Evaluation of Laboratory Performance Tests for Fatigue Cracking of Asphalt Pavements

April 2015 Mix ETG

FHWA Cooperative Study at Asphalt Institute

Project

- Principal Investigator
  - Mike Anderson, Asphalt Institute

- Evaluation of current cracking performance tests

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
- RAP/RAS content
- Warm-mix additives

Phase 1 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

Initial Testing Plan

Test	Test Temperature	Test Strain / Load Rate Condition	Equivalent Test Speed
4-Point Bending Beam Fatigue	15°C & 20°C	300 & 600με; 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) 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

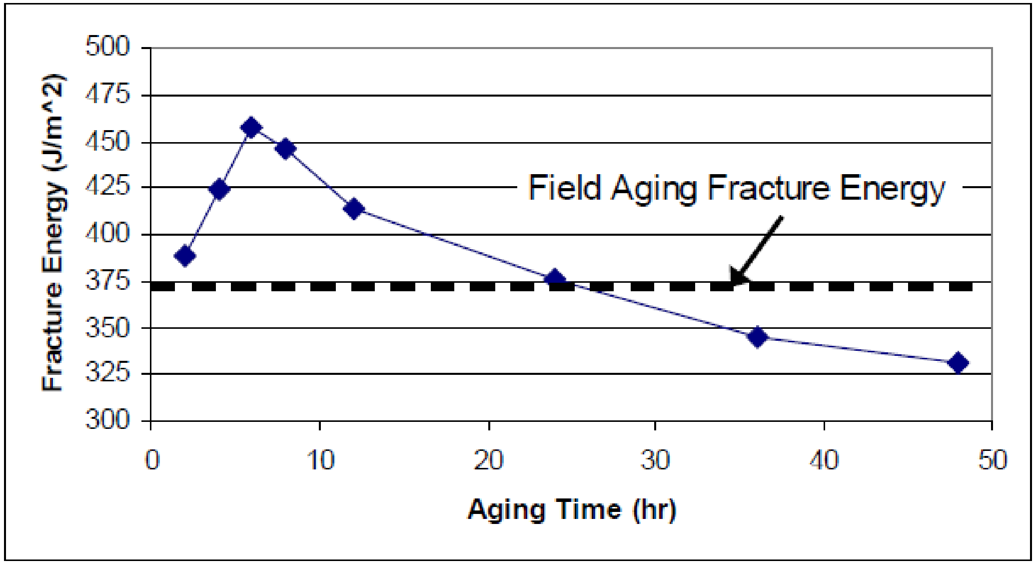


Figure 6 – Effect of 135°C Aging on M3 Fracture Energy

- 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)

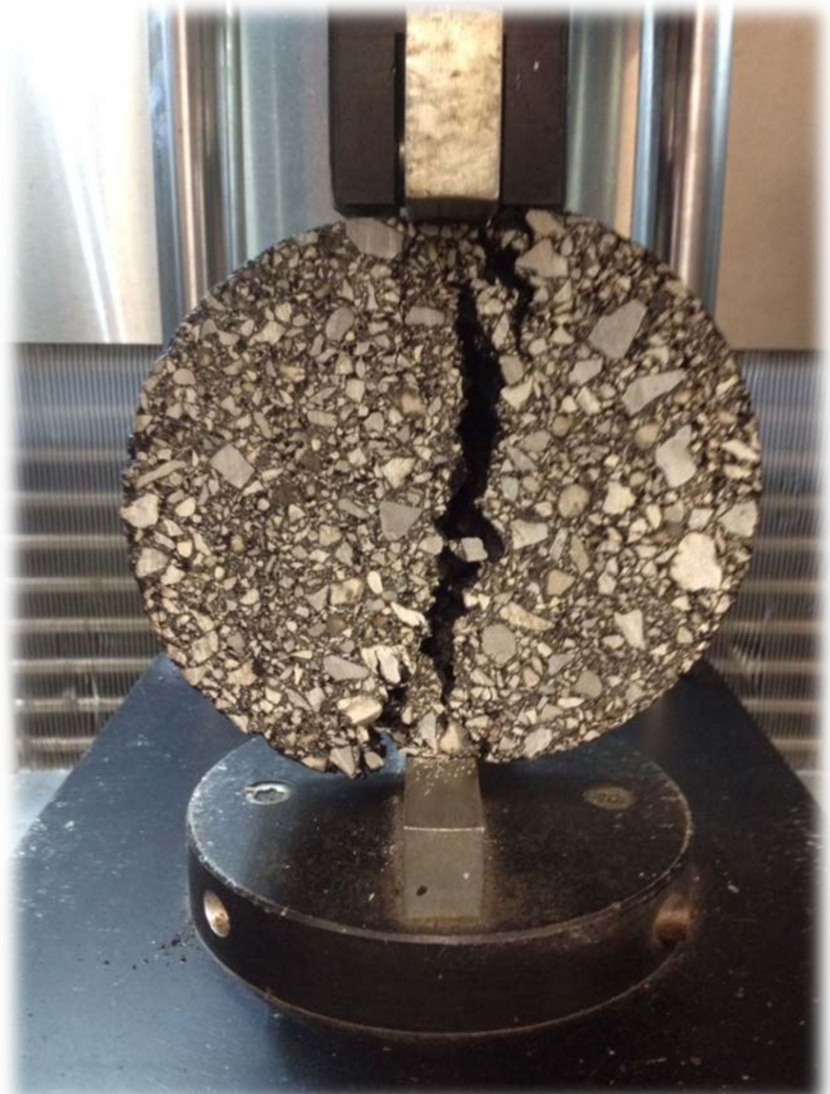
- Draft AASHTO standard by Richard Kim
- 18°C / 23°C
  - Not recommended to run over 21°C
- Various Strains
- Software builds curve based on three tests

Data Inconclusive

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

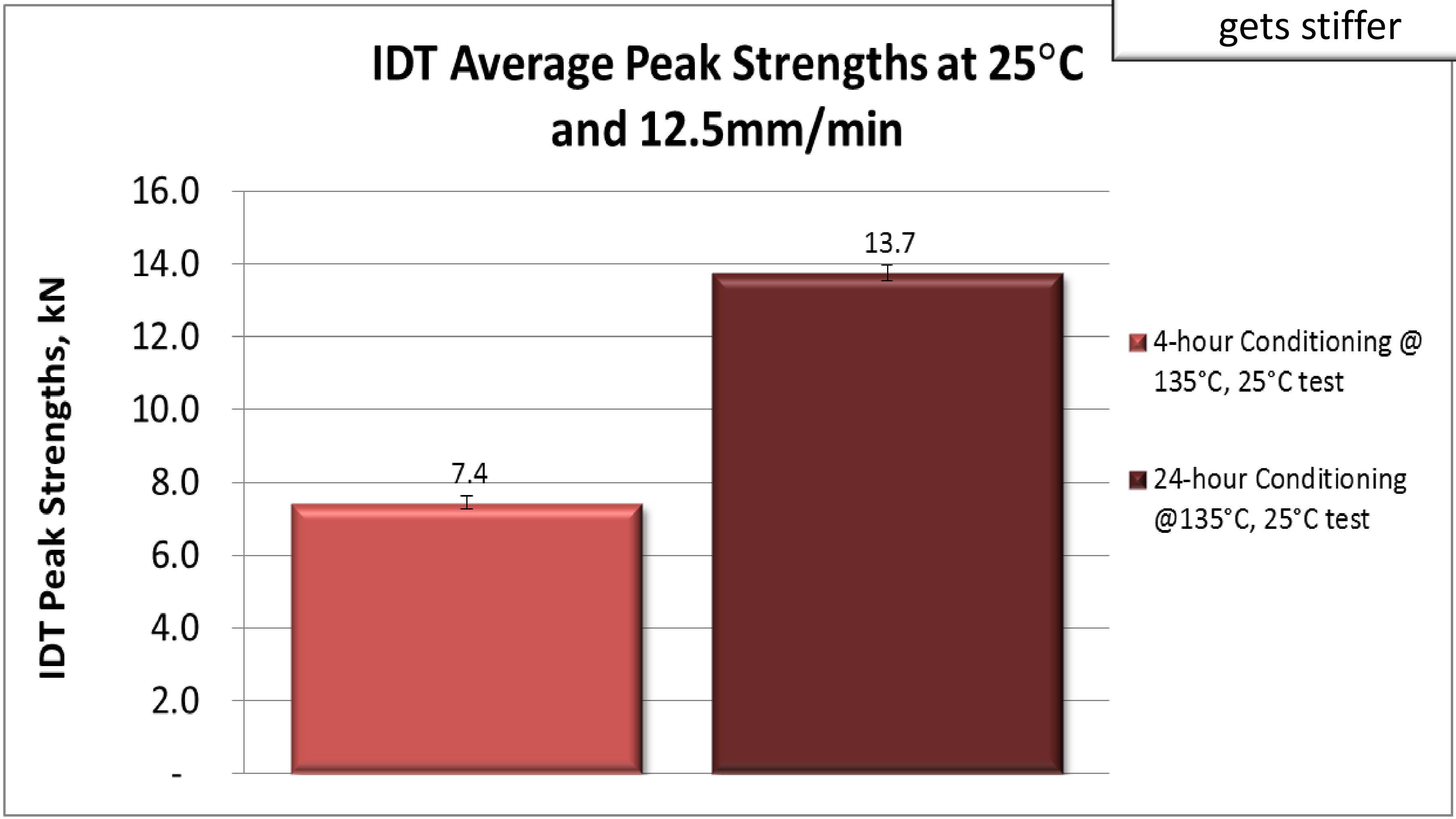
Indirect Tensile Strength (IDT)

- 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)

Simplest test, but just says that mix gets stiffer



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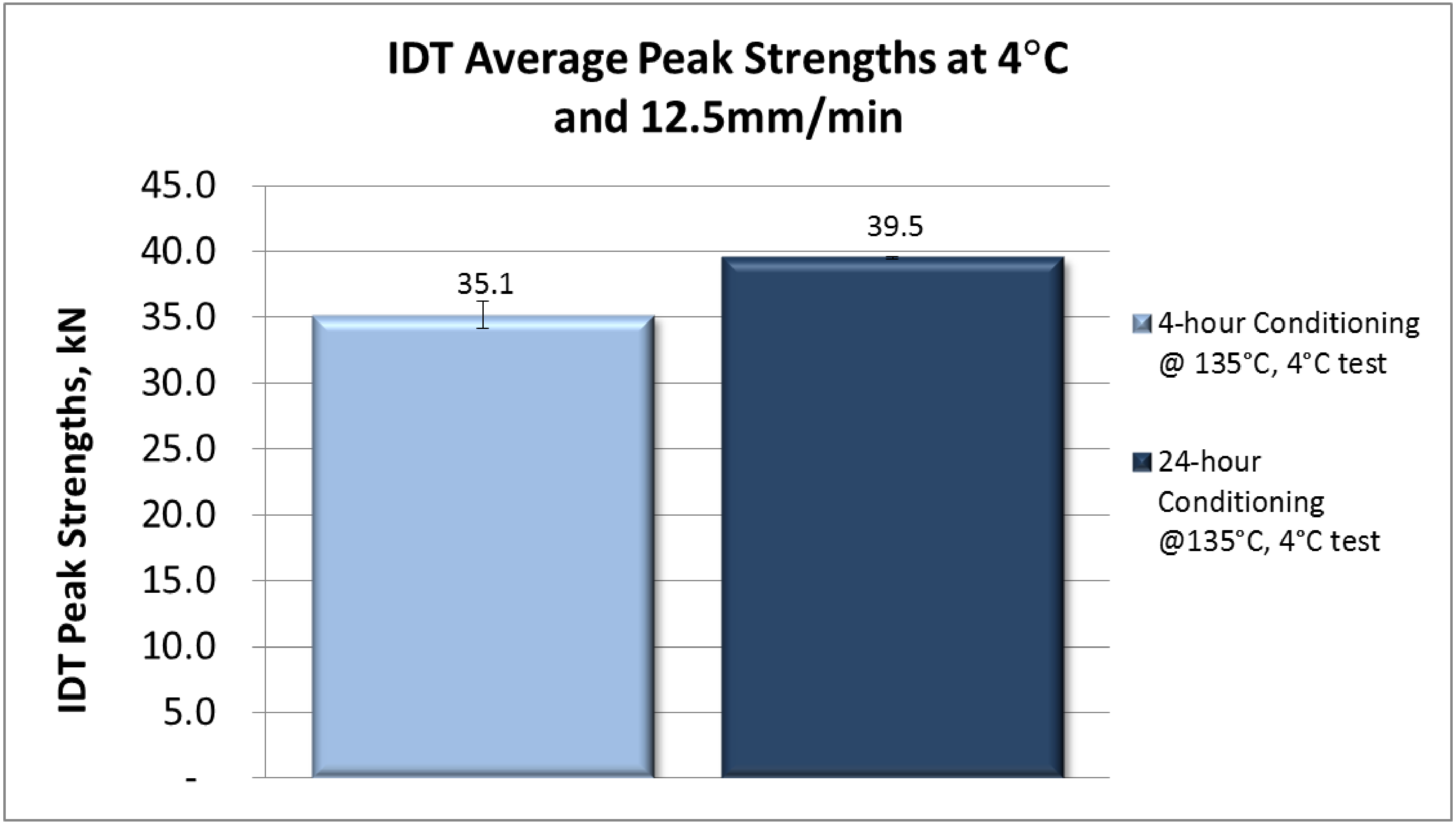

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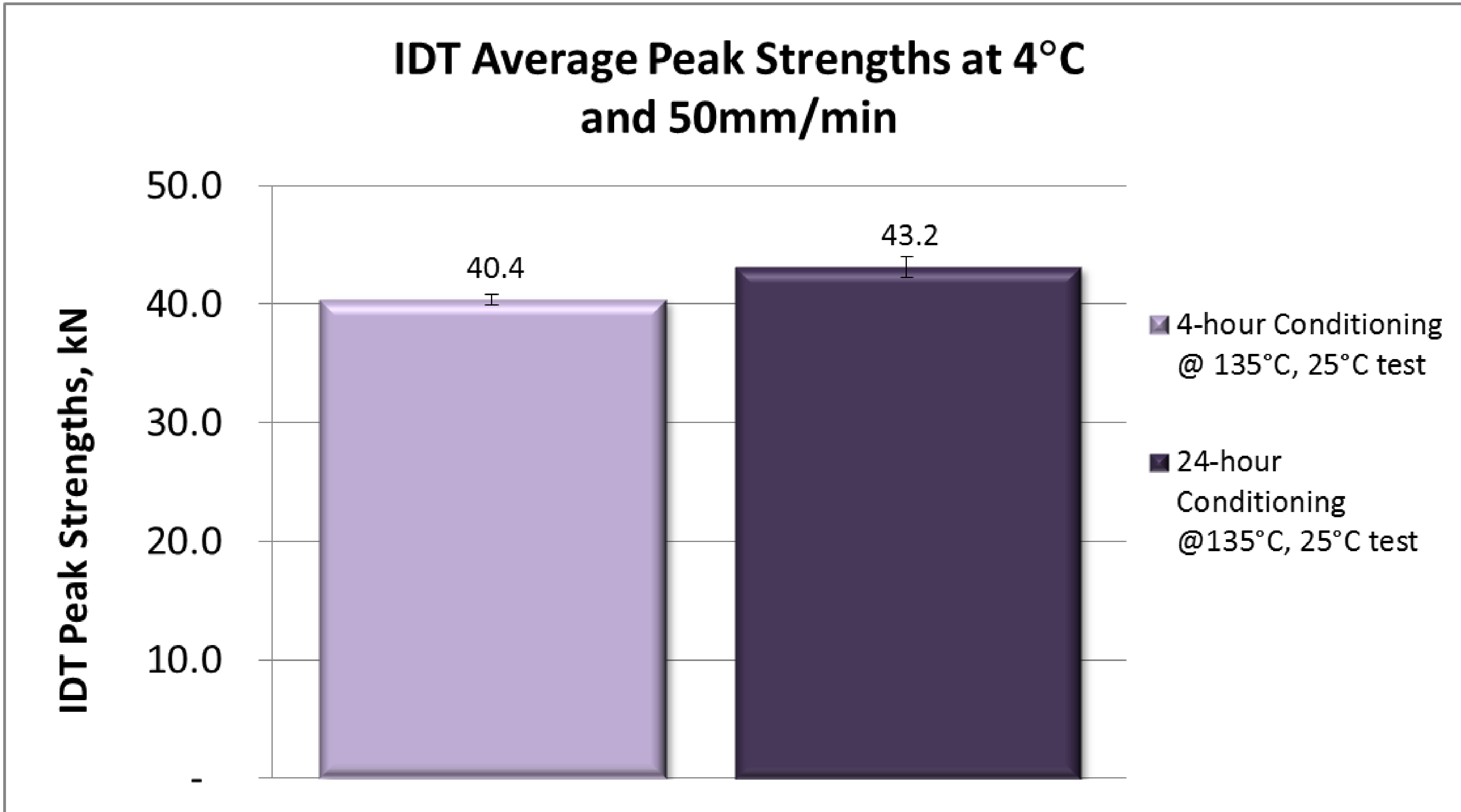

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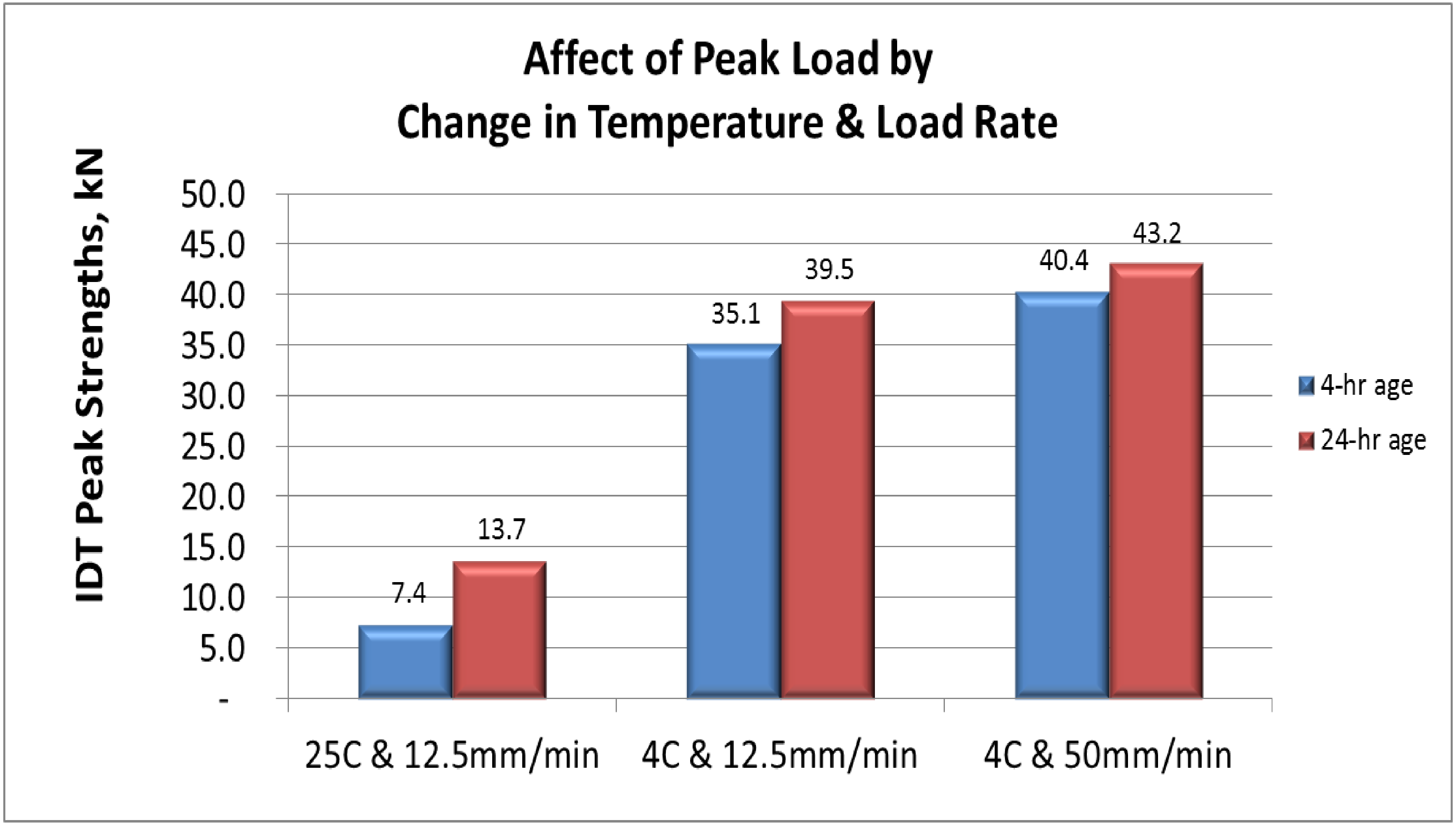
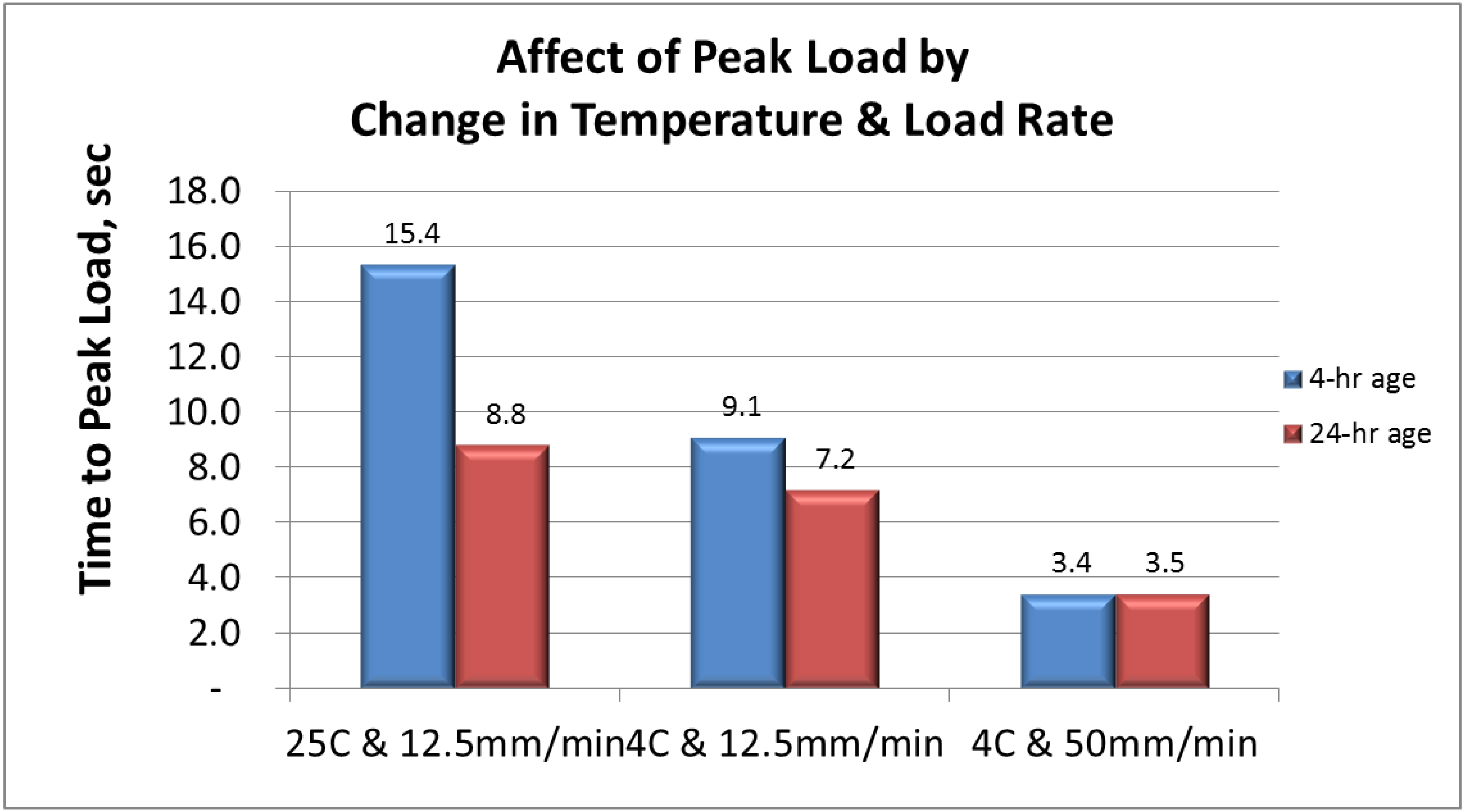


So what can we learn? Confirms that we need correct temperature/loading rate for cracking sensitivity. Peak load alone is not the answer.

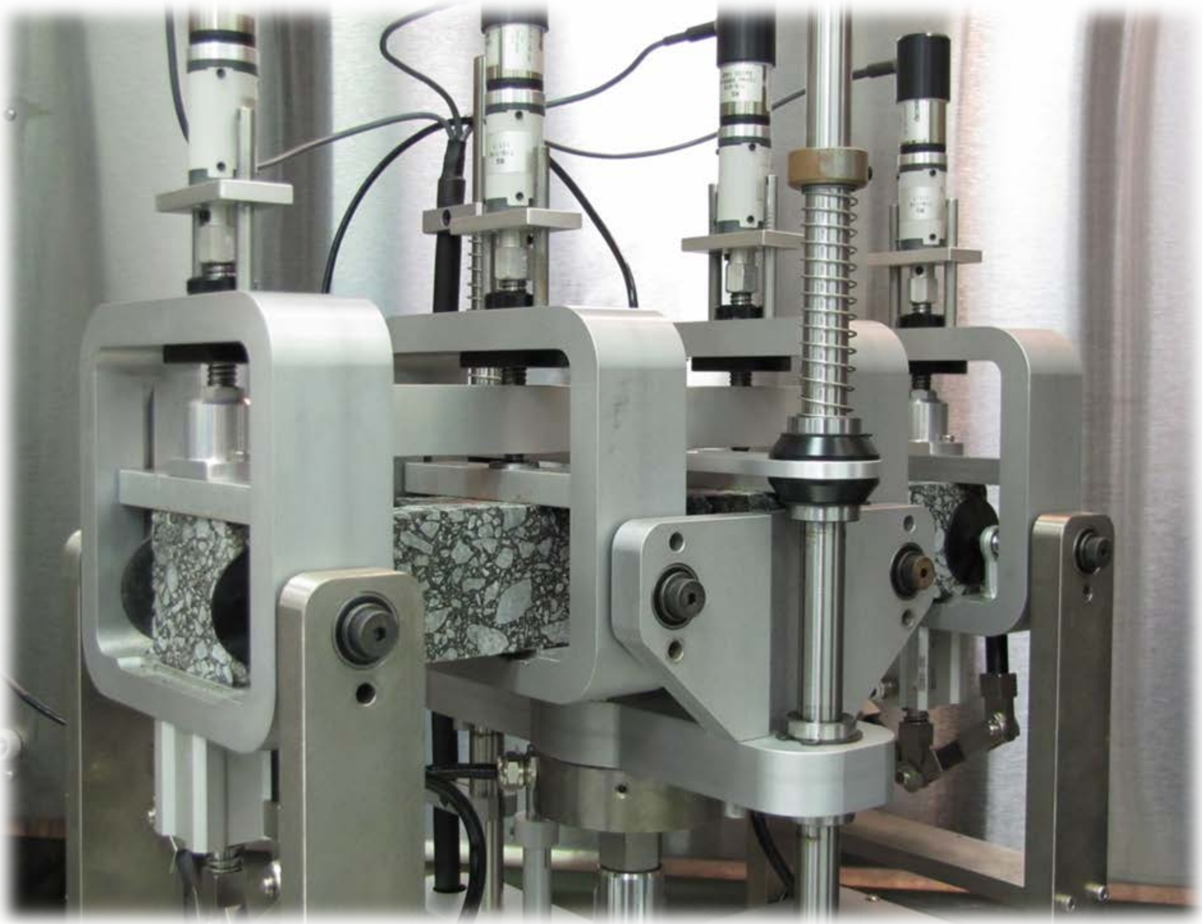
Indirect Tensile Strength (IDT)



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

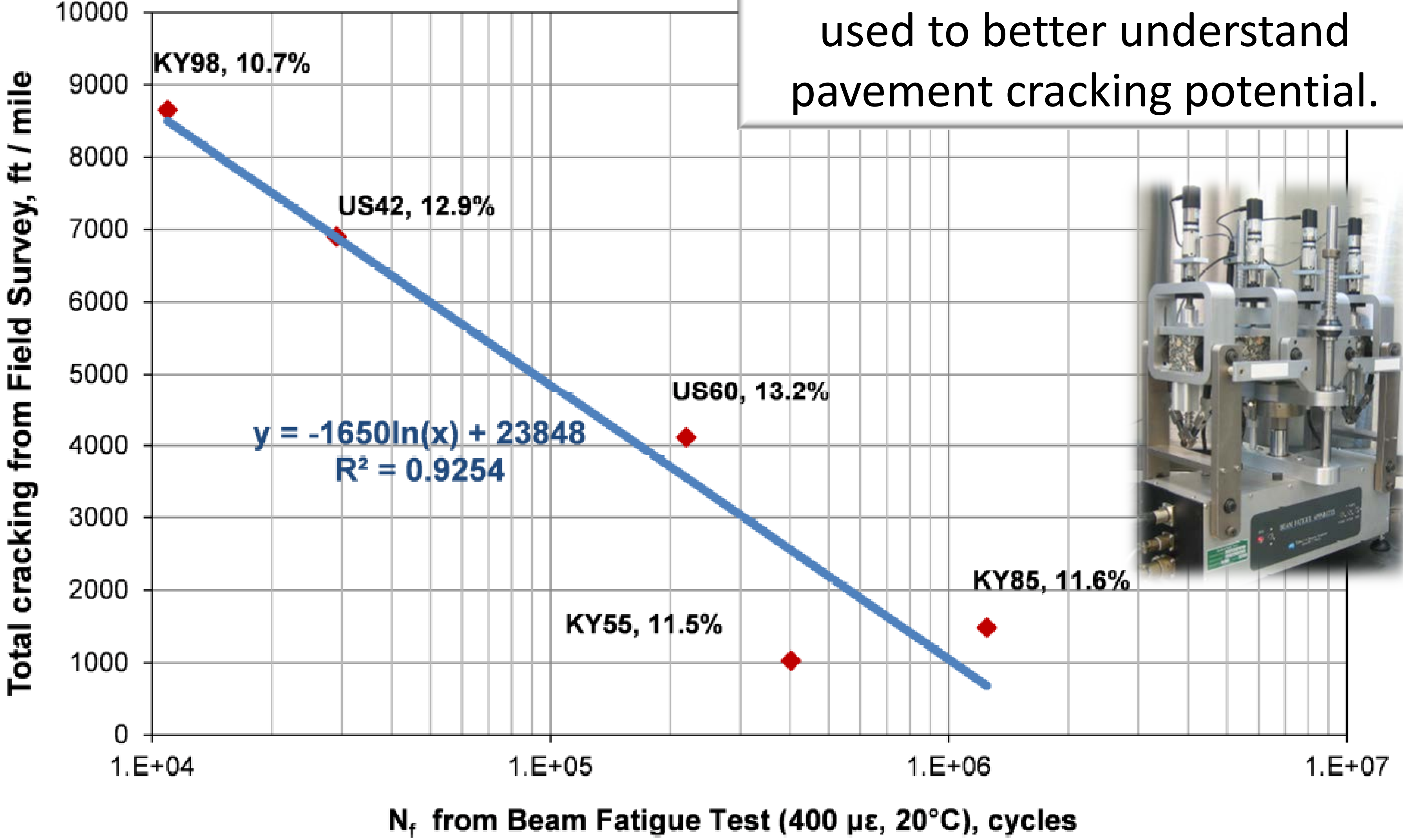
- 4-point bending beam fatigue (1950's / SHRP)
- AASHTO T321 & ASTM 7460
- Examined
  - 20.0°C & 15.0°C
  - Sine & haversine waves
- Rate of Movement: 10Hz, various strains (strain rates)
  - Ex: 300 ms = 0.16mm/0.1sec or 98mm/min
- 2 beams for average (per strain)



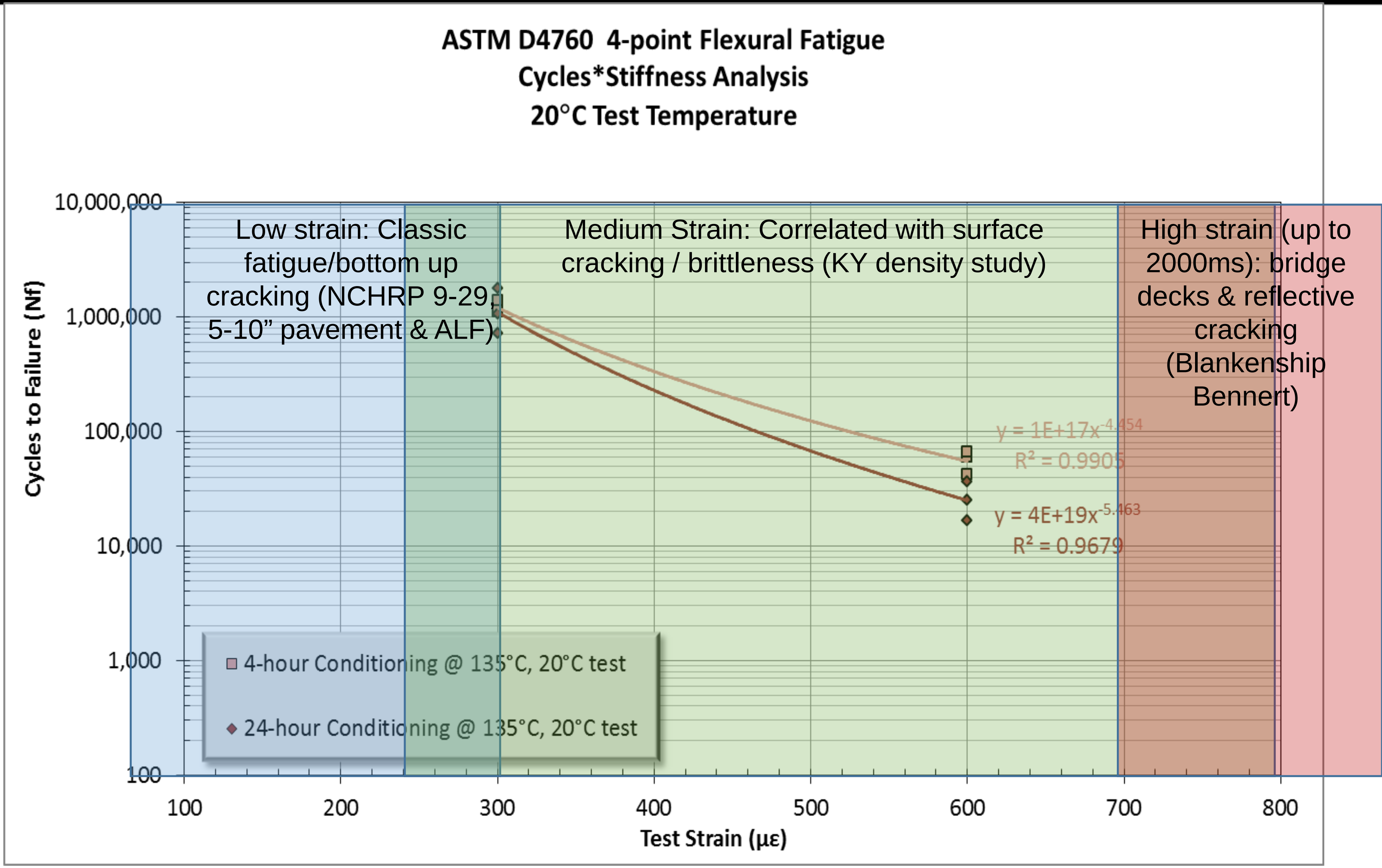
KY Density Study Findings with 24-hr Loose Mix Conditioning – M. Anderson

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

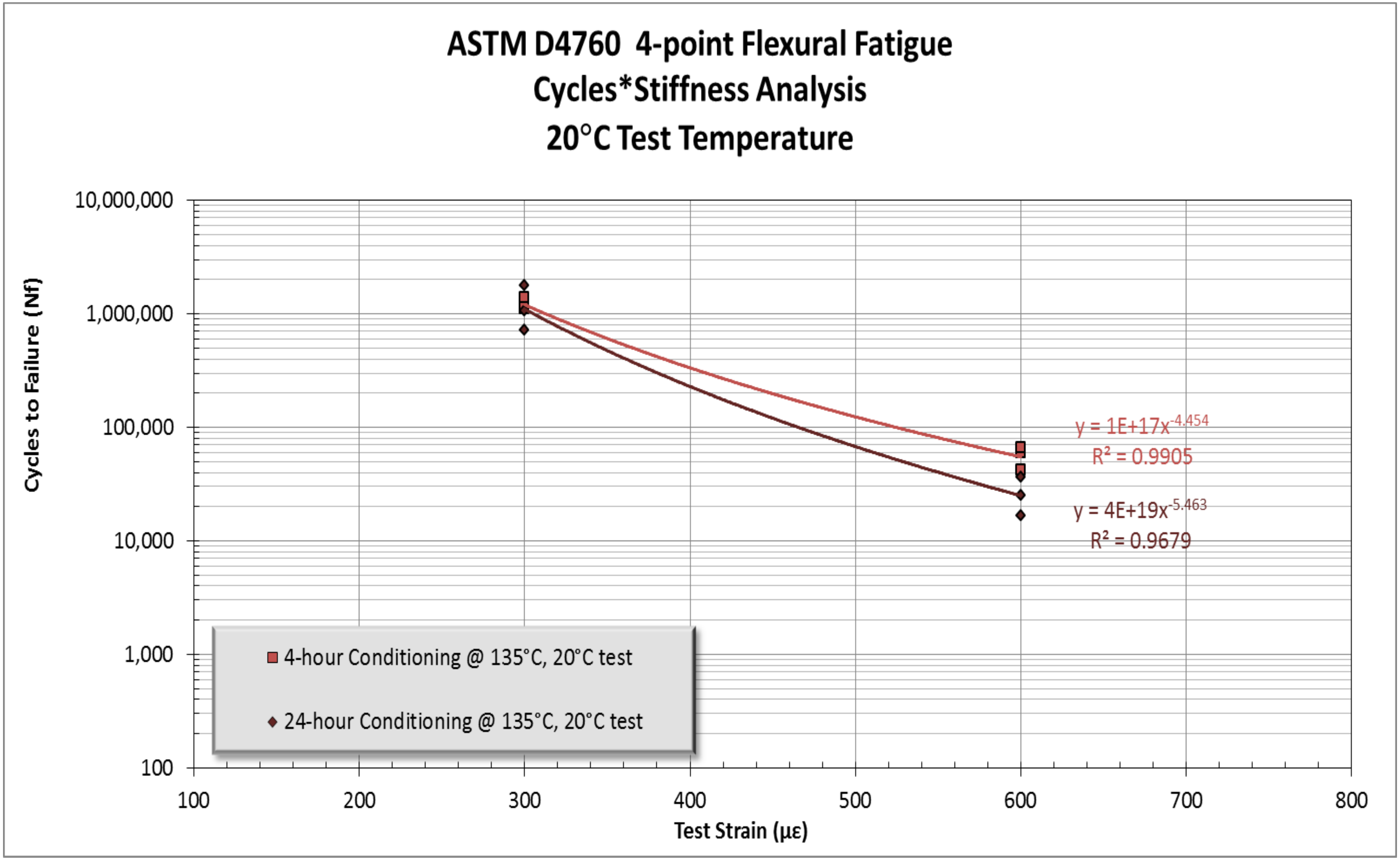
Beam fatigue device has been used to better understand pavement cracking potential.



Beam Fatigue – What strain do I use?



Beam Fatigue – 20°C & sine



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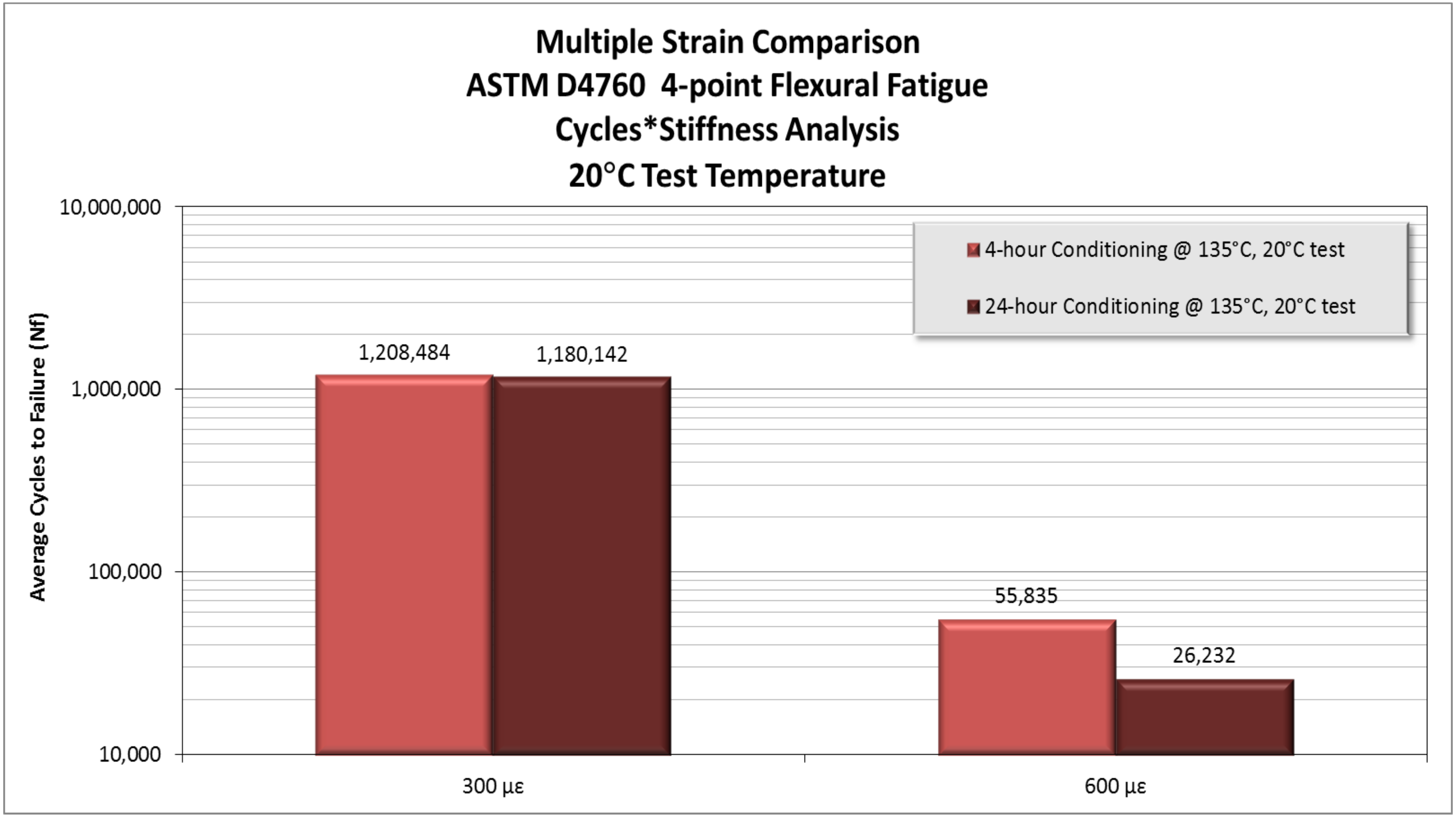
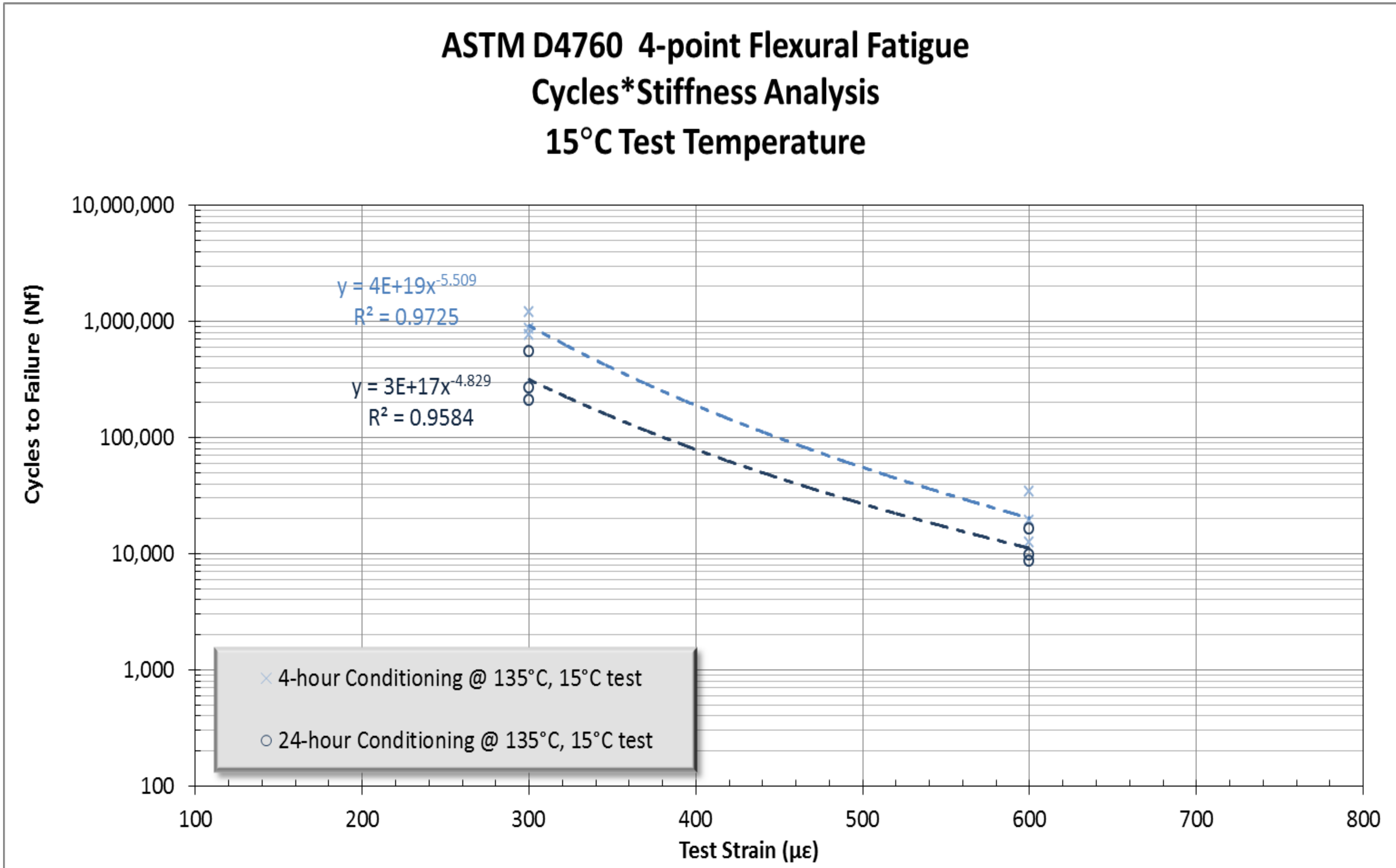


Beam Fatigue - 15°C & sine



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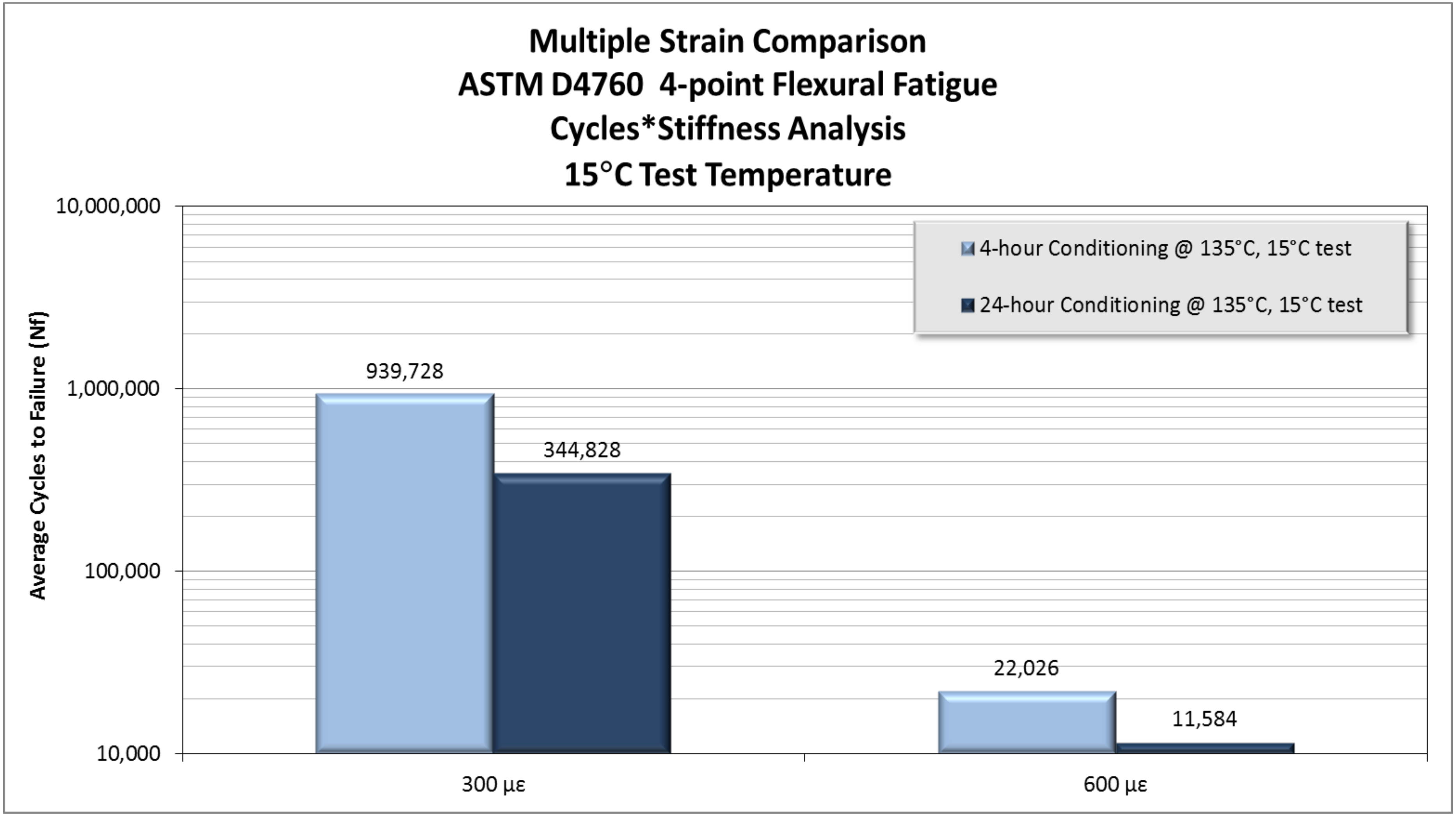
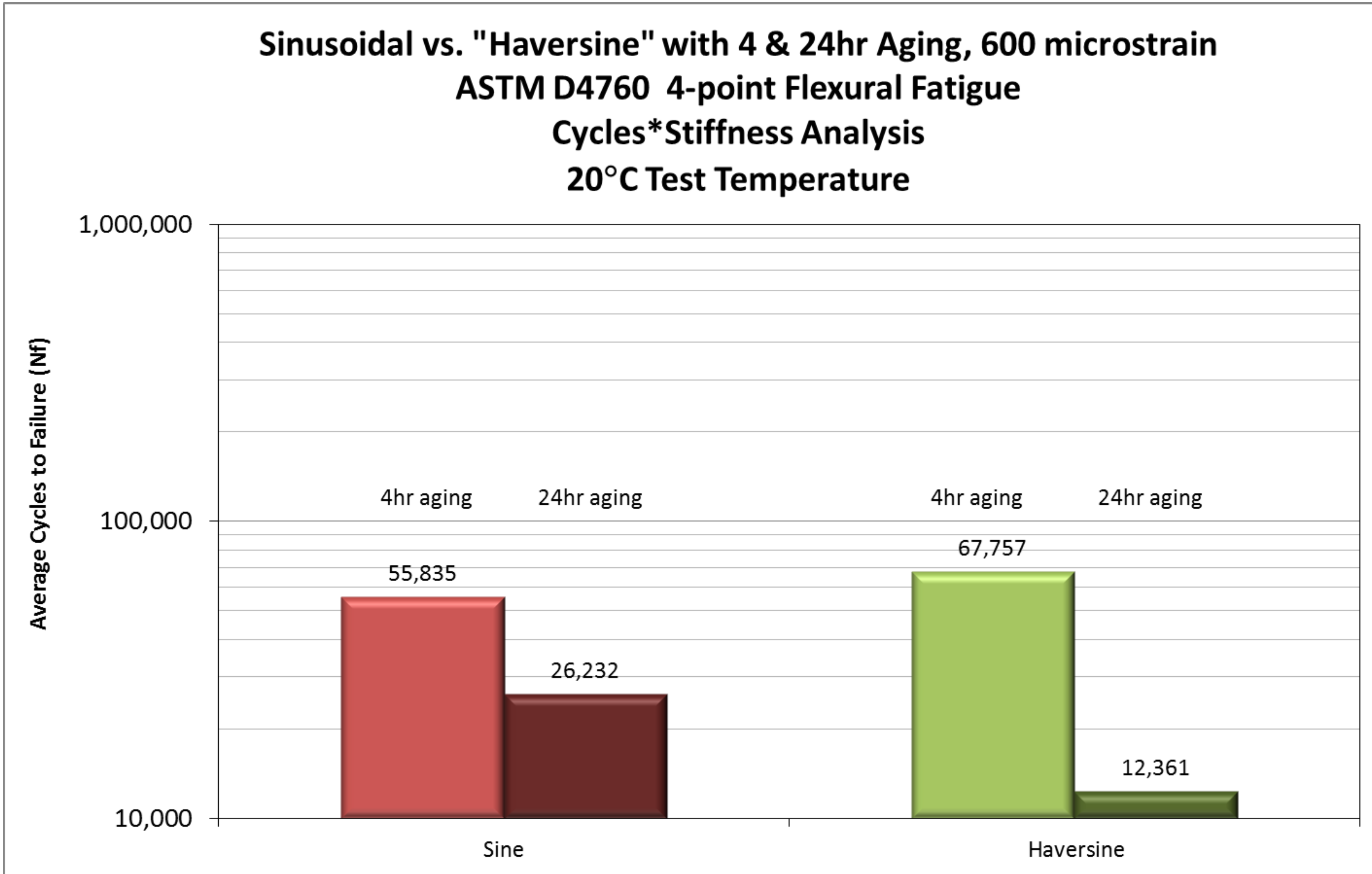
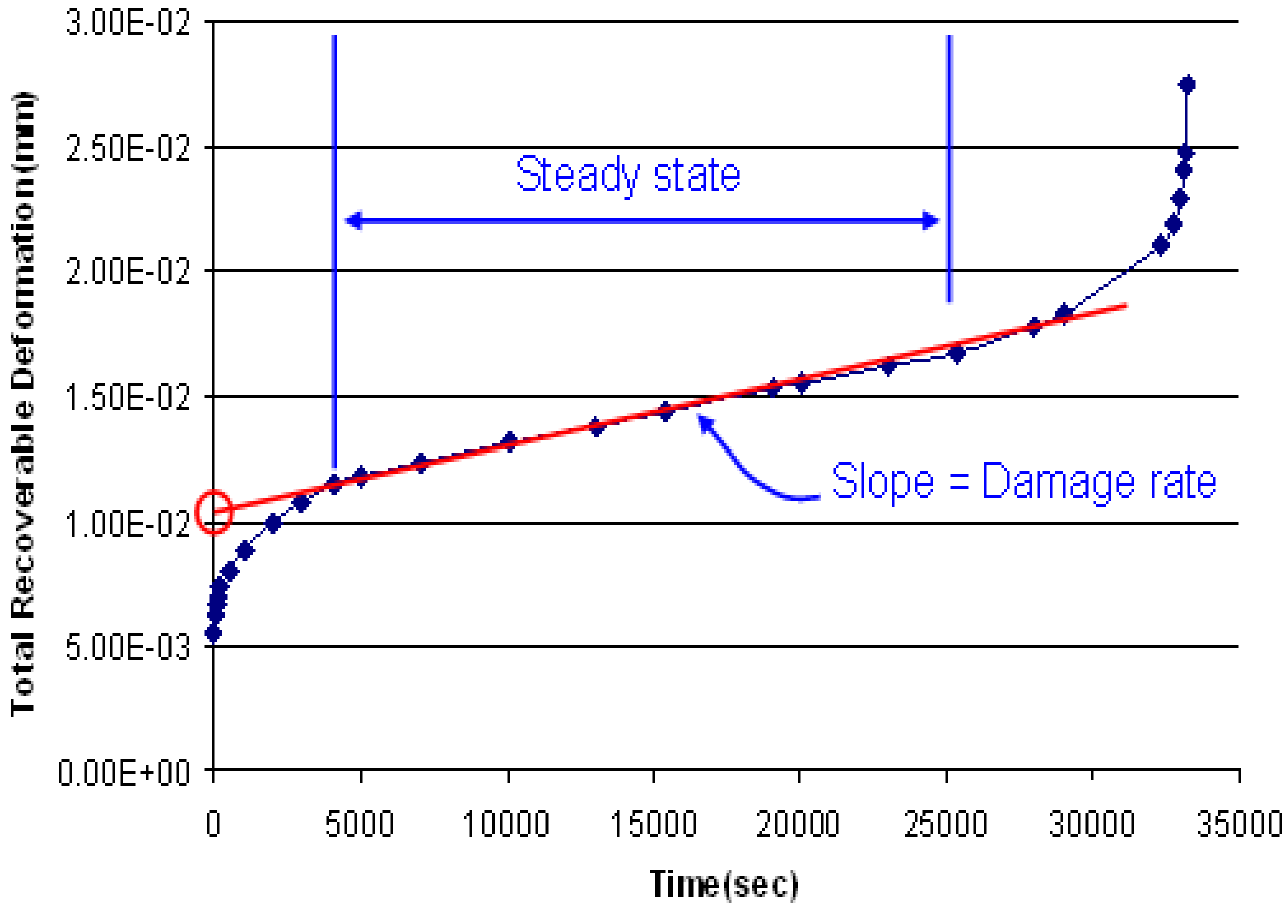


Beam Fatigue - 20°C, sine & haversine



Dissipated Creep Strain Energy (DSCE)

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



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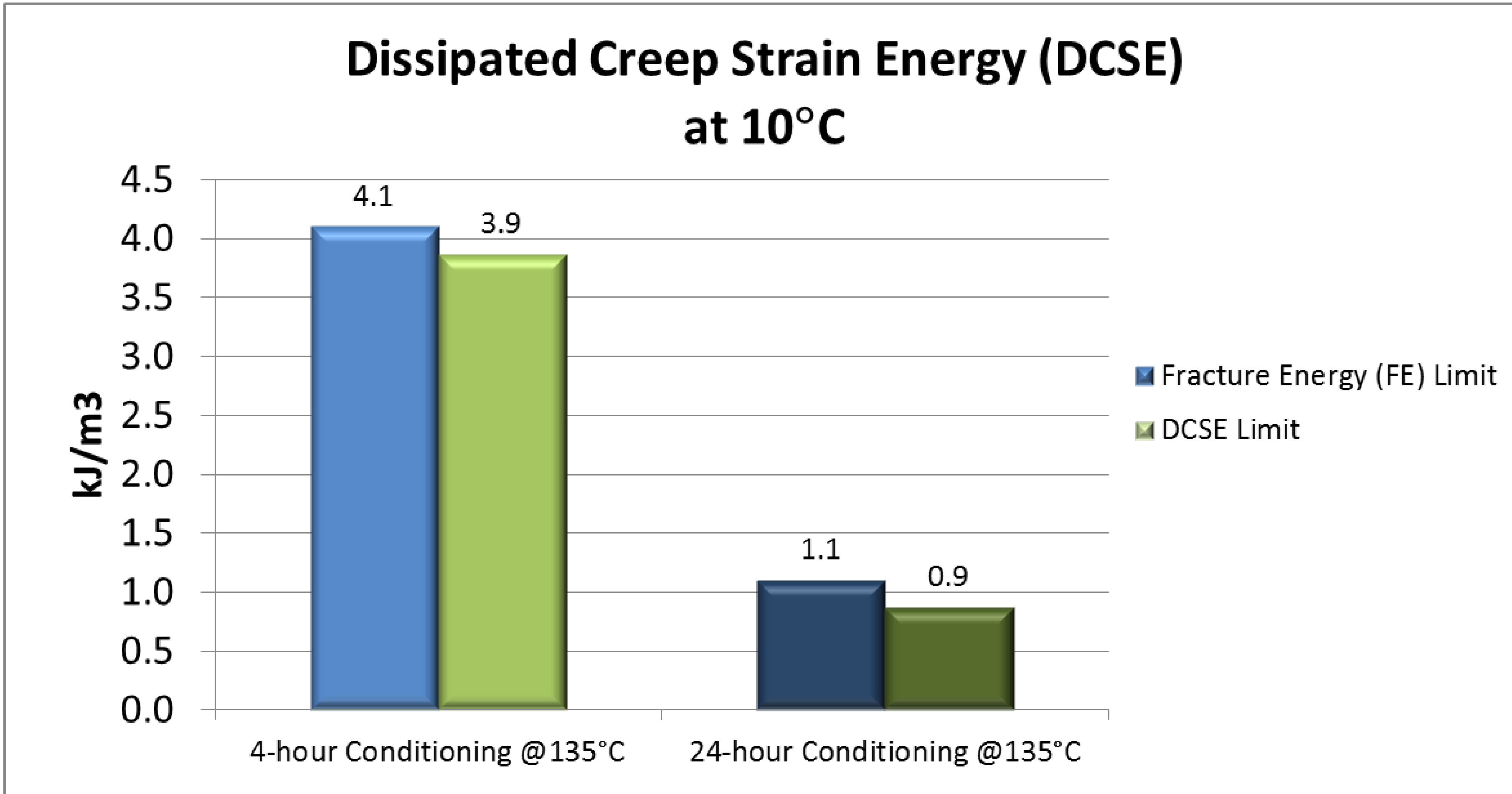

Note: Roque models not for 24hr aged mixture, but FE limit does shoe difference. COV's usually 7%.

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

Disk-Shaped Compact Tension [DC(t)]

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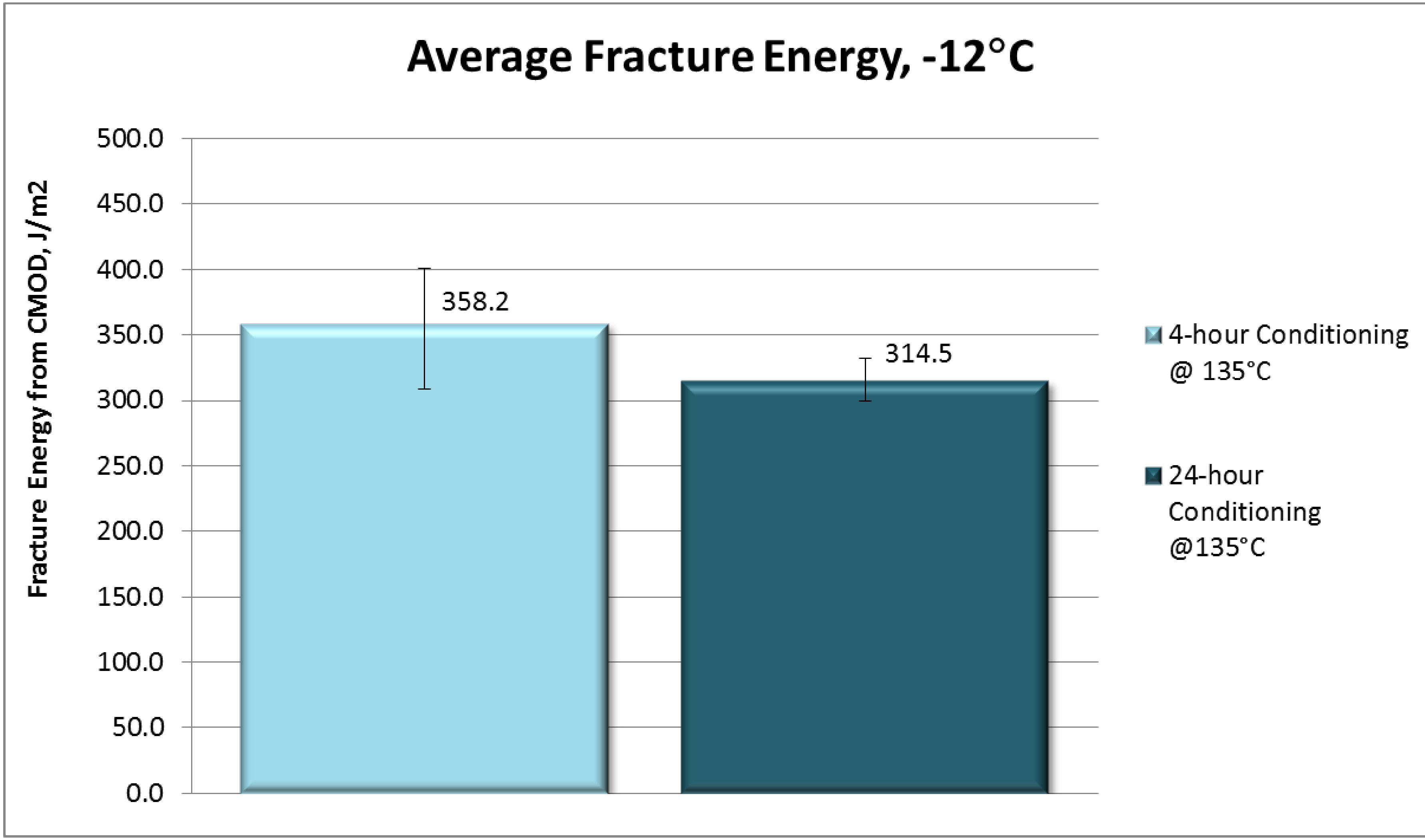
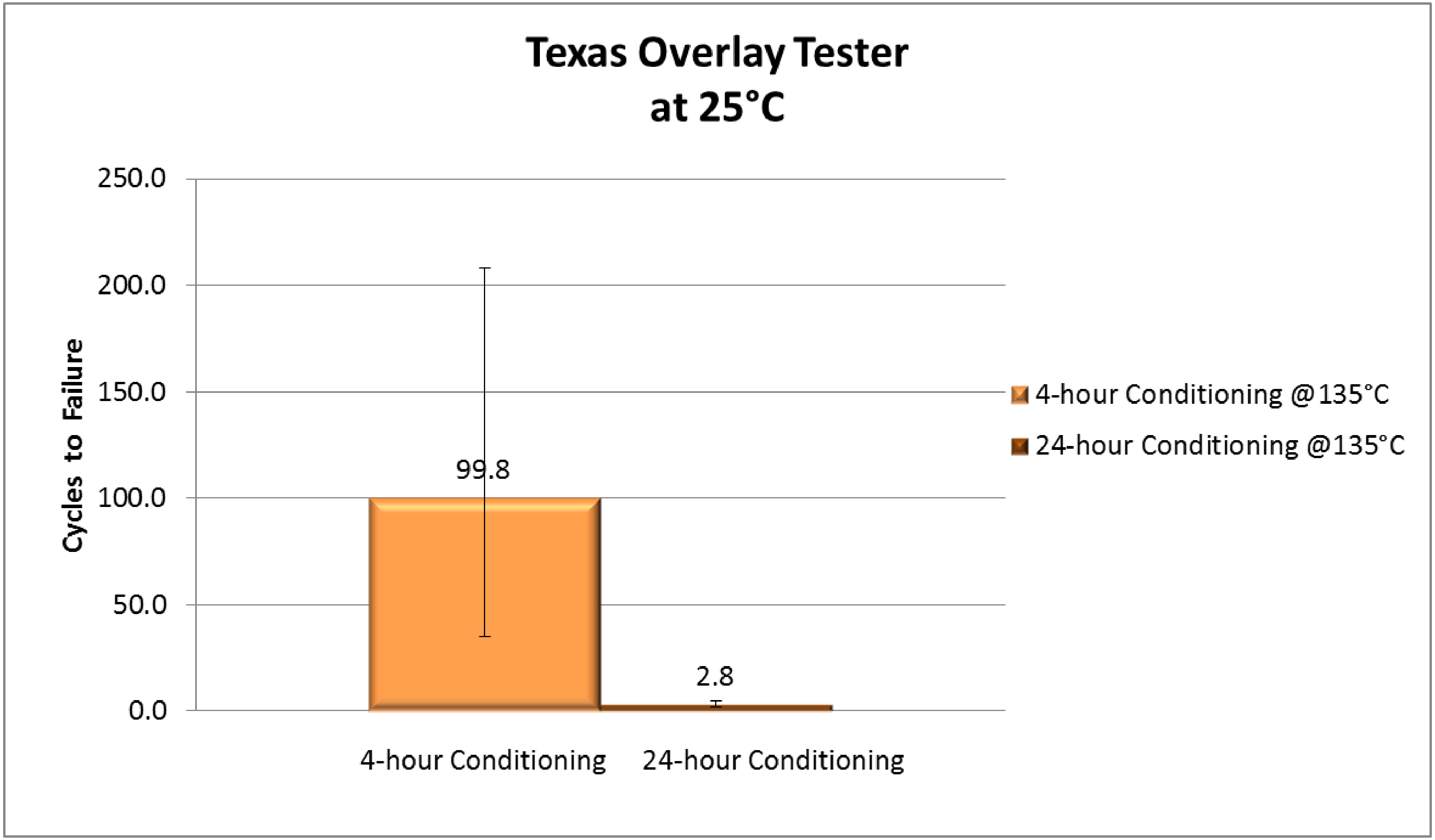


Note: COV's usually 10%

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)

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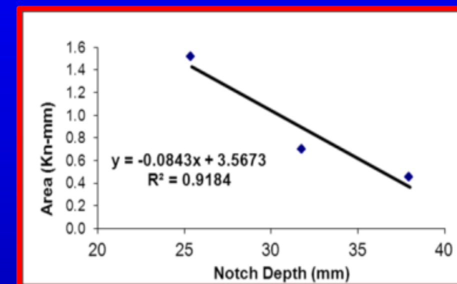
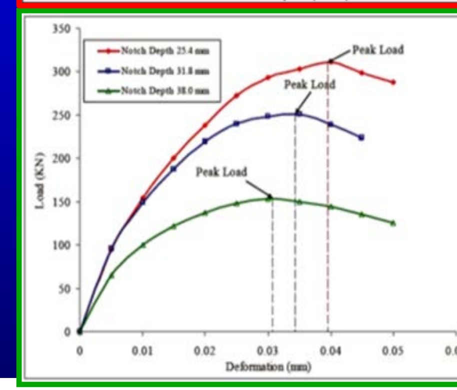
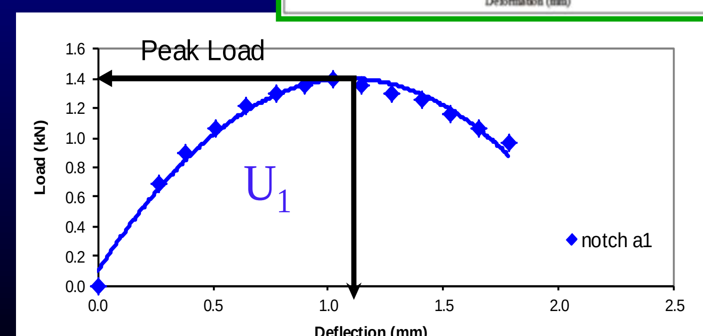
- Draft AASHTO standard by Louay Mohammad
- 25°C
- Rate of Movement: 0.5 mm/min

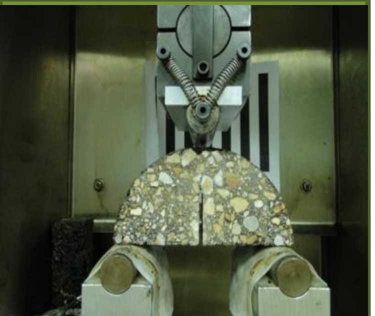
Semi Circular Bend (SCB) Test

- 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

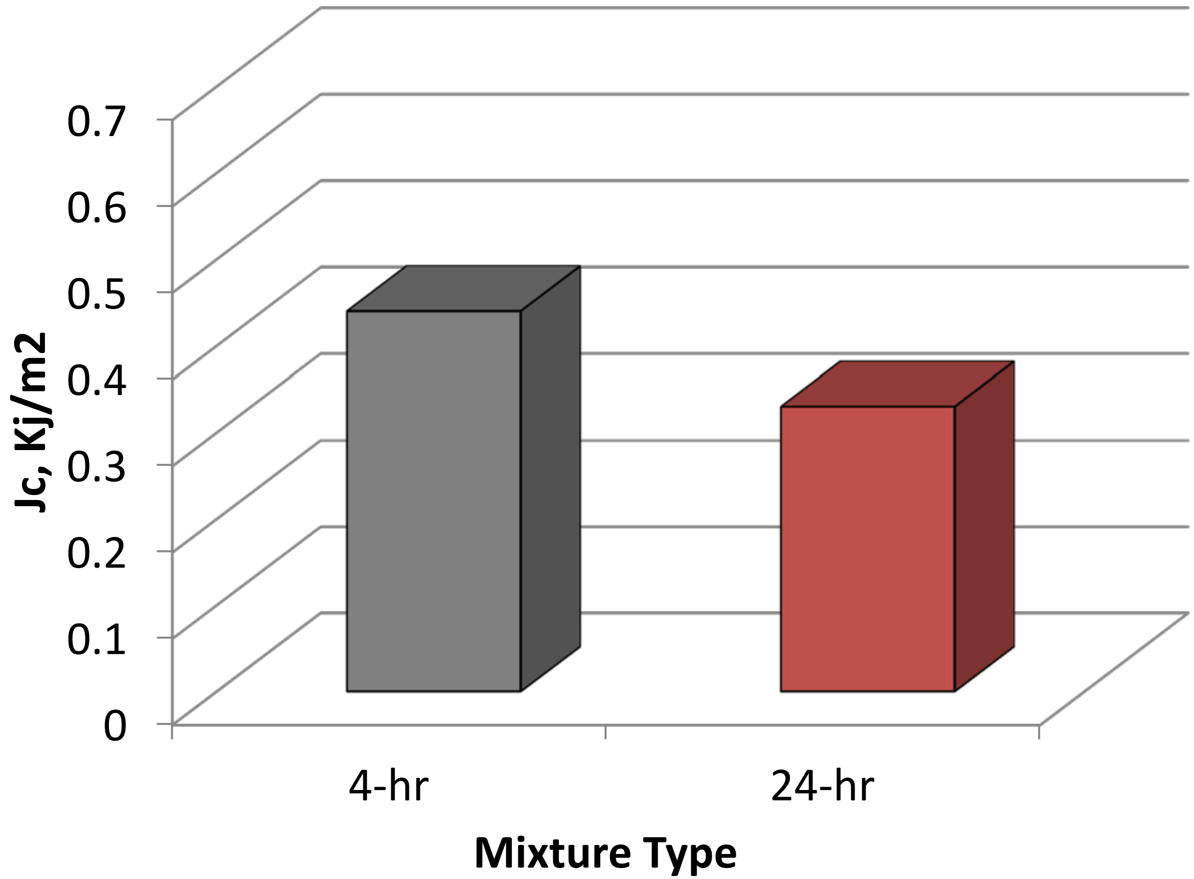








Semi-Circular Bend Test Results, 25°C



Note: Can have high error. Usually based on 6 samples.

Test Summary

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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		NA
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		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

Refer to NCHRP 9-57 for Further Info

NCHRP 9-57

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

Conclusions

- We need to condition mixtures to simulate proper field conditions at 7 to 10 years
- 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

Thank you

Phase 2 Test Plan

- Test devices: 7
- Binder:
  - PG 64-22, 76-22, 58-34
- Aggregates:
  - Virgin mix, RAP/RAS
  - 9.5 mm NMAS, dense mix; 12.5mm
- Aging:
  - 4-hour loose mix aging at 135°C
  - 24-hour loose mix aging at 135°C

Phase 2 Test Plan

- Other suggestions from Mix ETG:
  - Add ALF mixture to validate
  - Possible DOT mixtures