sample was loaded by turning the wheel
- Dial gage recorded the maximum load

# Testing Then and Now

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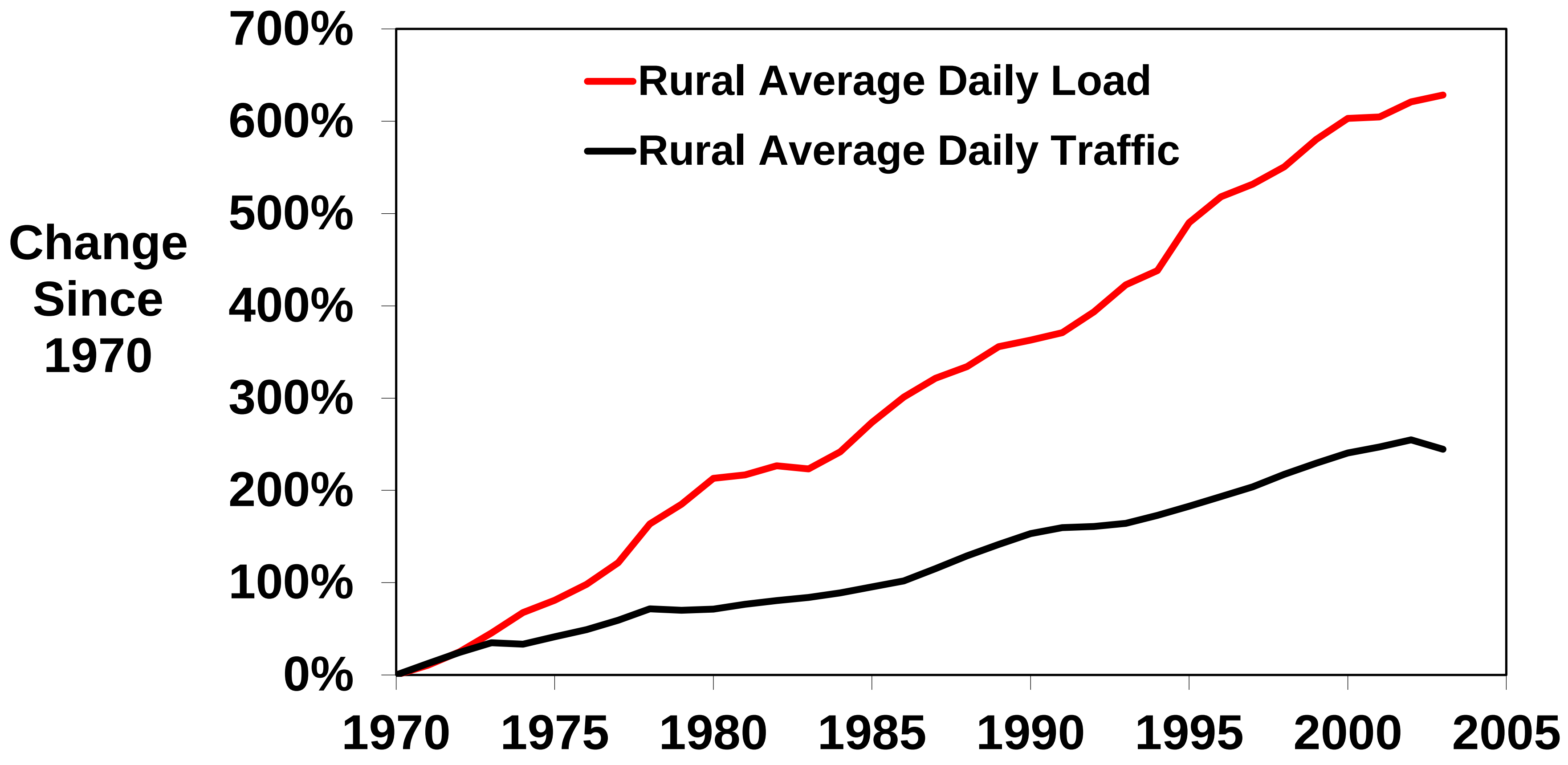
- By the 1940's:
  - Hubbard-Field stability test
  - Hveem stability test
  - Marshall stability and flow
  - Recorded data by hand or charts
- Today
  - TSR, Hamburg, APA, Texas Overlay tester, 4-point flexural fatigue, fracture energy (3-4 tests), resilient modulus, shear modulus, dynamic modulus, AMPT Flow Number, etc.

# Technology Today

- We can control test from 0.01 Hertz to 25 Hertz (25 cycles a second)
- Technology allows us to record data at fast rates like 100+ points a second
- Temperature control to the nearest 0.5°C (mix) and 0.1°C (binder)
  - Need of strict temperature control is something we learned during the SHRP research 1987-1992.
- The problem still remains…

# Traffic & Load Growth on Rural

## Interstate System




*FHWA Highway Statistics 2003*

# The Basics of Performance Testing

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✓Allow us to verify our estimates

✓Design and check for potential distresses

✓Custom design for specific loading

✓Think out-of-the-box with new materials and modifiers

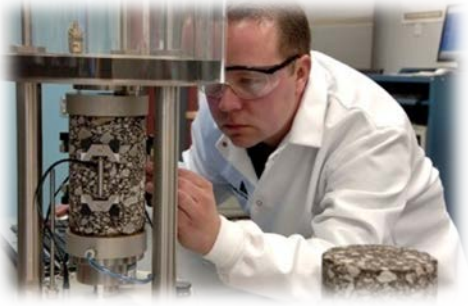
# What Should Have Happened…

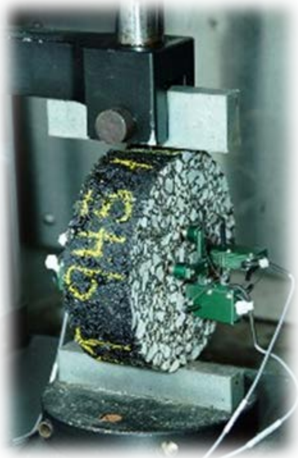
- Superpave called for Level 1, 2, and 3 testing based on traffic load
- Level 1 (Volumetrics + TSR) was only for up to around 1 million ESALS
- Level 2 and 3 were to be used for higher traffic loads and included rutting and cracking performance test
- Since we saw such good performance (with materials in 1993-2000), Levels 2 and 3 were soon forgotten

# Fundamental Performance Tests



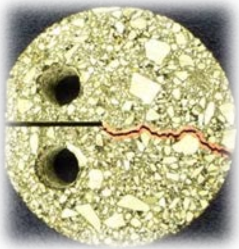
- Flexural Beam Fatigue
  - Brittleness
- Asphalt Mixture Performance Test
  - Dynamic modulus (used in MEPDG for design)
  - Flow number (rutting)
- Superpave Shear Tester
  - Rutting
  - Modulus
- Indirect Tension Test
  - Low temperature cracking

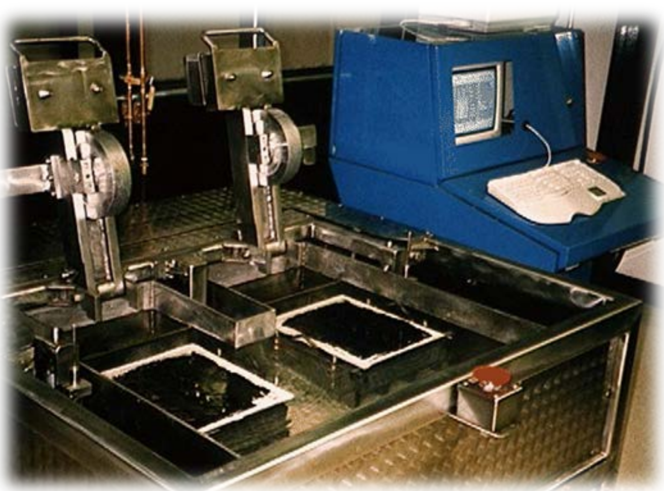




# Performance Tests

- Other tests
  - Hamburg Wheel Tester
  - Asphalt Pavement Analyzer
  - Disk-Shaped Compact Tension test
  - Overlay (crack) tester





# Cracking Test Evaluation Project

# The Project

- Principal Investigator
  - Mike Anderson, Asphalt Institute

- Evaluation of current cracking performance tests

# Acknowledgements

This material is based upon work supported by the U.S. Department of Transportation under Cooperative Agreement No. DTFH61-11-H-00033. The Authors thank the Federal Highway Administration (FHWA) for their financial support and **John Bukowski, Michael Arasteh, and Matthew Corrigan**, all of the FHWA, for their technical support.

# Objective

- To assist with deployment of a fatigue cracking test that is:
  - Sensitive properties of mix components
  - Sensitive to mixture aging
  - Repeatable and reproducible
  - Easy to implement
  - Practical, low cost

# Plan

- An experimental study to examine various cracking tests
- Evaluate capability of the tests in discerning the factors of interest
- Evaluation on practicality and ease of use

# Primary Factors

- Asphalt grade
- Mix properties
- Load range (test strains/stresses)
- Asphalt aging and hardening

# Test Plan

- Test devices: 7
- Binder:
  - PG 64-22
- Aggregates:
  - Virgin mix
  - 9.5 mm NMAS, dense mix
- Aging:
  - 4-hour loose mix aging at 135°C
  - 24-hour loose mix aging at 135°C

# Testing Plan

| Test | Test Temperature | Test Strain / Load Rate Condition | Equivalent Test Speed |
|---|---|---|---|
| 4-Point Bending Beam Fatigue | 15°C & 20°C | 300 & 600με;<br>sine & haversine | 300με = 0.16mm/0.1sec or 98mm/min; 600με = 195mm/min |
| AMPT Push/Pull Fatigue (S-VECD) | 18.0°C | Various | |
| Indirect Tensile Strength (IDT) | 25°C & 4°C | 12.5 mm/min for low temp (AASHTO T322)<br>50mm/min for mid-temp. strength (ASTM D6931) | 12.5 mm/min |
| Disk-Shaped Compact Tension [DC(t)] | -12°C | 1.0 mm/min | 1.0 mm/min |
| Texas Overlay | 25°C | 0.6mm/5sec | 72 mm/min |
| Dissipated Creep Strain Energy (DCSE) | TBD | Standard Methods | NA |
| Semi-Circular Bending (SCB) | 25°C | 0.5 mm/min | 0.5 mm/min |

# Phase 1 Testing Plan

- Lab Standard Mix
- Aging:
  - 4-hour loose mix aging at 135°C
  - 24-hour loose mix aging at 135°C

# Why 24 Hour Loose Mix Aging

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- Focus on aging of the top ~1-2 inches
- University of Illinois – study on in-place mixtures
  - Andrew F. Braham, William G. Buttlar, Timothy R. Clyne

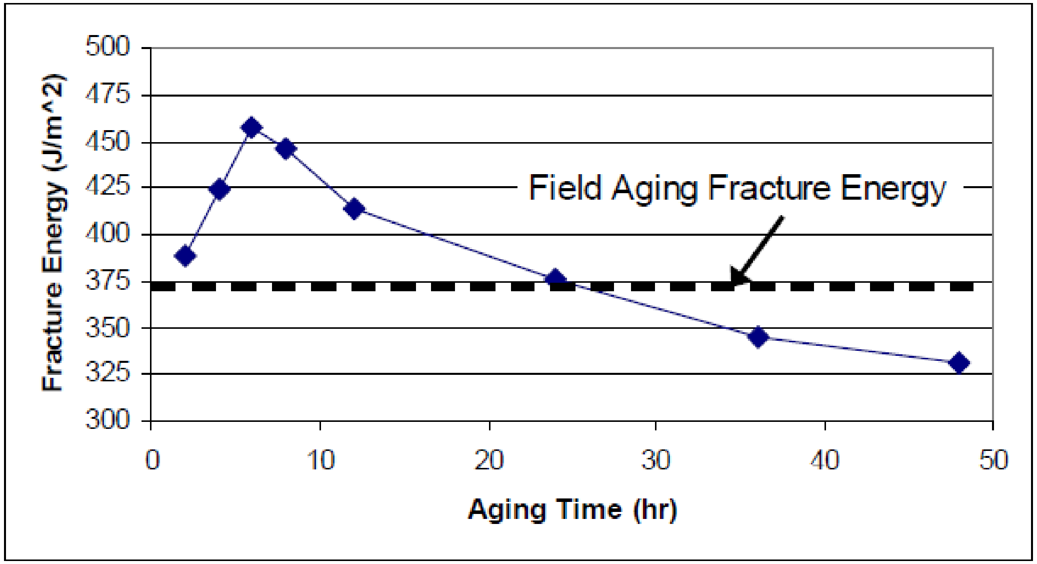



Figure 6 – Effect of 135°C Aging on M3 Fracture Energy

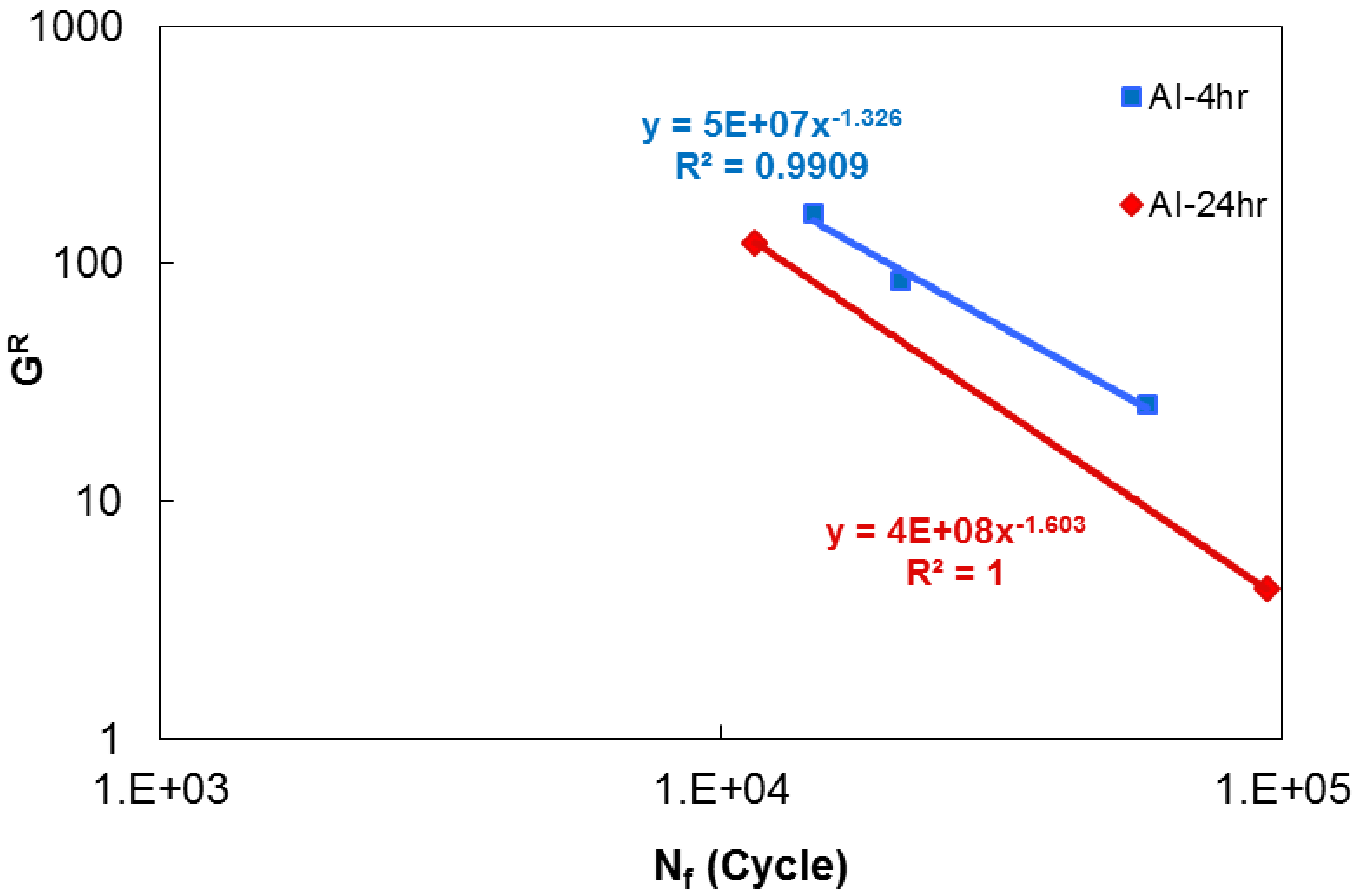
- AAPTP non-load associated cracking study
  - Also found that 18hr loose mix ≈ 20hr PAV
- KY density study
  - Correlates 24hr loose mix conditioned, fatigue testing to field cracking

# AMPT Push/Pull Fatigue (S-VECD)

- Draft AASHTO standard by Richard Kim
- 18°C / 23°C
  - Not recommended to run over 21°C
- Various Strains
- Software builds curve based on three tests

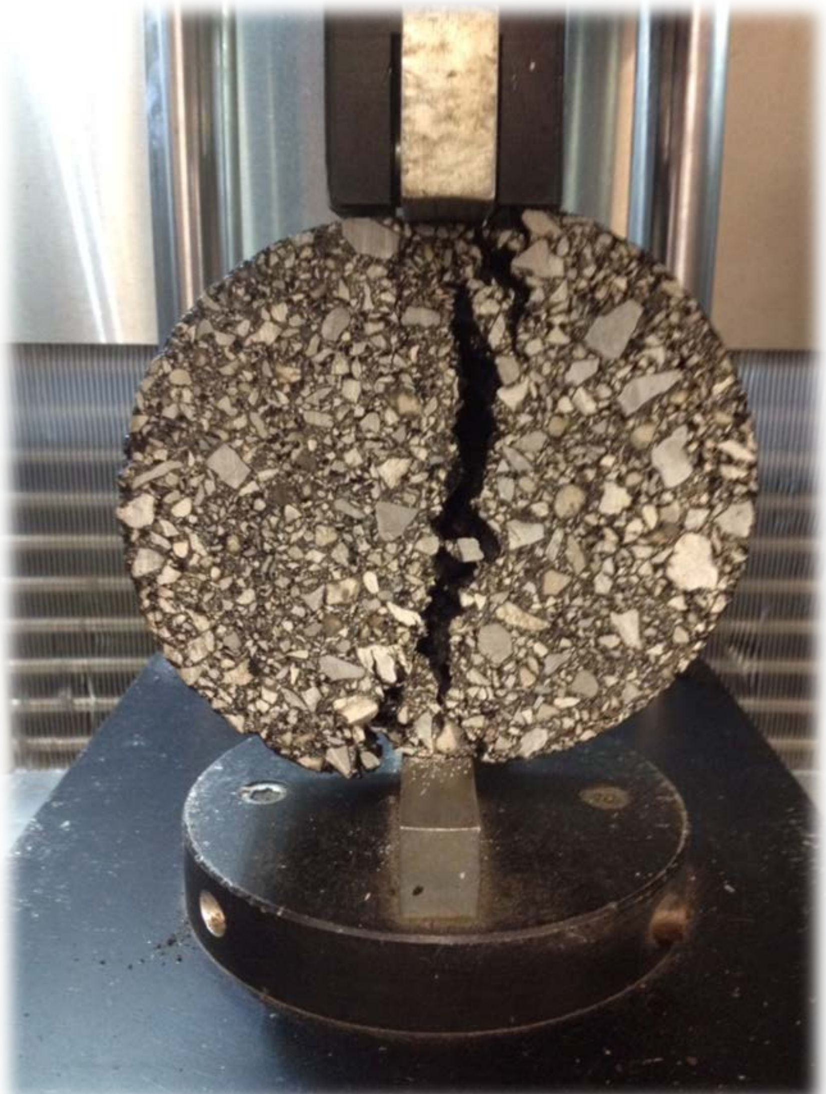
# AMPT Push/Pull Fatigue (S-VECD)

- Good test for design
- Not intended for 24 aged mixtures



# Indirect Tensile Strength (IDT)

- ASTM D 6931
- Related AASHTO T322
- 25.0°C and 4.0°C
- Rate of Movement: 12.5 and 50 mm/min



# Indirect Tensile Strength (IDT)

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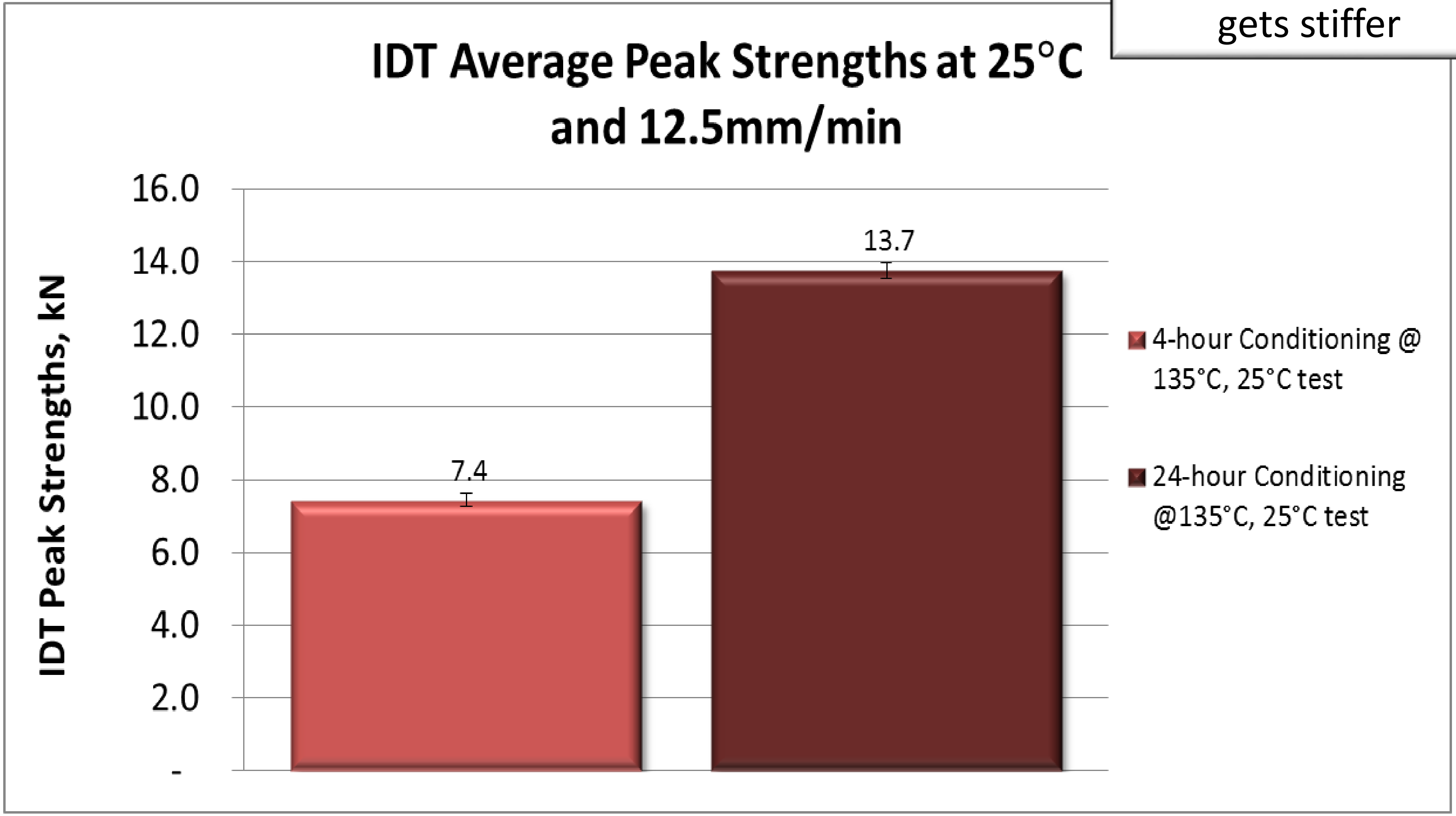
Simplest test, but just says that mix gets stiffer



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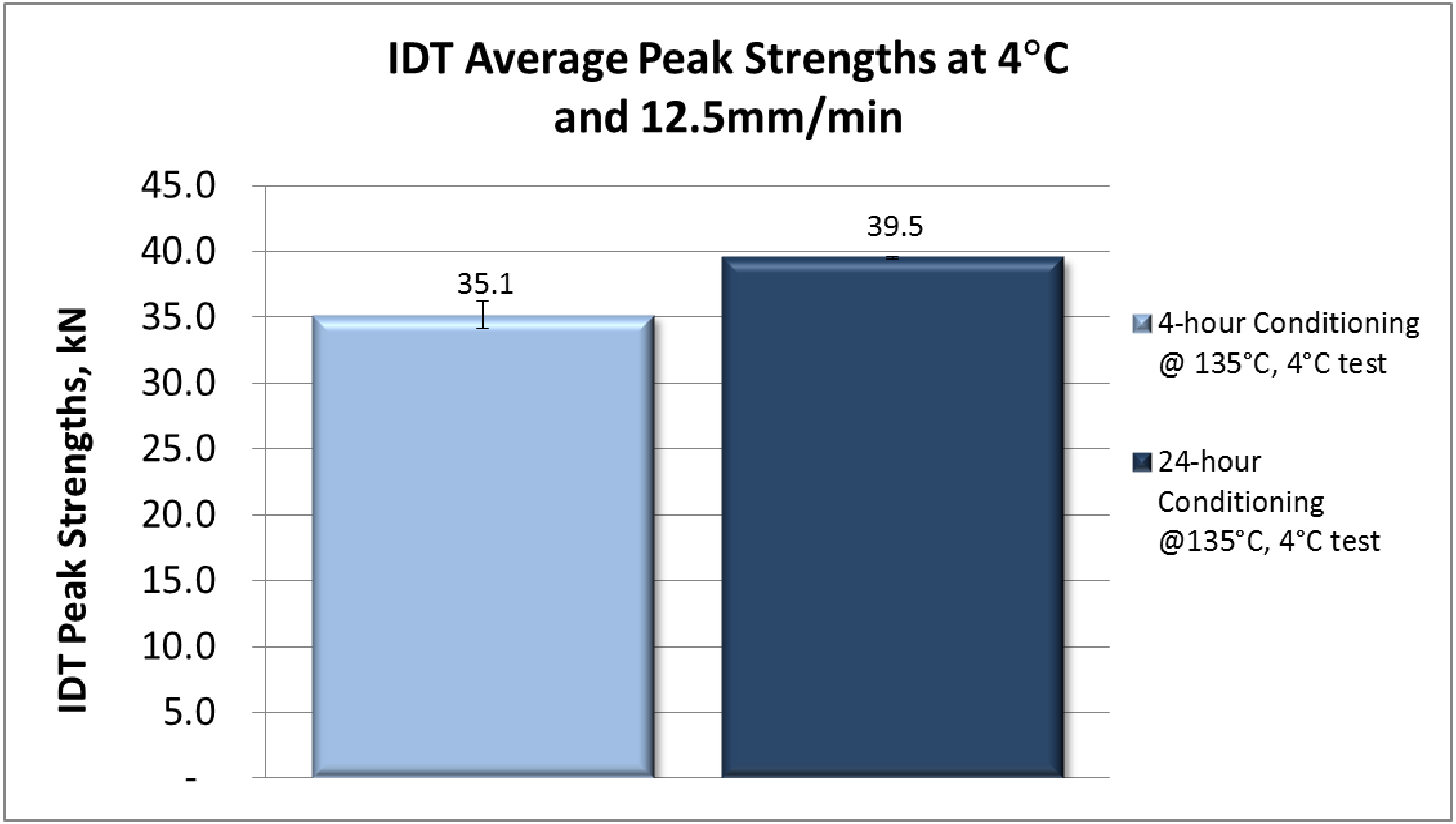

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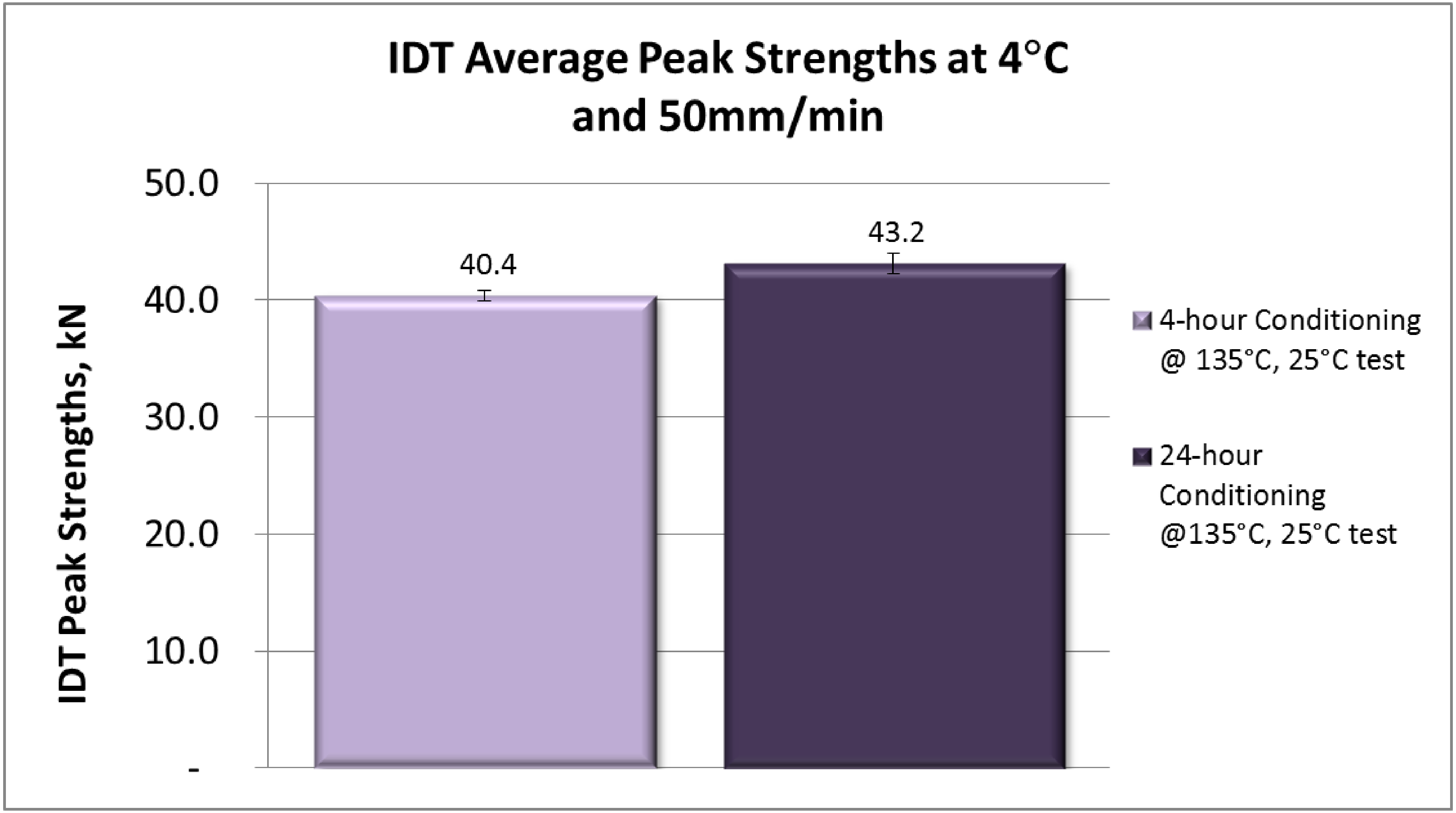

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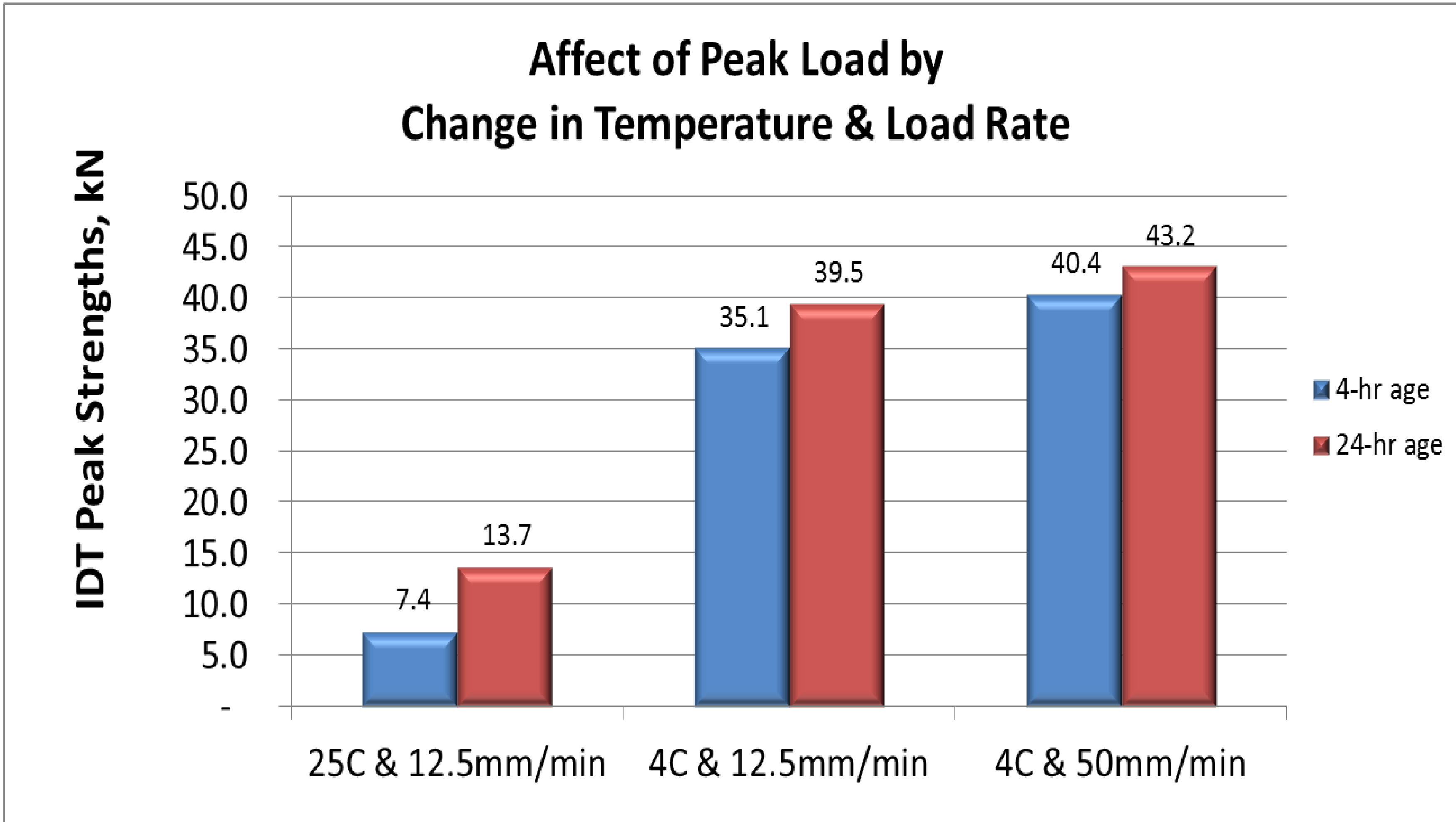
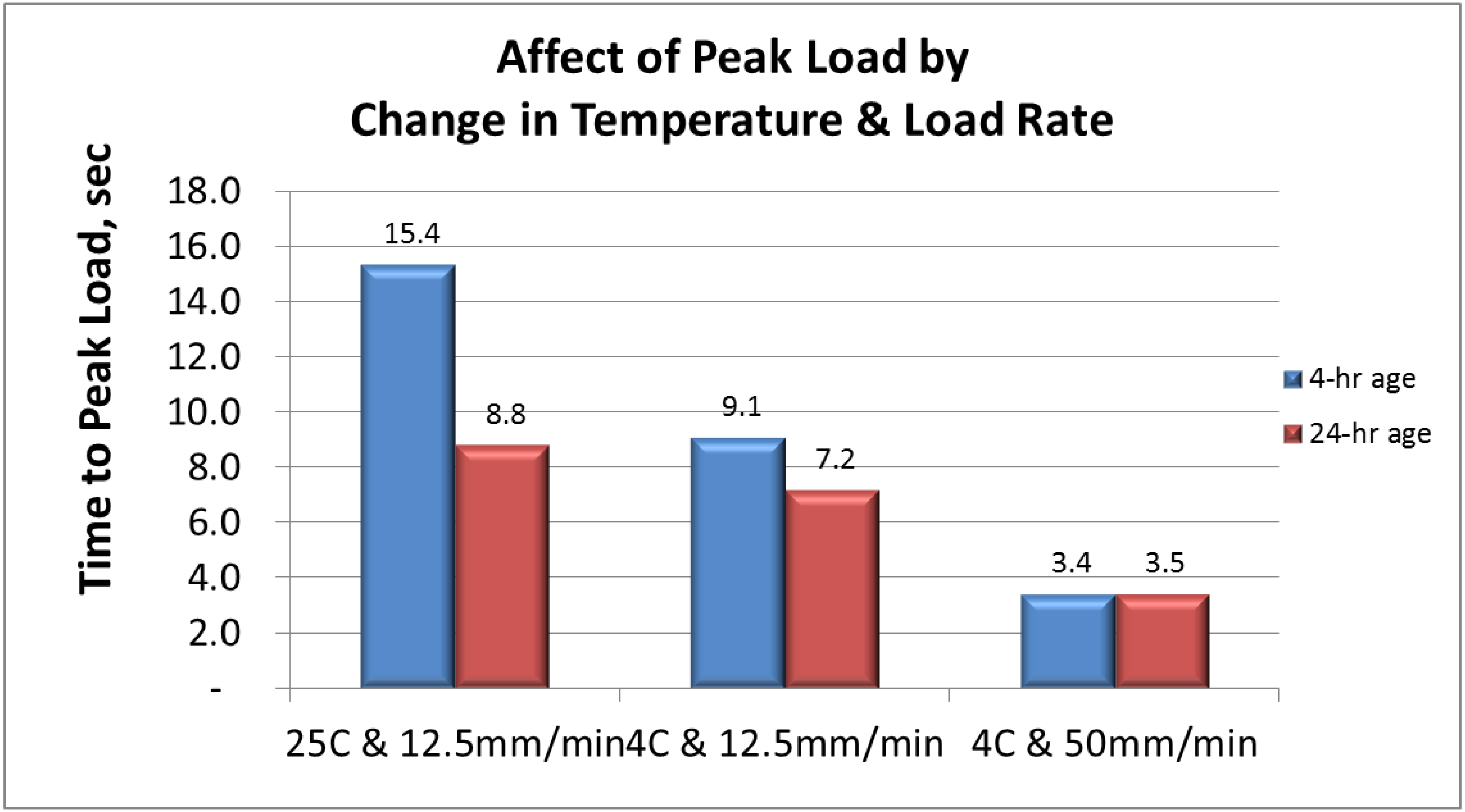



So what can we learn? Confirms that we need correct temperature/loading rate for cracking sensitivity. Peak load alone is not the answer.

# Indirect Tensile Strength (IDT)




So what can we learn? Confirms that we need correct temperature/loading rate for cracking sensitivity. Peak load alone is not the answer…but combine with time/distance ➔ **FRACTURE ENERGY**

# 4-Point Bending Beam Fatigue

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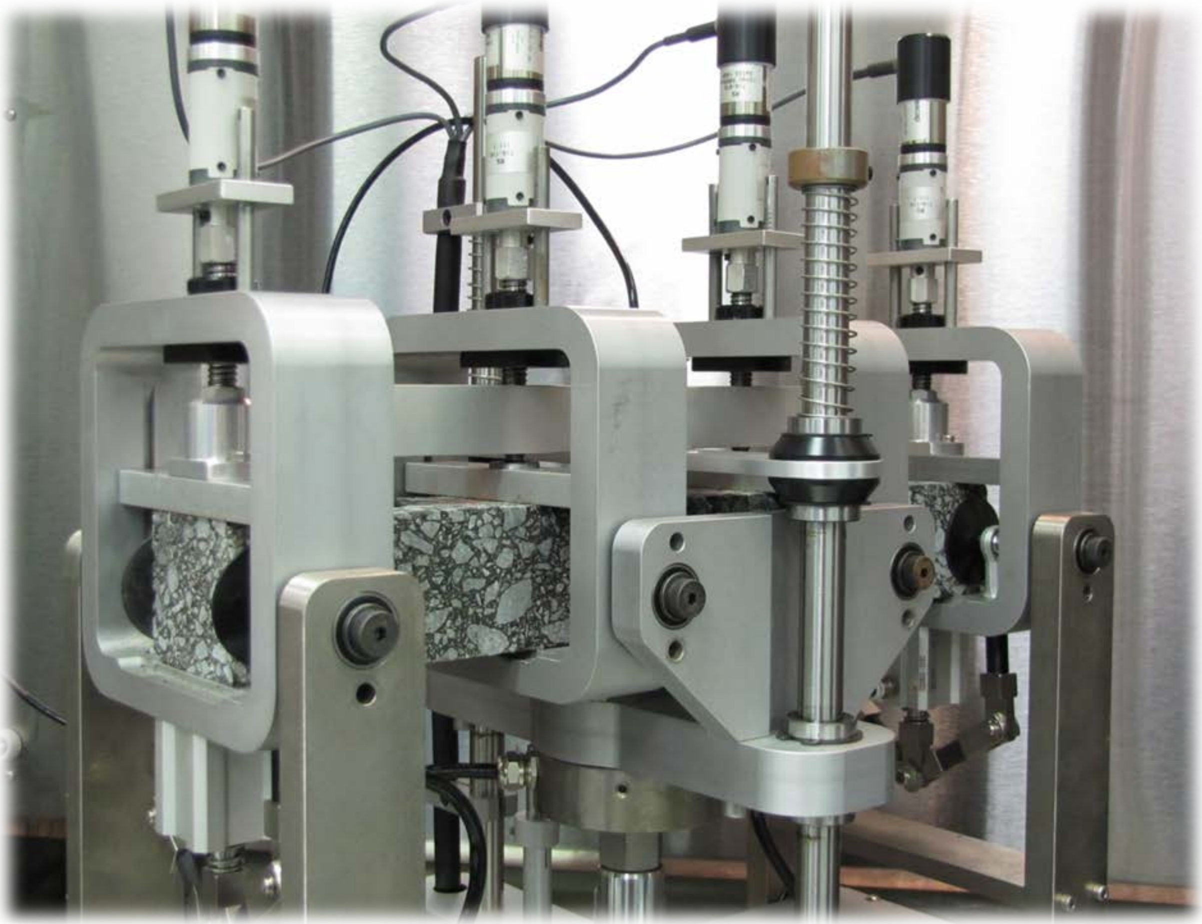
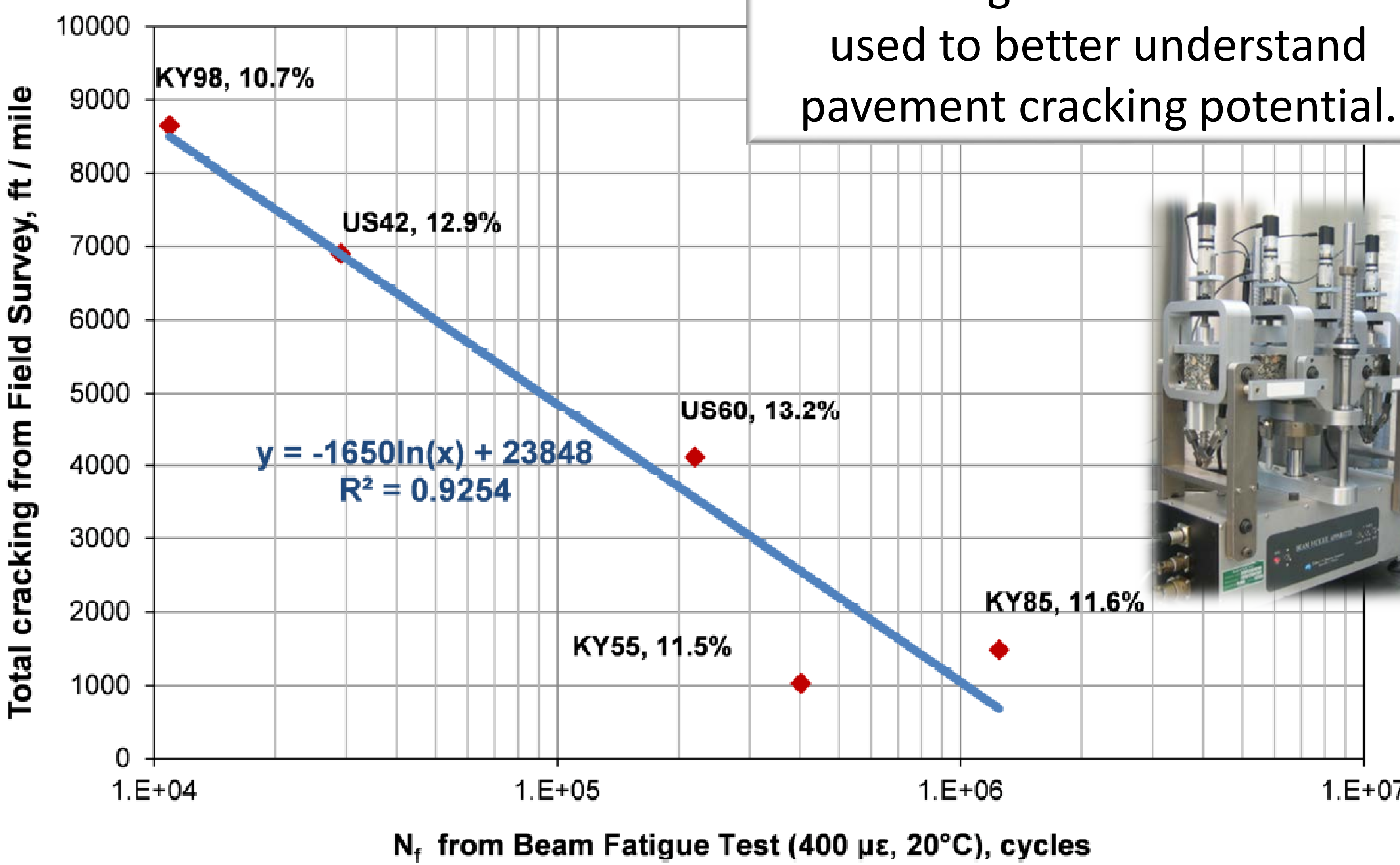
- 4-point bending beam fatigue (1950's / SHRP)
- AASHTO T321 & ASTM 7460
- Examined
  - 20.0°C & 15.0°C
  - Sine & haversine waves
- Rate of Movement: 10Hz, various strains (strain rates)
  - Ex: 300 ms = 0.16mm/0.1sec or 98mm/min
- 2 beams for average (per strain)



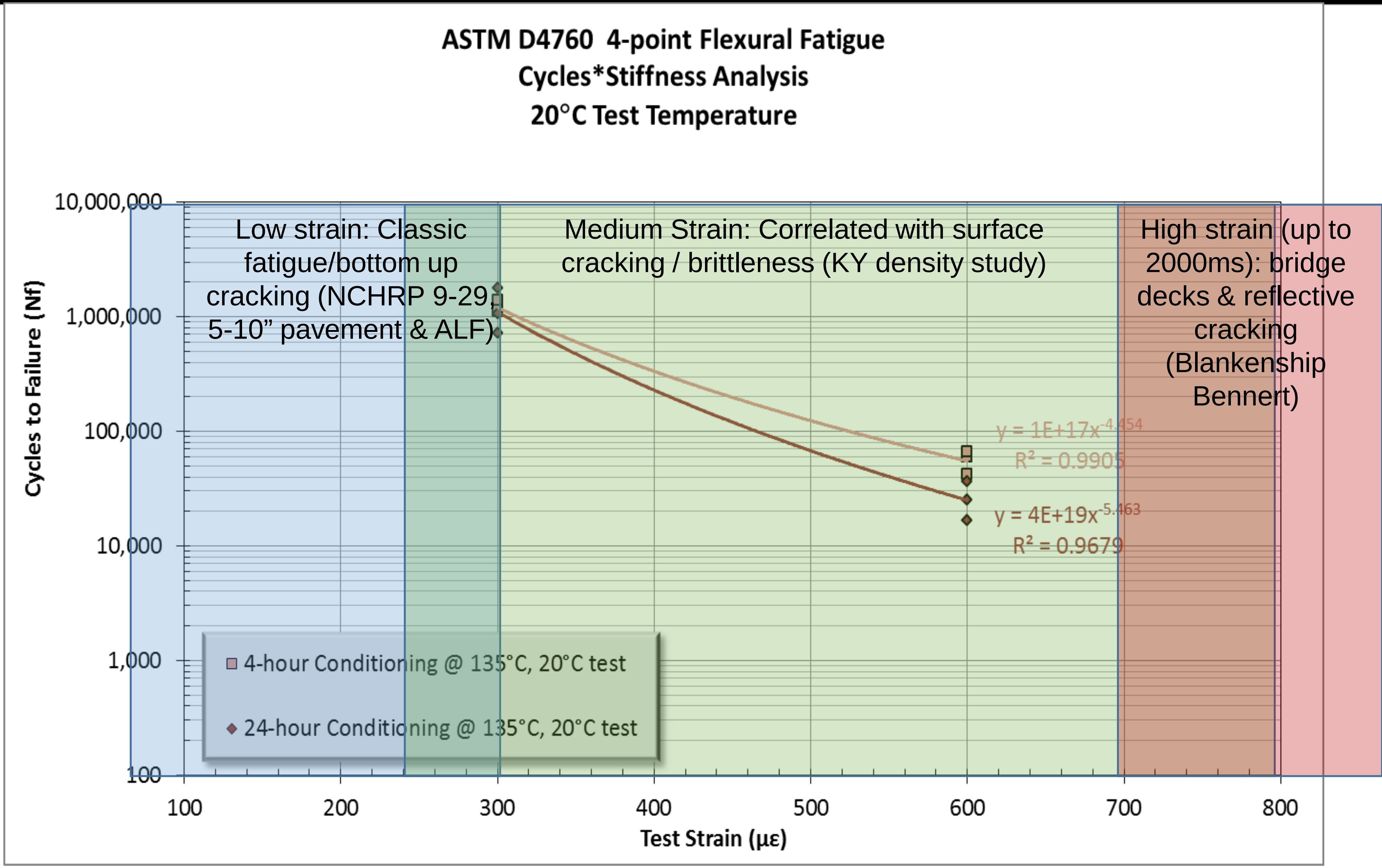
# KY Density Study Findings with 24-hr Loose Mix Conditioning – M. Anderson

**Alireza Zeinali, Phillip B. Blankenship, Kamyar C. Mahboub**

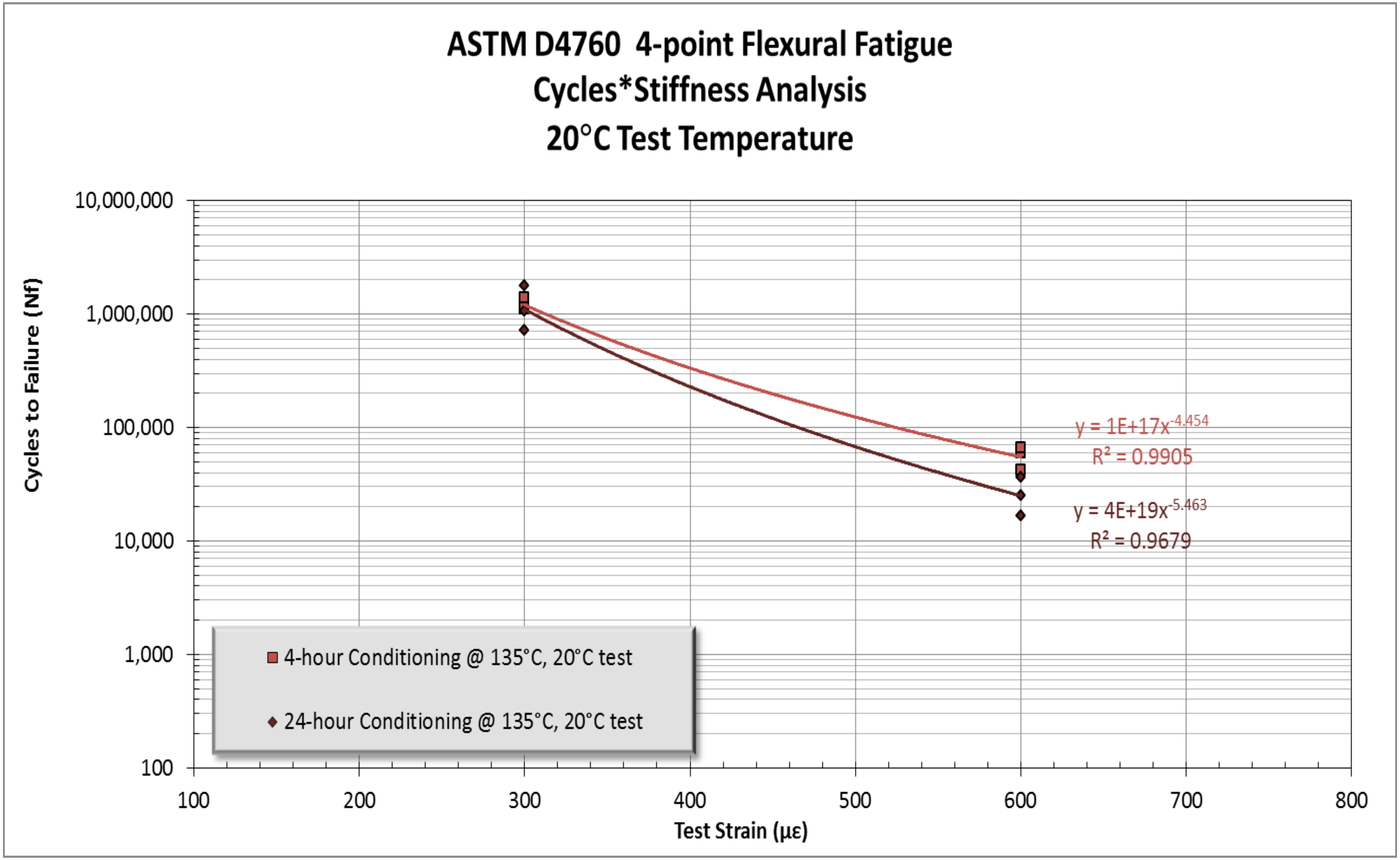
Beam fatigue device has been used to better understand pavement cracking potential.



# Beam Fatigue – What strain do I use?



# Beam Fatigue – 20°C & sine



# Beam Fatigue – 20°C & sine

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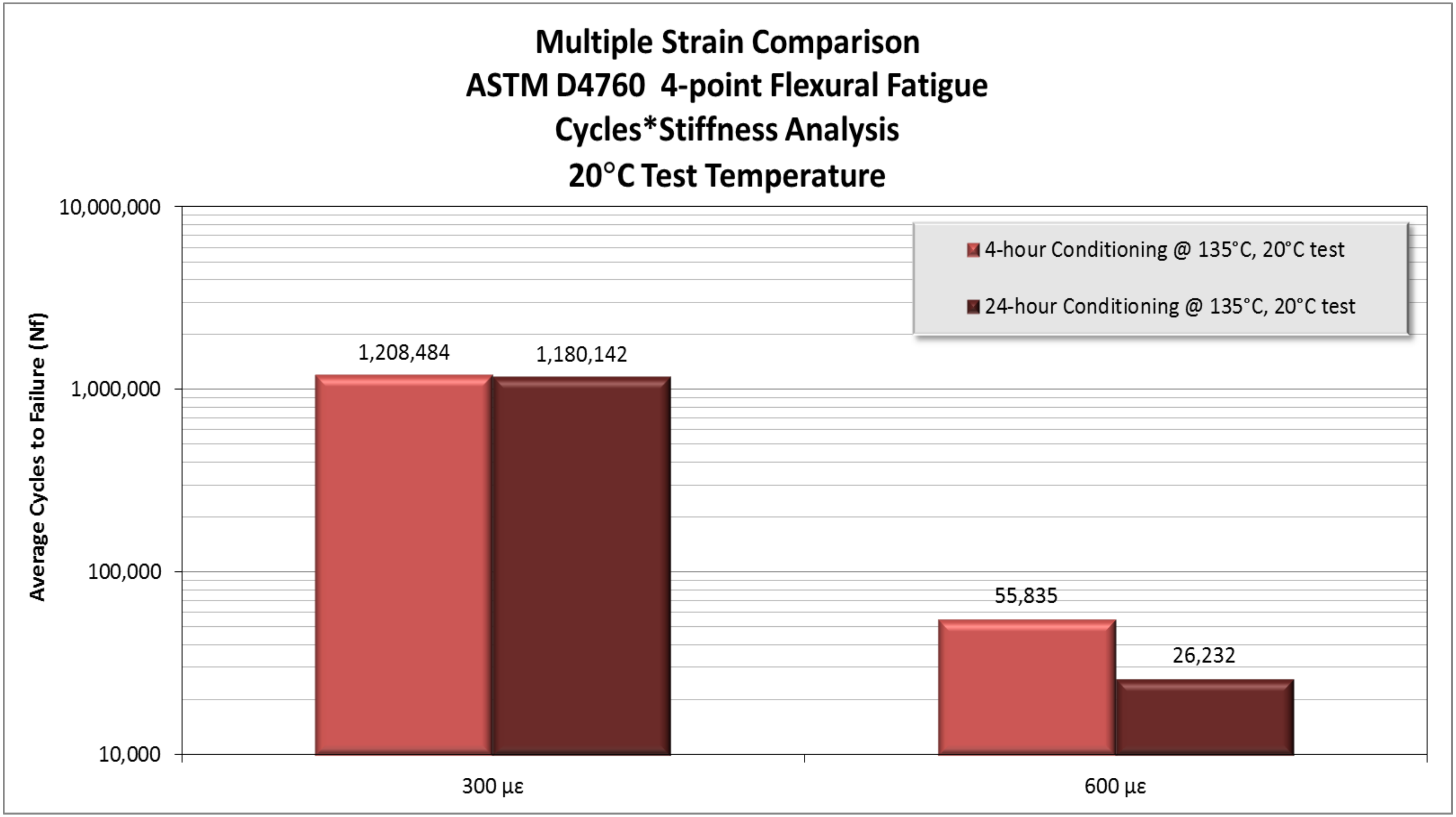
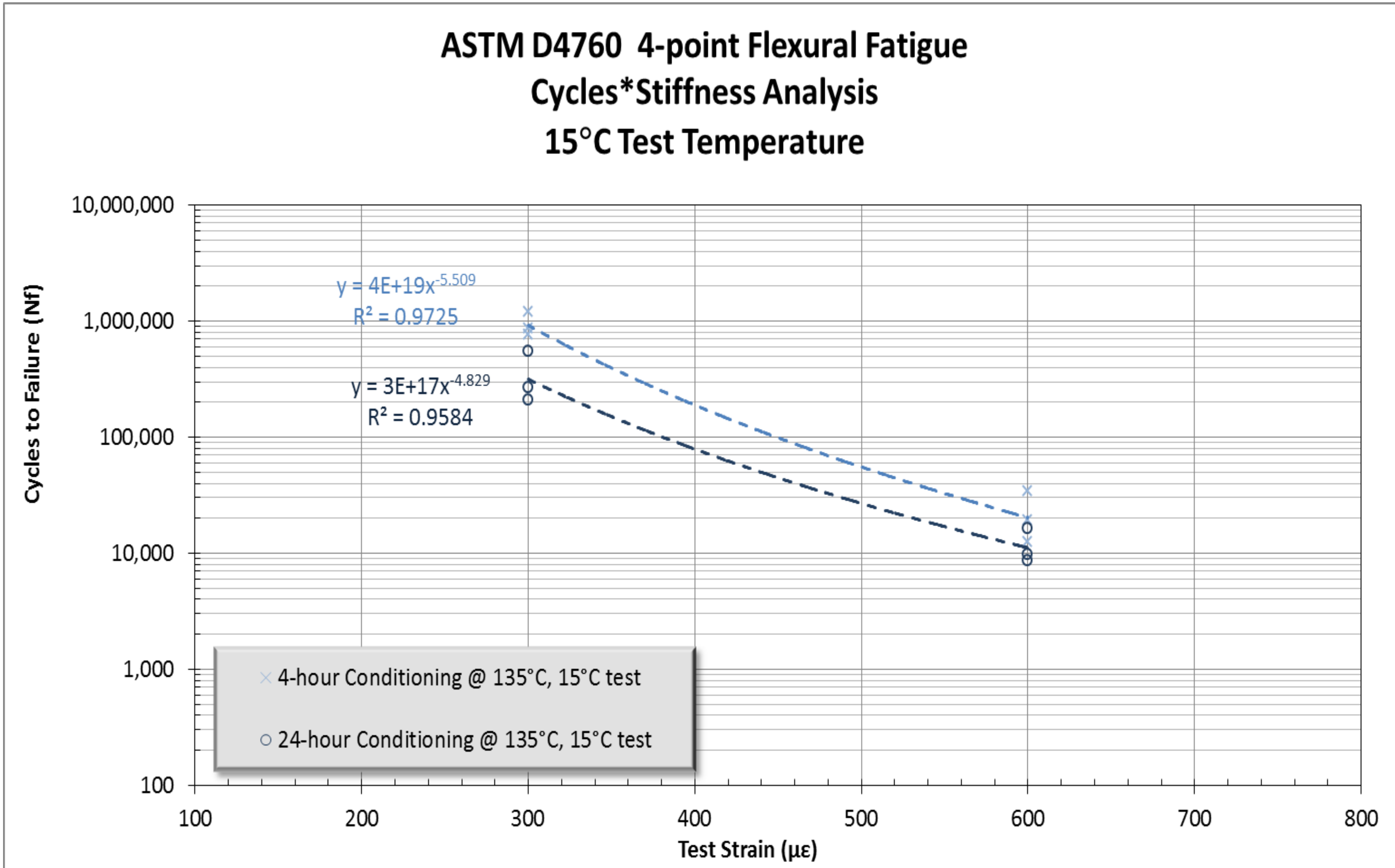
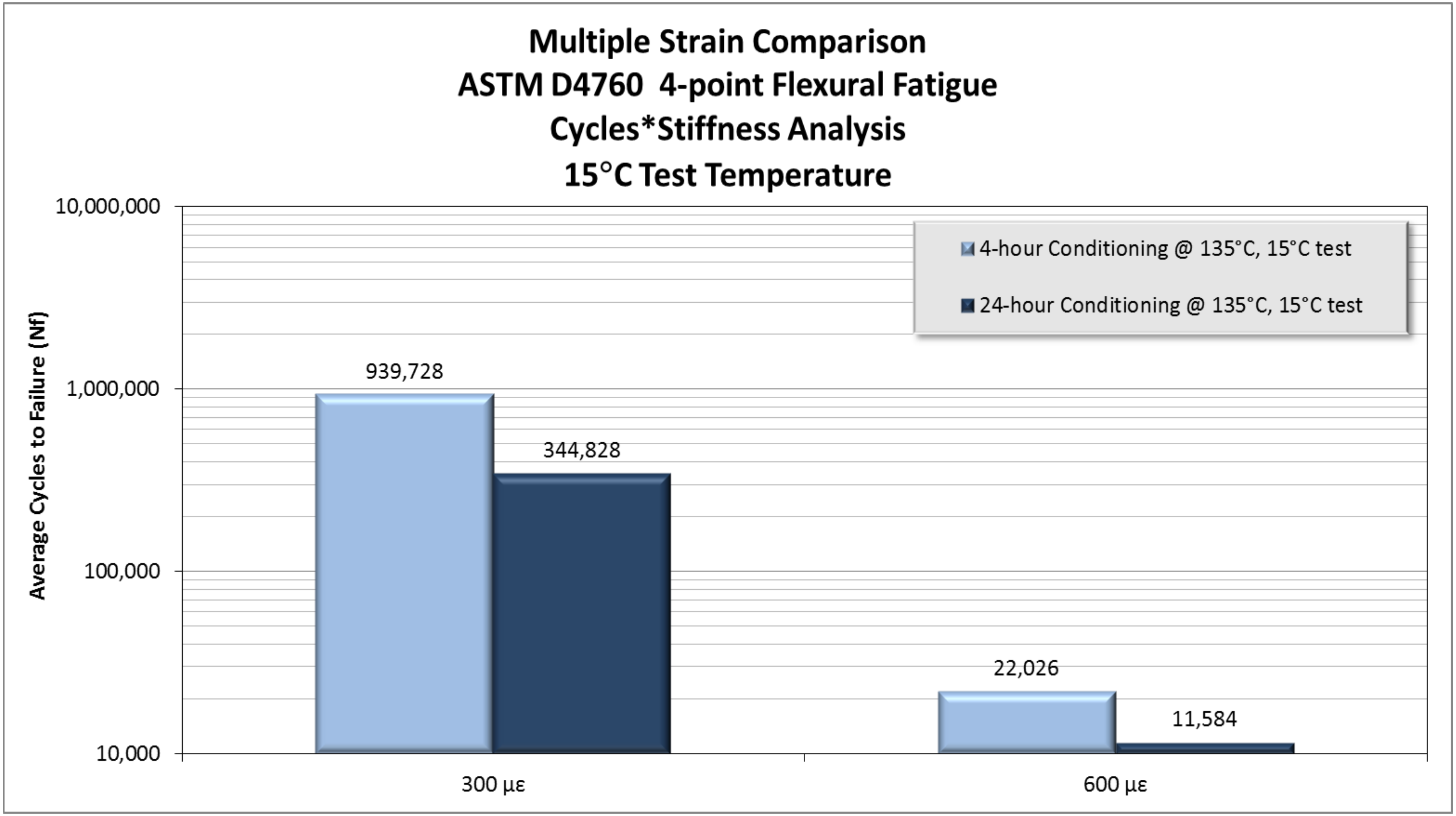


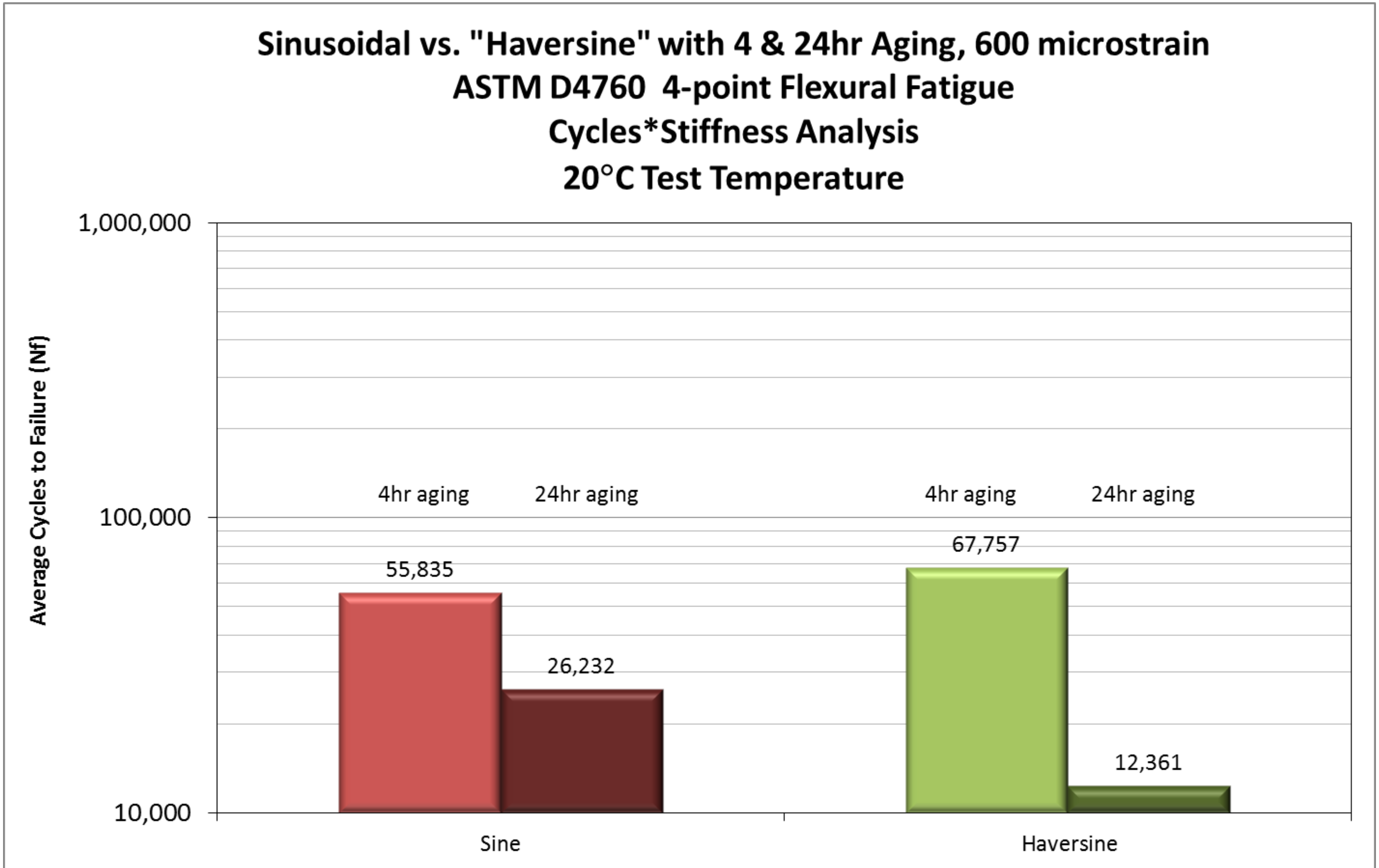
# Beam Fatigue - 15°C & sine



# Beam Fatigue - 15°C & sine



# Beam Fatigue - 20°C, sine & haversine



# Dissipated Creep Strain Energy (DSCE)

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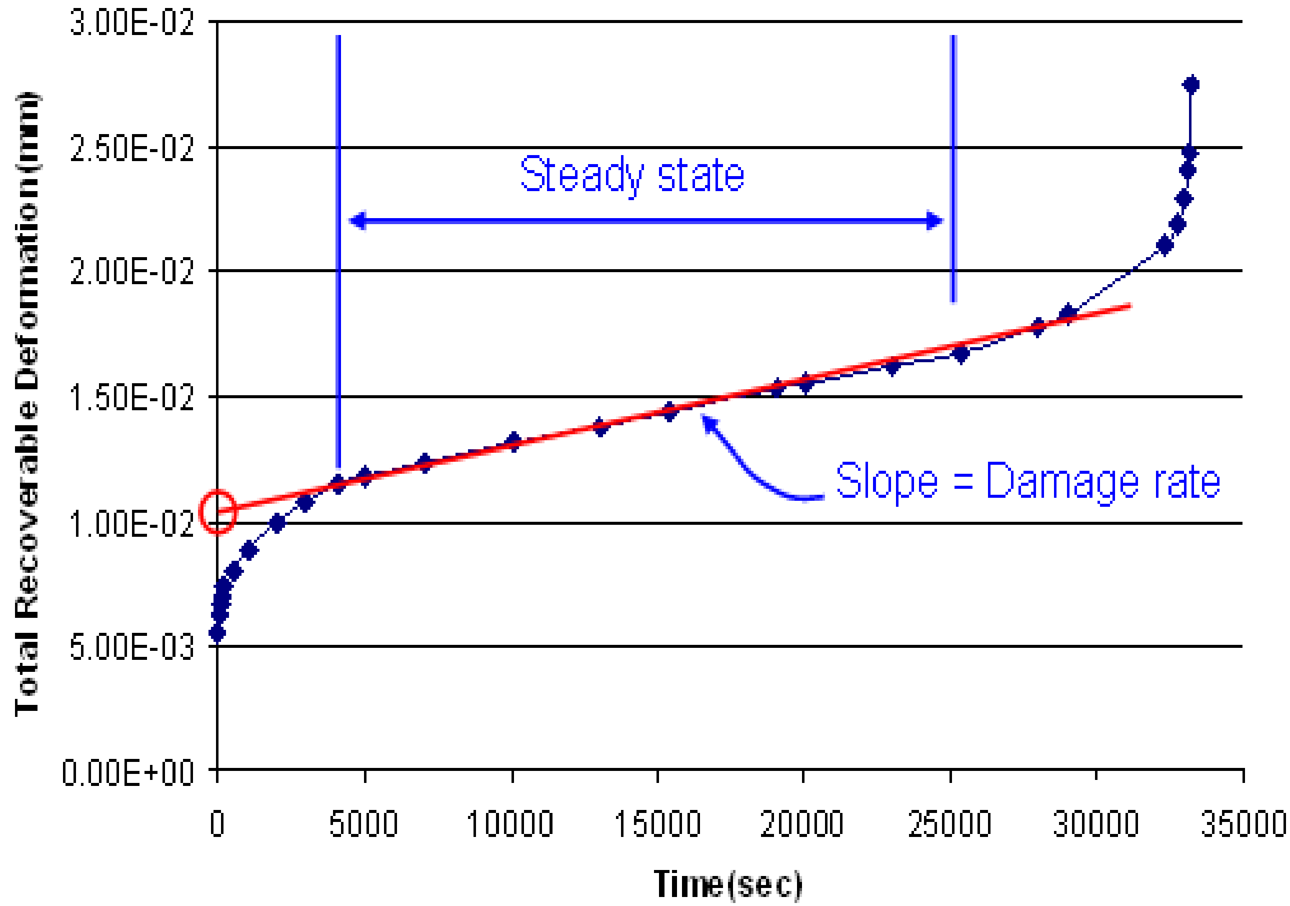
- Draft standard by Rey Roque
- Uses IDT configuration
- Creep based on load & time
- 10°C
- 3 samples for average



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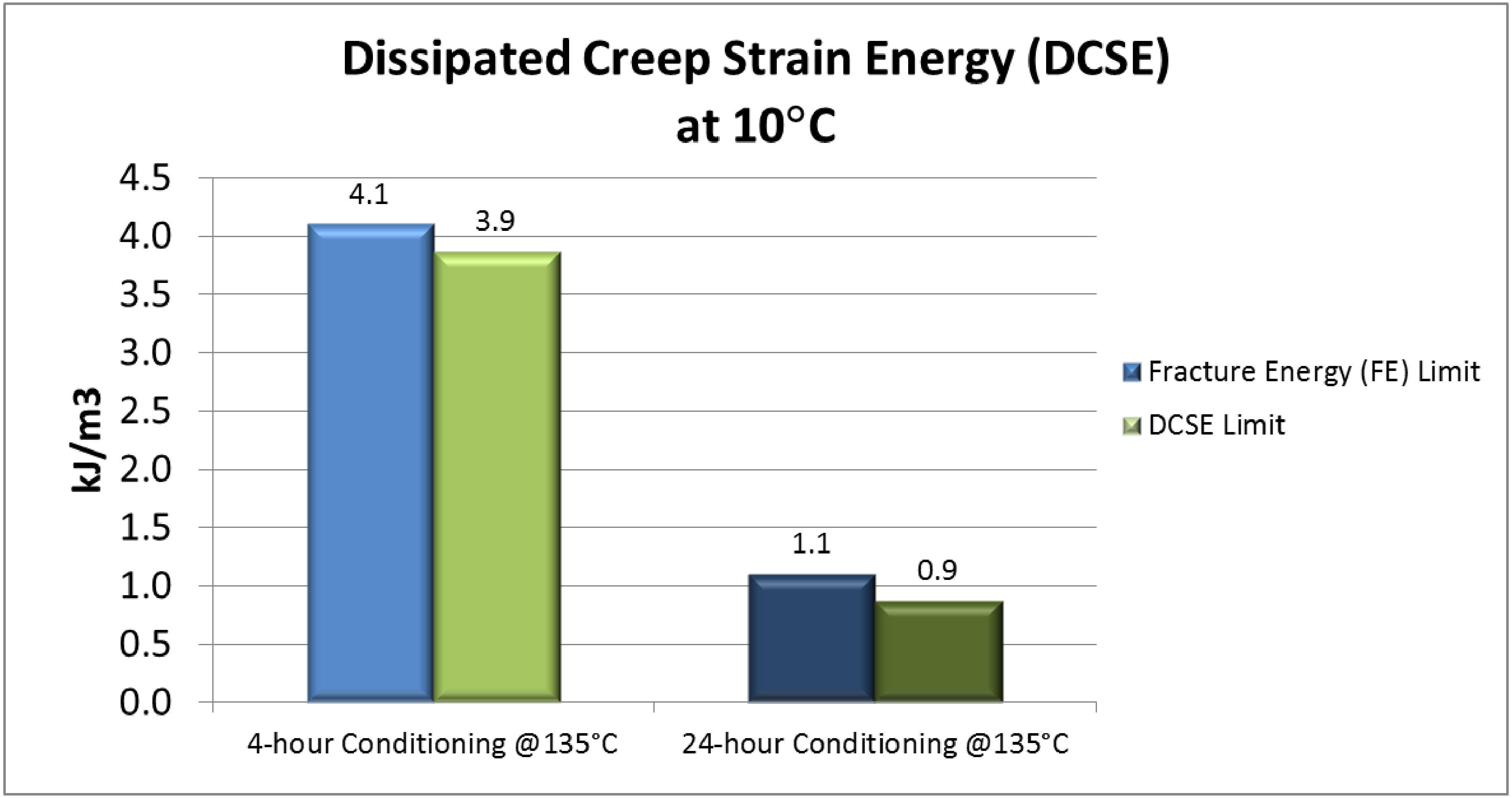
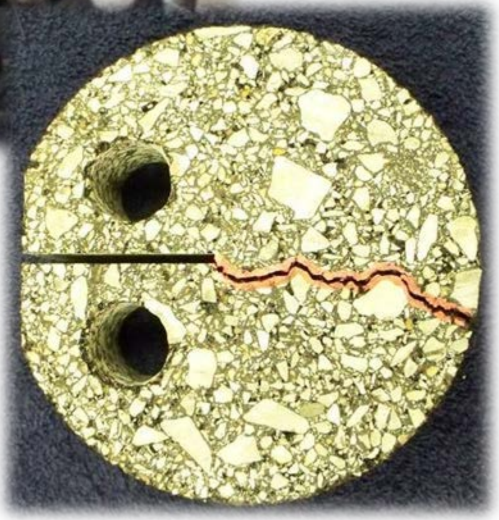



Note: Roque models not for 24hr aged mixture, but FE limit does shoe difference. COV's usually 7%.

# Disk-Shaped Compact Tension [DC(t)]

- ASTM D 7313
- Run at +10°C from critical low temp PG
- -12.0°C
- Rate of Movement: 1 mm/min
- 3 samples for average



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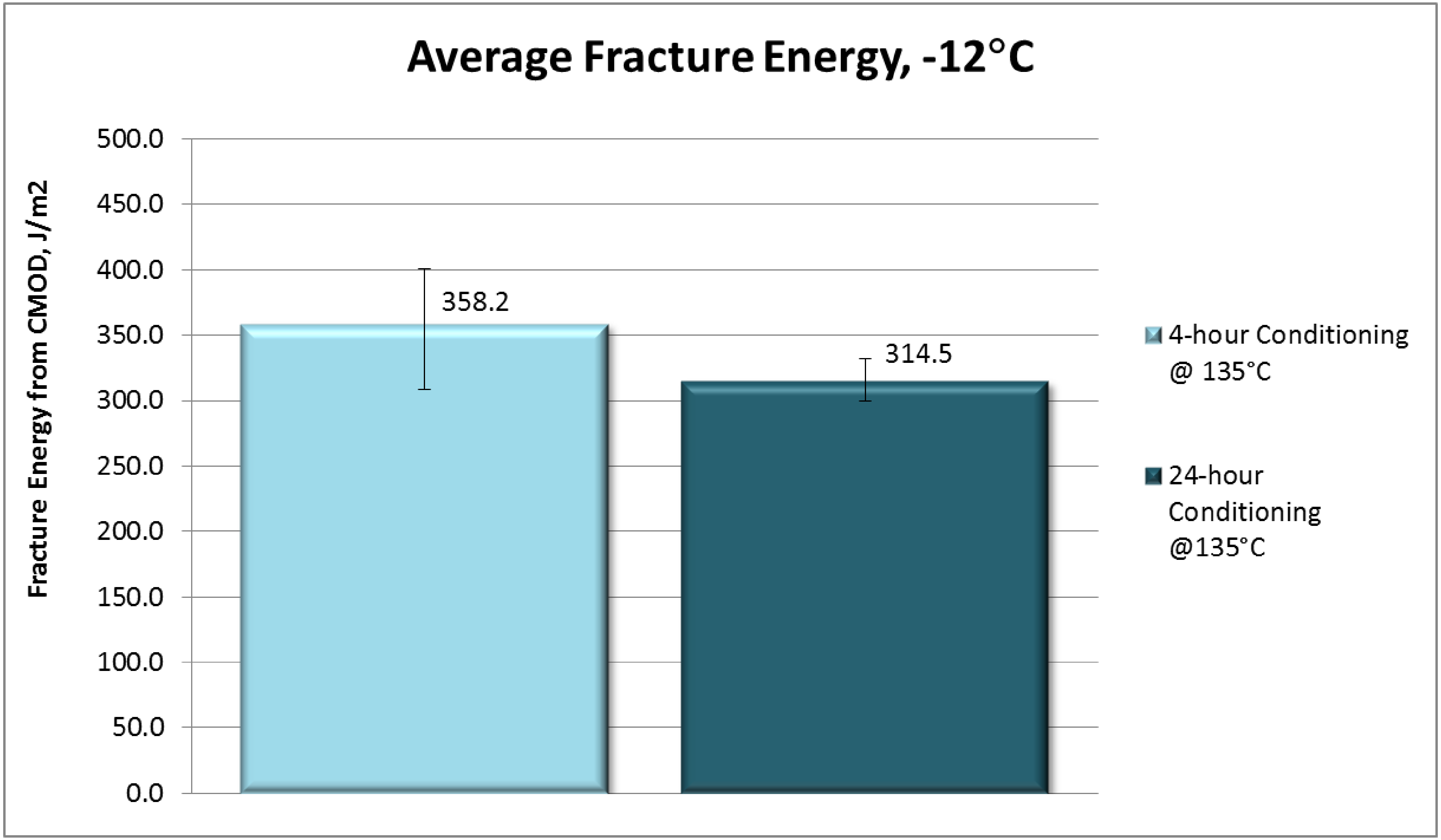
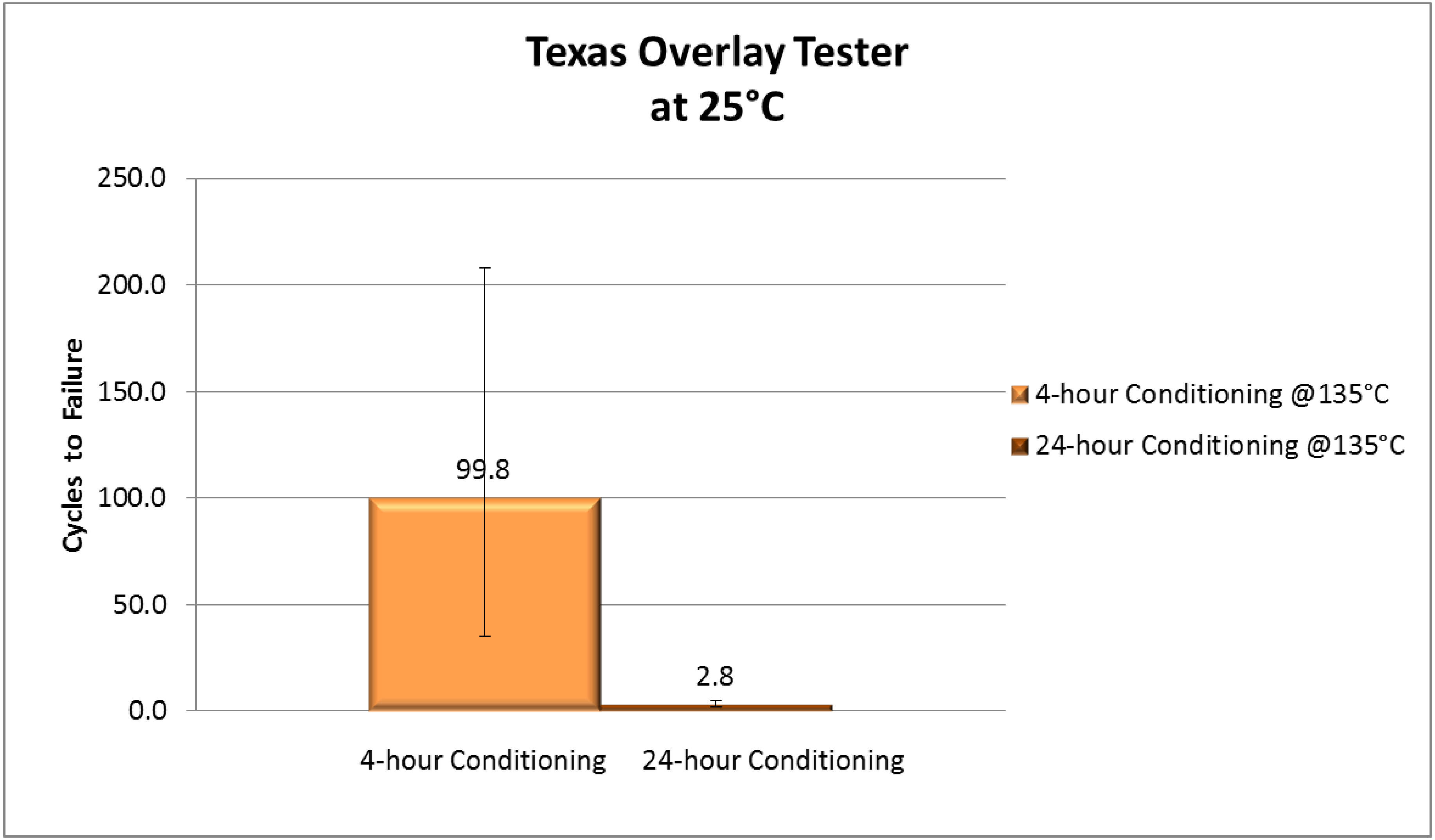



Note: COV's usually 10%

# Texas Overlay Test

- Tx DOT Standard
- Tex-248-F
- 25°C
- Rate of Movement: 0.6 mm/5 sec and returns (fatigue) or 7.2mm/min
- 0.1 Hz
- 6 samples for average

# Texas Overlay Test



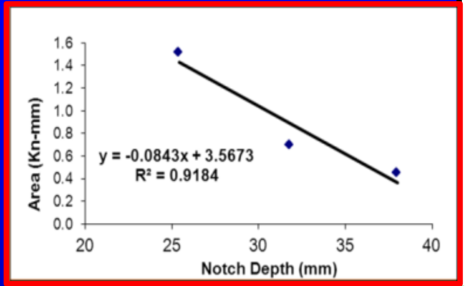

Note: High error. Data is usually trimmed average.

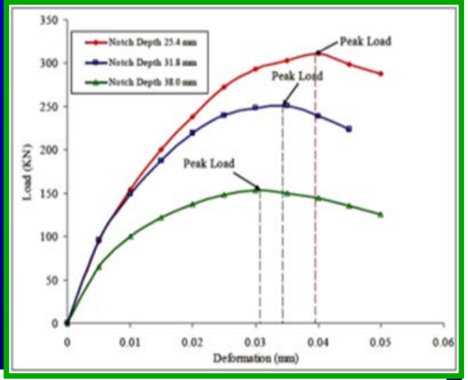
# Semi-Circular Bending (SCB)-ASTM

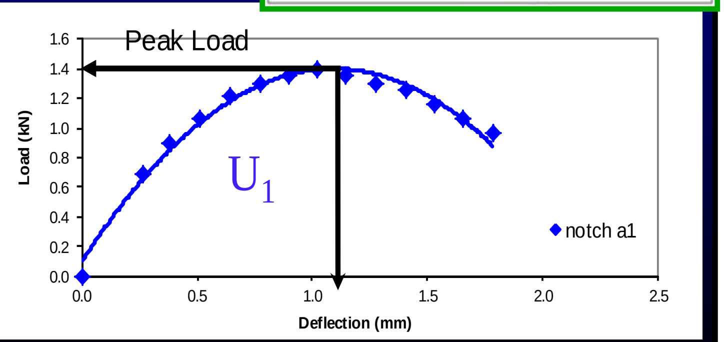
- ASTM standard by Louay Mohammad
- 25°C
- Rate of Movement: 0.5 mm/min


# Semi Circular Bend (SCB) Test

- Fracture mechanics
- Temperature: 25°C
- Half-circular Specimen
  - Laboratory prepared
  - Field core
  - 150mm diameter X 57mm thickness
  - simply-supported and loaded at mid-point
- Notch controls path of crack propagation
  - 25.4-, 31.8-, and 38.0-mm
- Loading type
  - Monotonic
  - 0.5 mm/min
  - To failure
- Record Load and Vertical Deformation
- Compute Critical Strain Energy: Jc

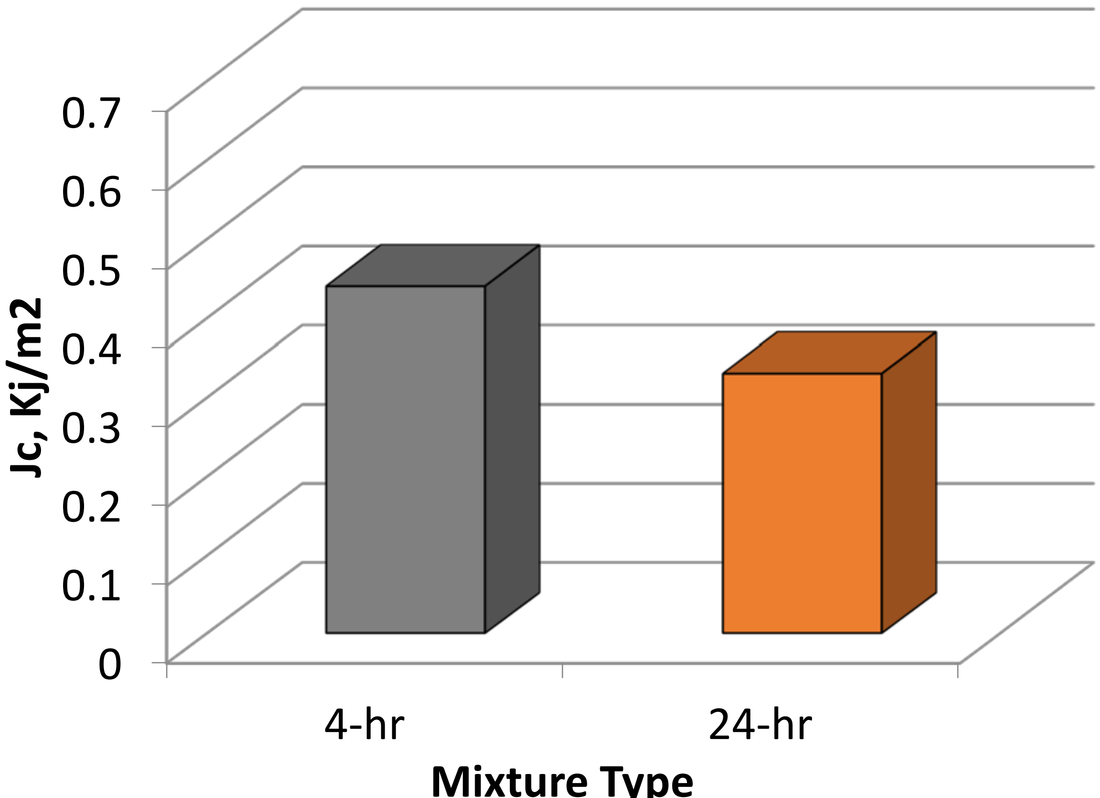


# Semi-Circular Bend Test Results, 25°C

- Note
  - Can have high error. Usually based on 6 samples
  - Higher temps or lower PG yields lower energy
    - This is opposite of what should happen



# Test Summary

**0-easy, 5-difficult**

| Test | Cost – saw/coring not included | Sample Prep. | Run Test | Data Analysis | Speed of Test (3x)- conditioning not included | Sensitive to Aged (24hr) vs. Unaged (4hr) Samples |
|---|---|---|---|---|---|---|
| 4-Point Bending Beam Fatigue | $50,000 | 3-trim 4x; 2 beams | 2 | 2-normalized cycles | 3-24 hours | Yes |
| AMPT Push/Pull Fatigue (S-VECD) | $10,000 to $15,000 to upgrade | 5-trim 2x, core, glue, instrument; 3 samples | 5 | 5-specialized software | 1-4 hrs | Yes |
| Indirect Tensile Strength (IDT) | $0 – could use TSR device at 25°C | 1-trim 1x; 3 samples | 1 | 1-direct reading | 10 min. | Yes, but just shows stiffness without time/movement analysis |
| Disk-Shaped Compact Tension [DC(t)] | $ to upgrade AMPT | 5-trim 2x, core, notch (2 samples), instrument; 3 samples | 2 | 3-area under curve | 30 min | Yes |
| Texas Overlay | $ to up to upgrade AMPT | 4-trim 1x, glue; 6 samples | 2 | 1-cycles to failure | 1-3 hours | Yes |
| Dissipated Creep Strain Energy (DCSE) | $70,000 | 2-trim 2x and instrument; 3 samples | 2 | 3-area under curve | 30 min | Yes |
| Semi-Circular Bending (SCB) | $ to upgrade AMPT | 3-trim, cut, notch 2x; 6 samples | 2 | 3-area under curve | 30 min | Yes |

# What About iFit?
# Semi-Circular Bending (SCB)-AASHTO

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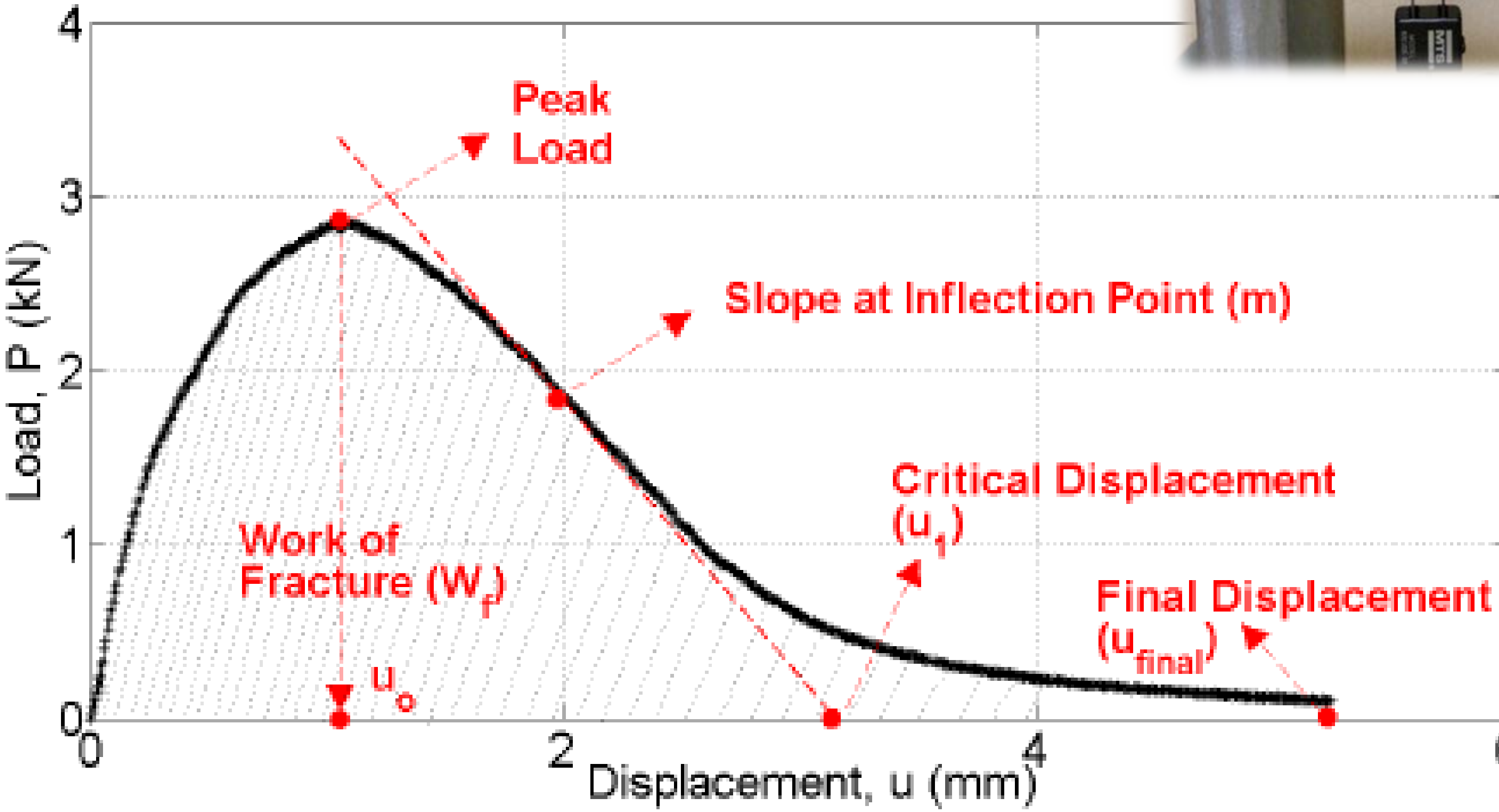
- AASHTO TP-124 by Imad Al-Qadi
- 25°C
- Rate of Movement: 50 mm/min
- Focus on latest standard on Flexibility Index (FI)


# What about iFit?




From Research Report No. FHWA-ICT-15-017, "Testing Protocols to Ensure Performance of High Asphalt Binder Replacement Mixes Using RAP and RAS" by Al-Qadi, et.al.

# What about iFit?


- Showing much promise
- Current work on field mixes
- More work to come on longer aged mixes

# Refer to NCHRP 9-57 for Further Info

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## NCHRP 9-57

### Experimental Design for Field Validation of Laboratory Tests to Assess Cracking Resistance of Asphalt Mixtures

# Conclusions

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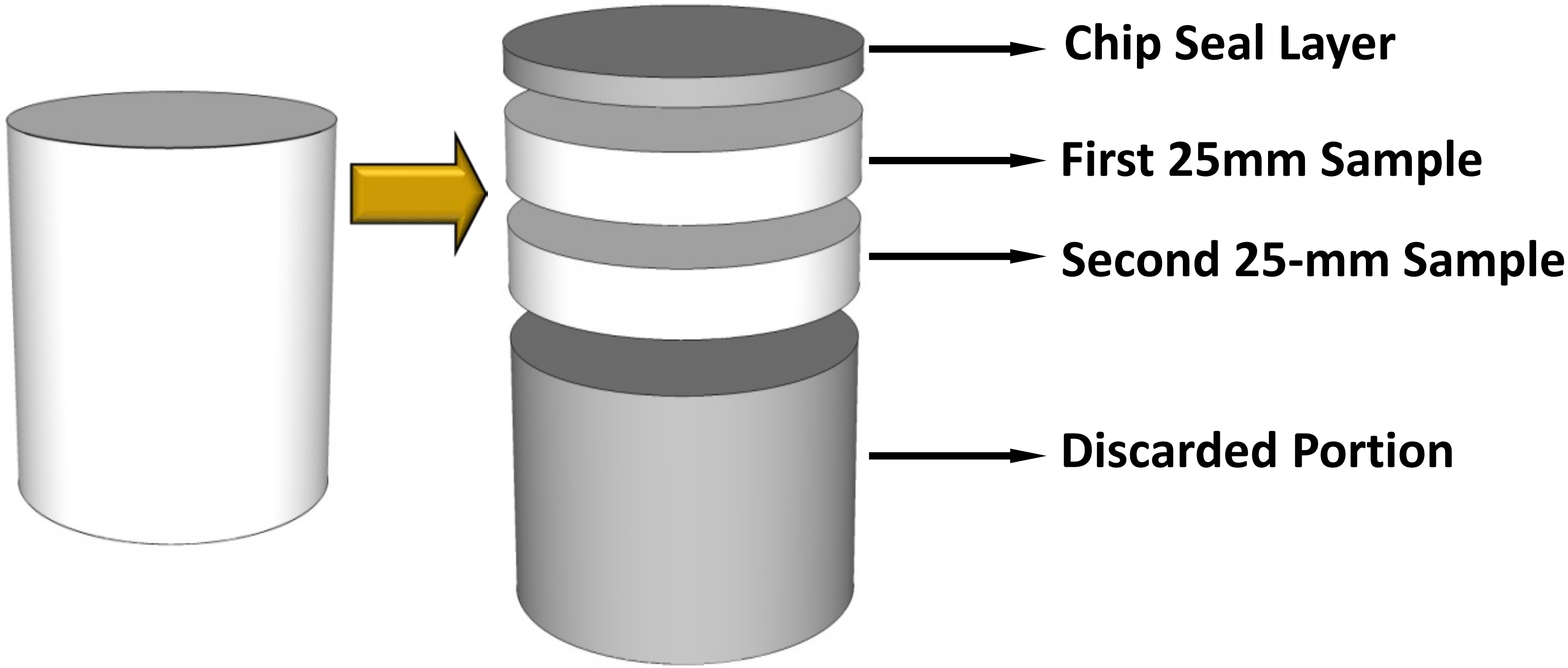
- We need to condition mixtures to simulate proper field conditions at 7 to 10 years
  - 24-hr loose mix aging @ 135C (best we know)
- All tests seem to recognize the conditioned mixtures except for the IDT strength
  - Strength alone is not enough
  - S-VECD is meant more for design. Good test but in different “league”.
- Need to accept tests for what they are and designed to do
- Begin to adjust tests for climates

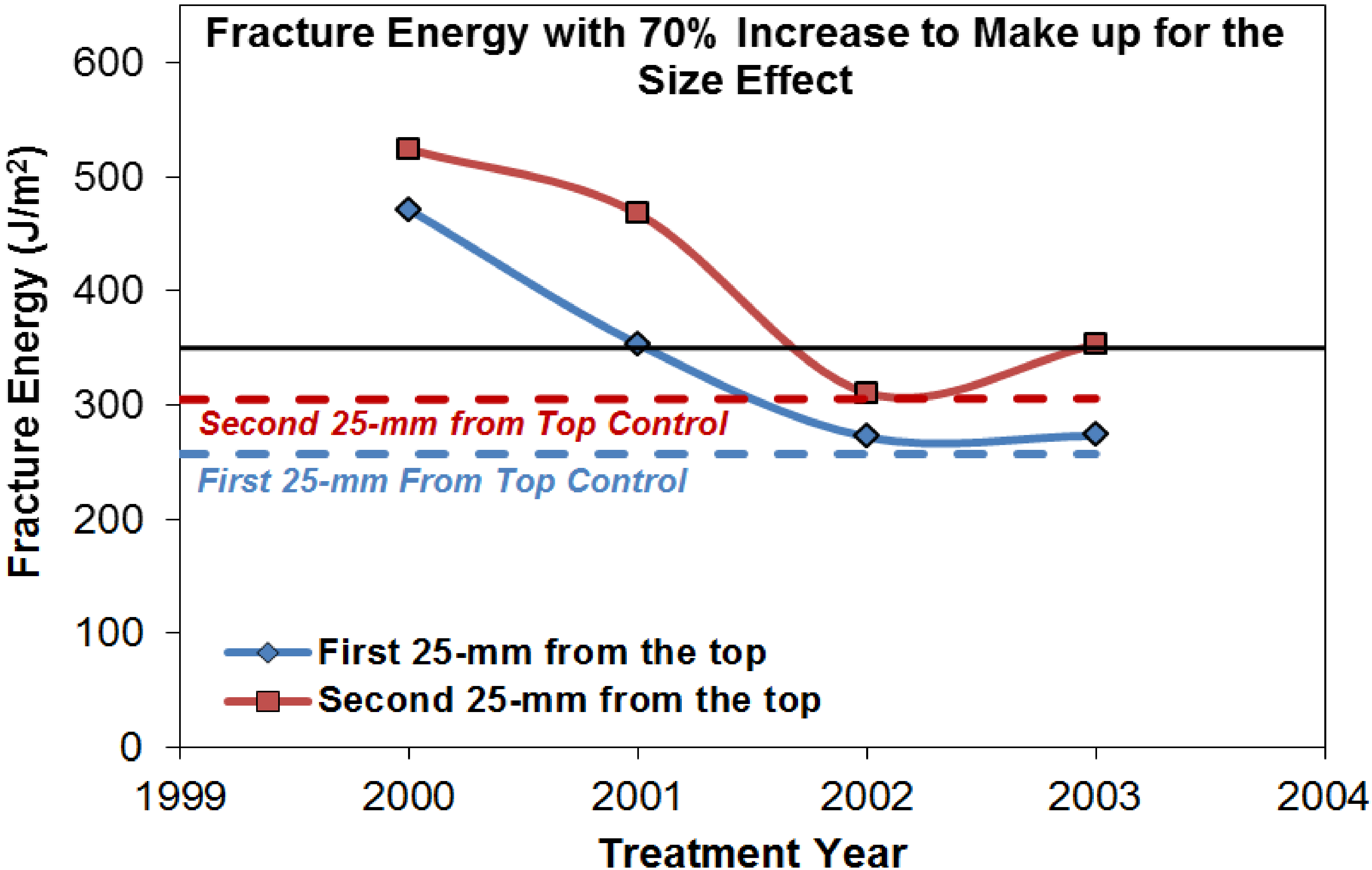
# Application

# Pavement Preservation - Chip Seal on TH 56, MN DOT
## Preparation of Cores

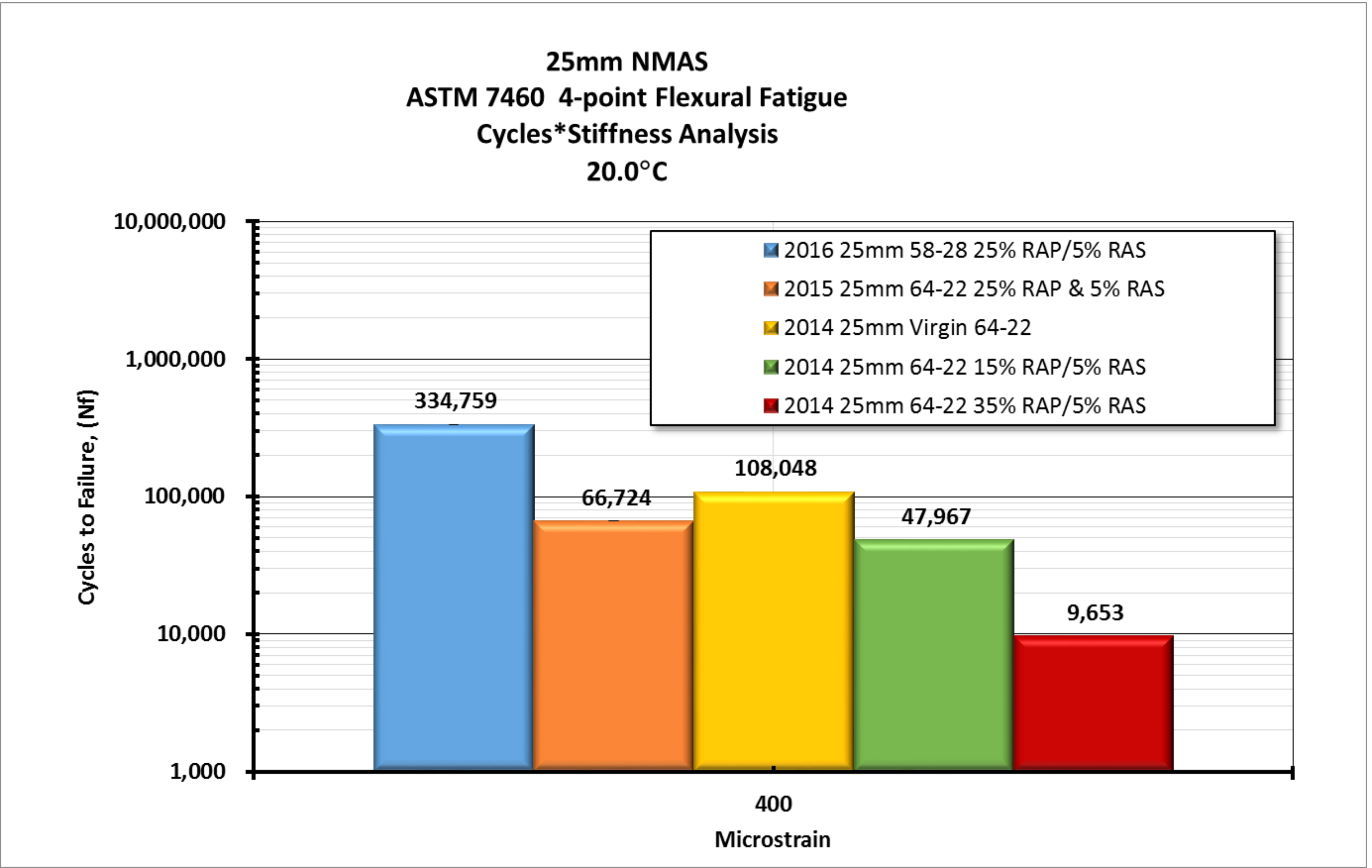




# Pavement Preservation with Chip Seal



# RAP in a DOT Mix – 25mm



# RAP in a DOT Mix – 19mm

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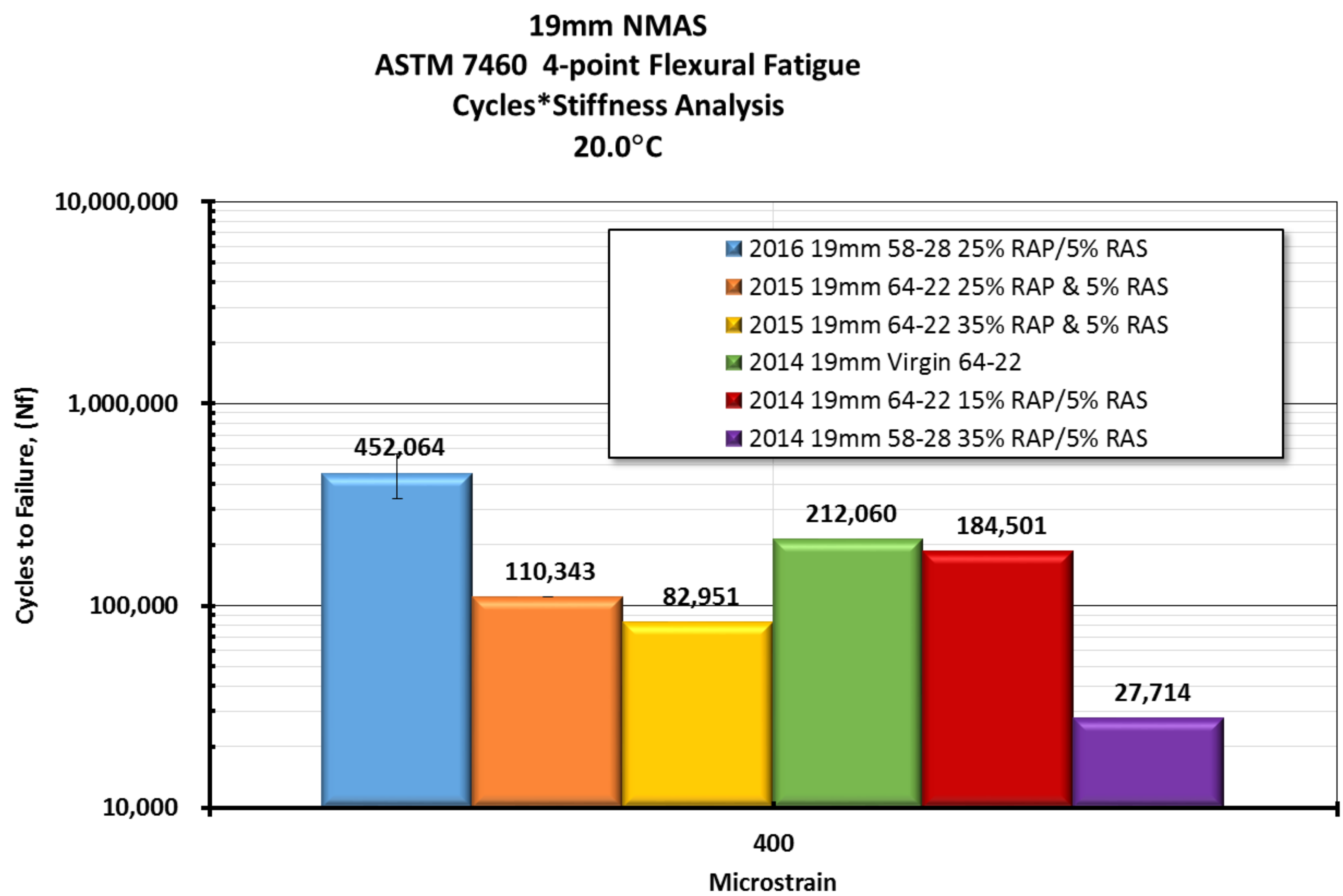
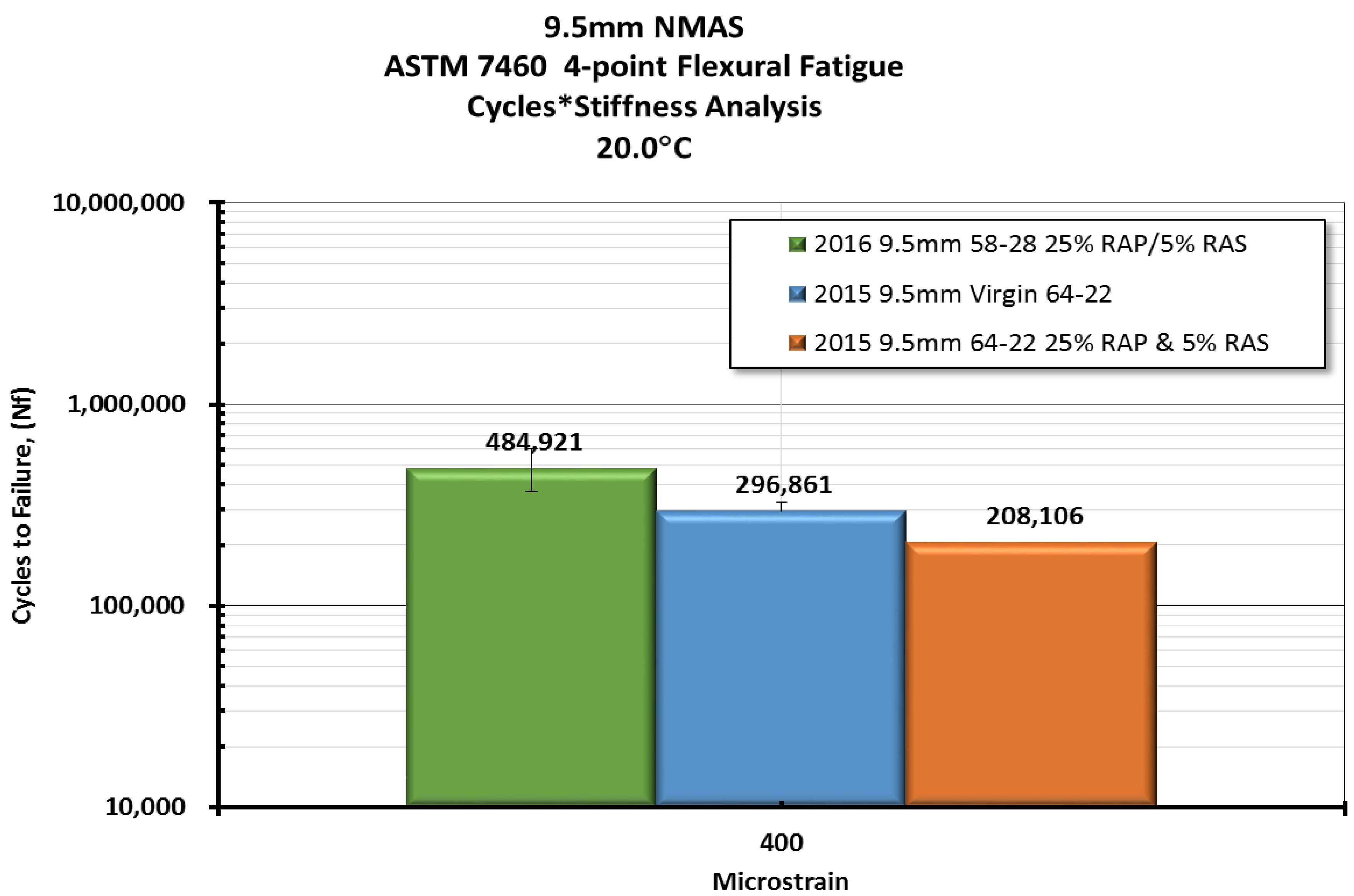


# RAP in a DOT Mix – 9.5mm



# RAP Study - 24 hour aged

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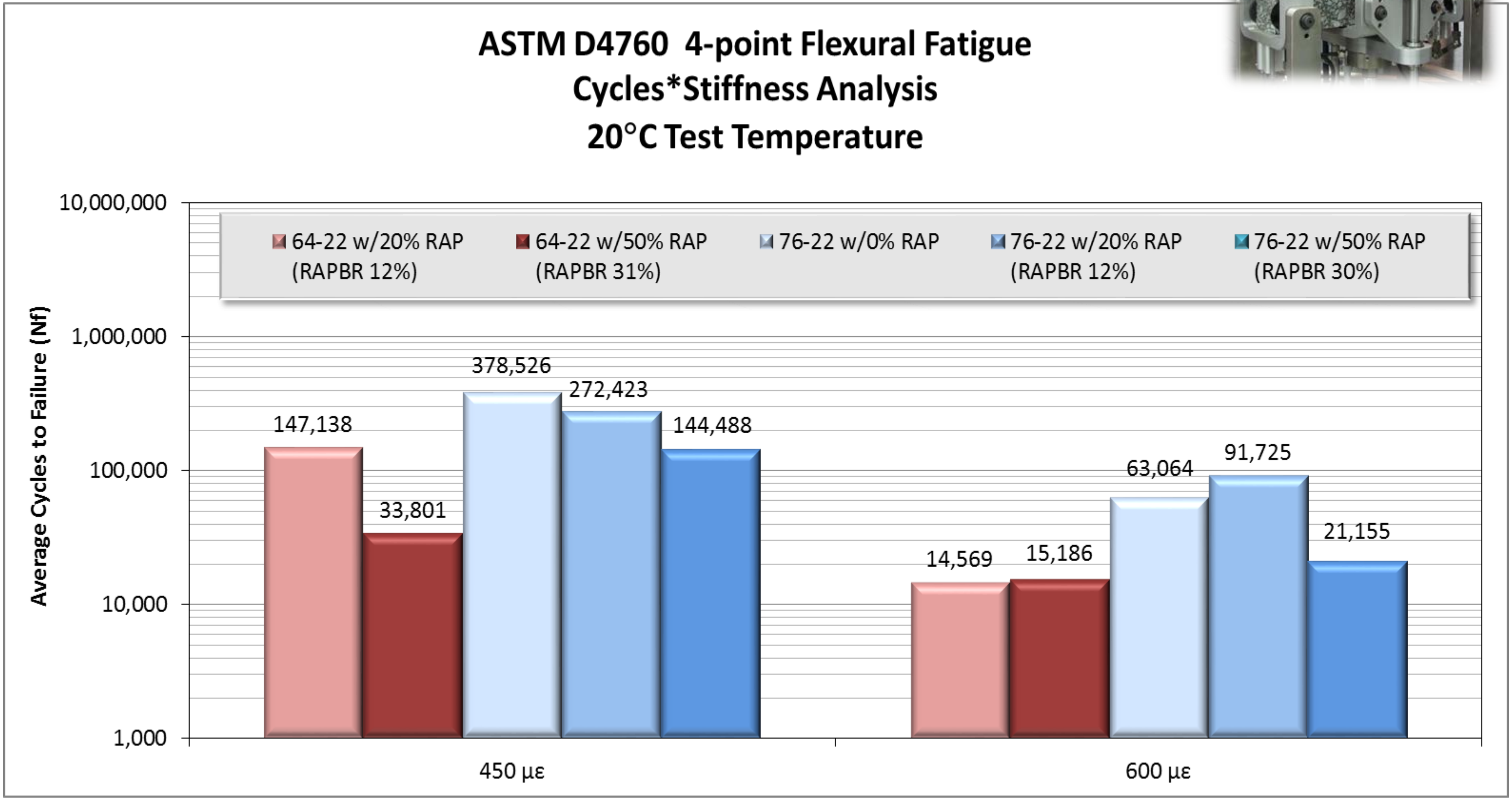
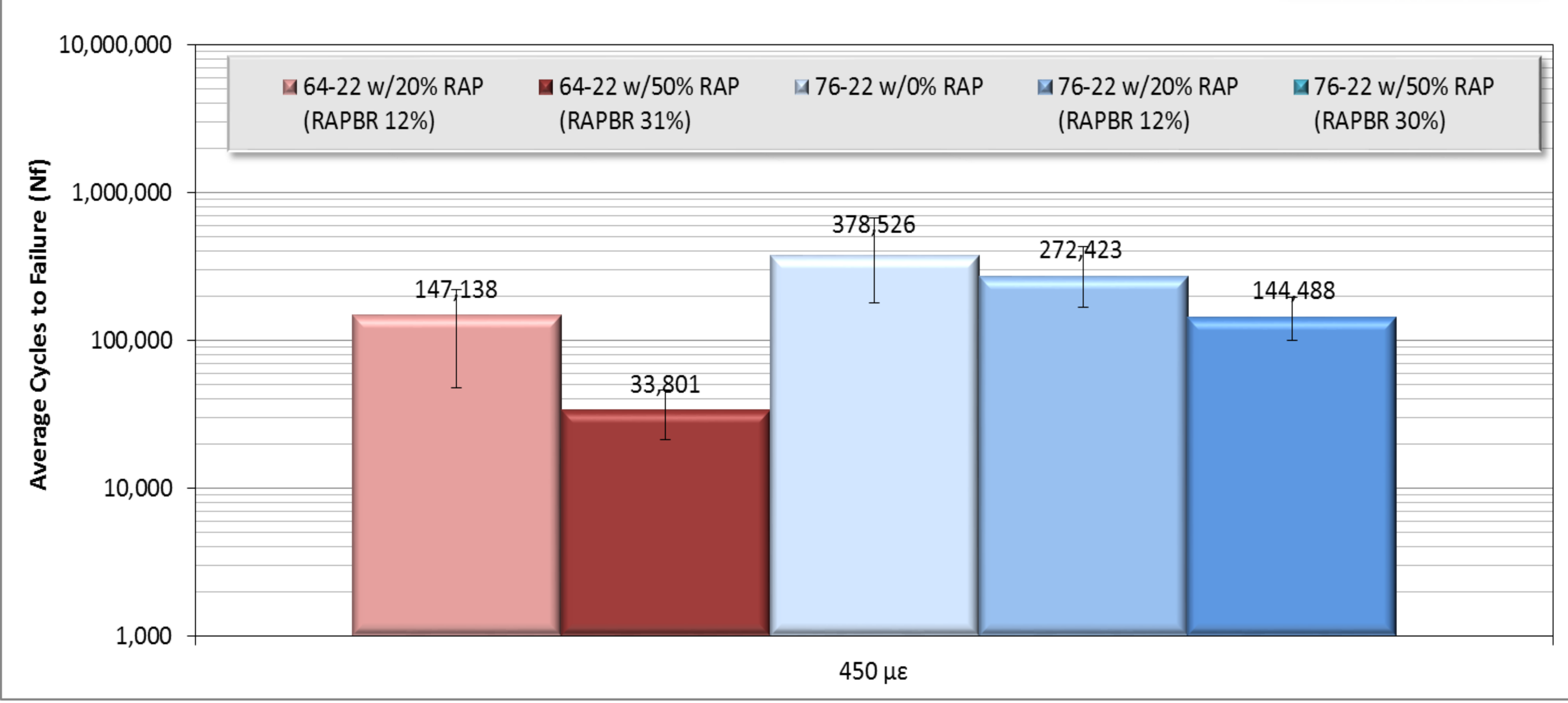


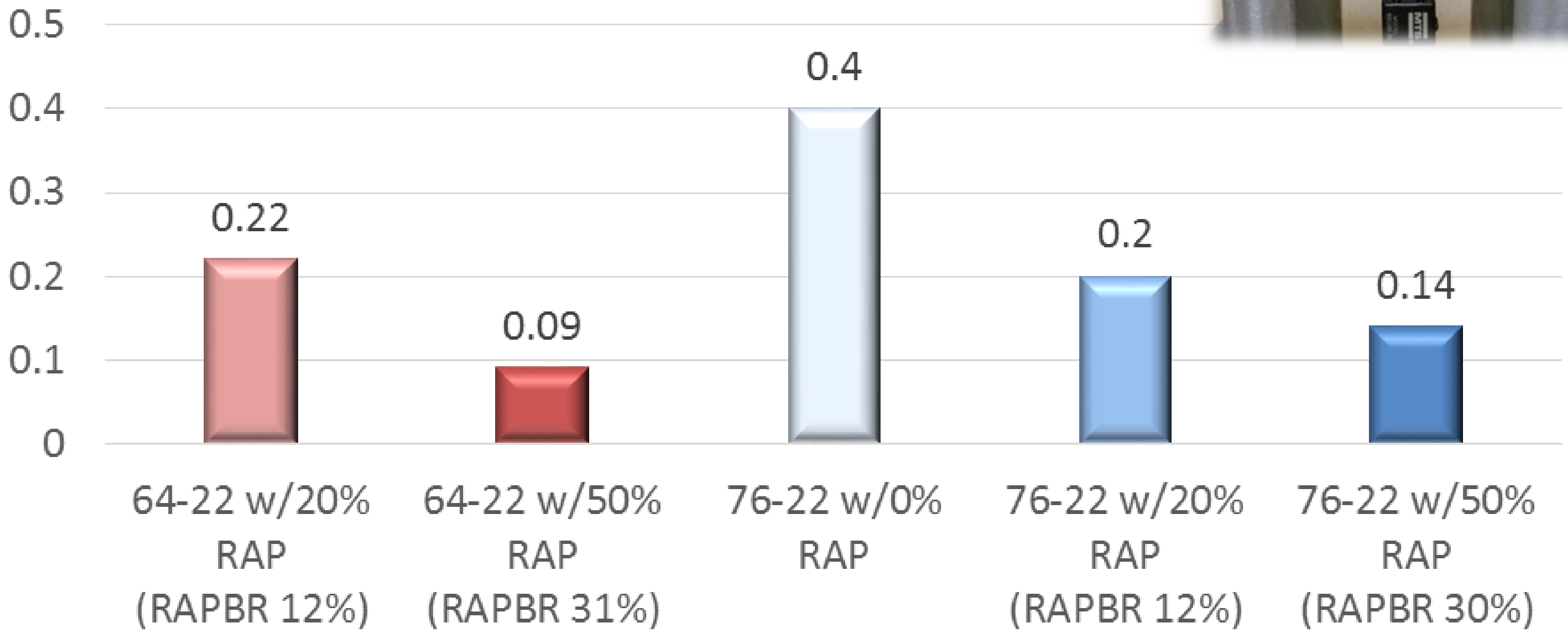
# RAP Study - 24 hour aged

## 400 microstrain only

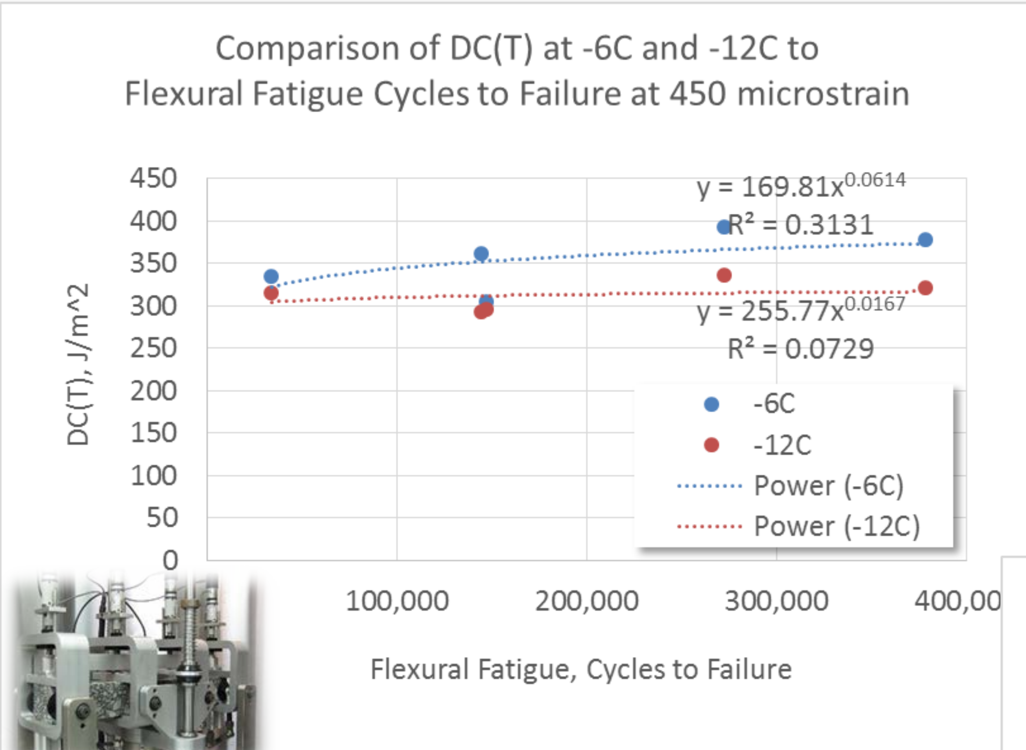


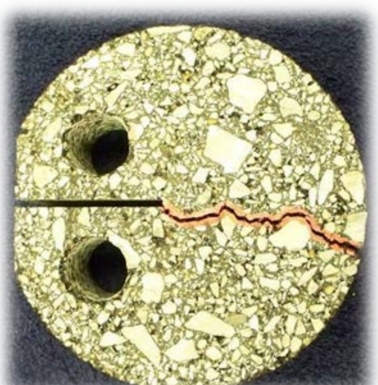
# RAP Study - 24 hour aged

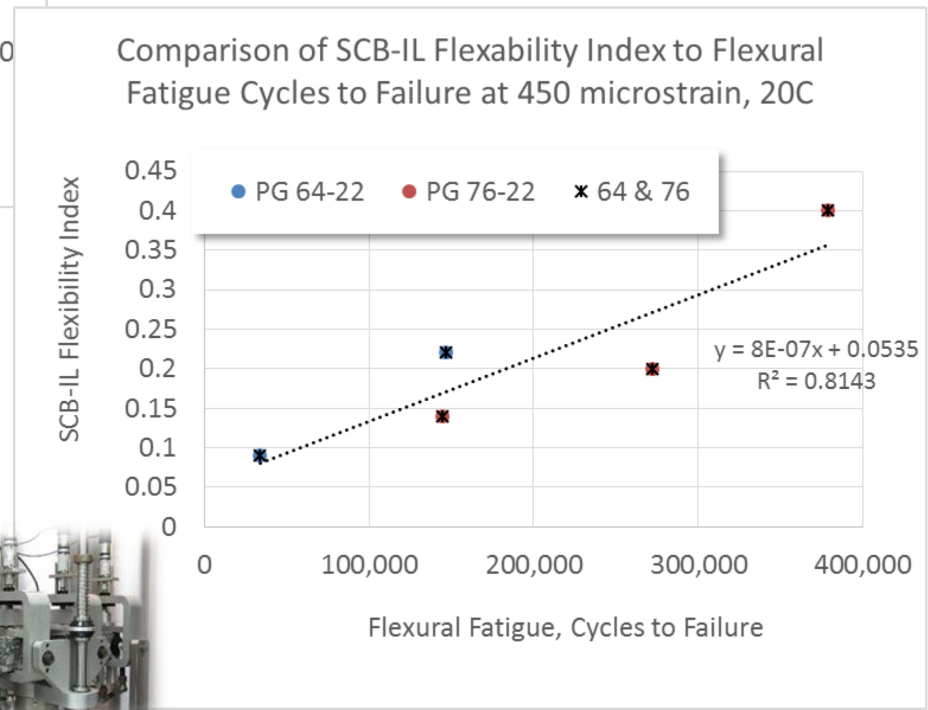
SCB-IL Method
25C, 24-hr aged @ 135C



# How The Tests Relate





# Cracking Tests – The Big Picture

## Phil's Opinion

# Become an AAPT Member!

Association of Asphalt Paving Technologists

- Access to information and emerging technologies
- Part of a technical community comprised of individuals from all parts of the asphalt industry
- Debate on important technical issues
- North American-based organization with significant international membership and focus
- Association operates without organizational biases
- Support the next generation of asphalt technologists through a robust student scholarship program

http://asphalttechnology.org/membership.html

# 2017 Asphalt Institute members

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