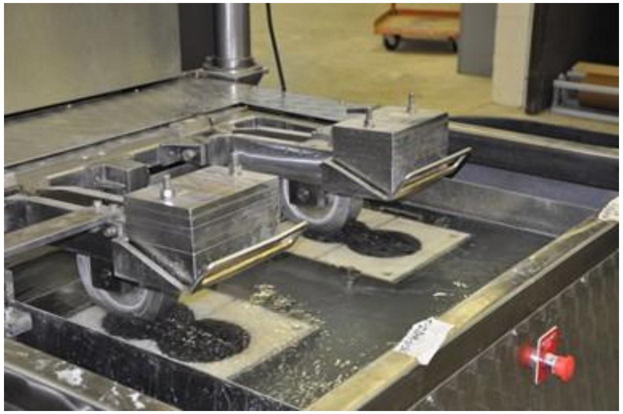
Illinois Center for Transportation
University of Illinois at Urbana Champaign

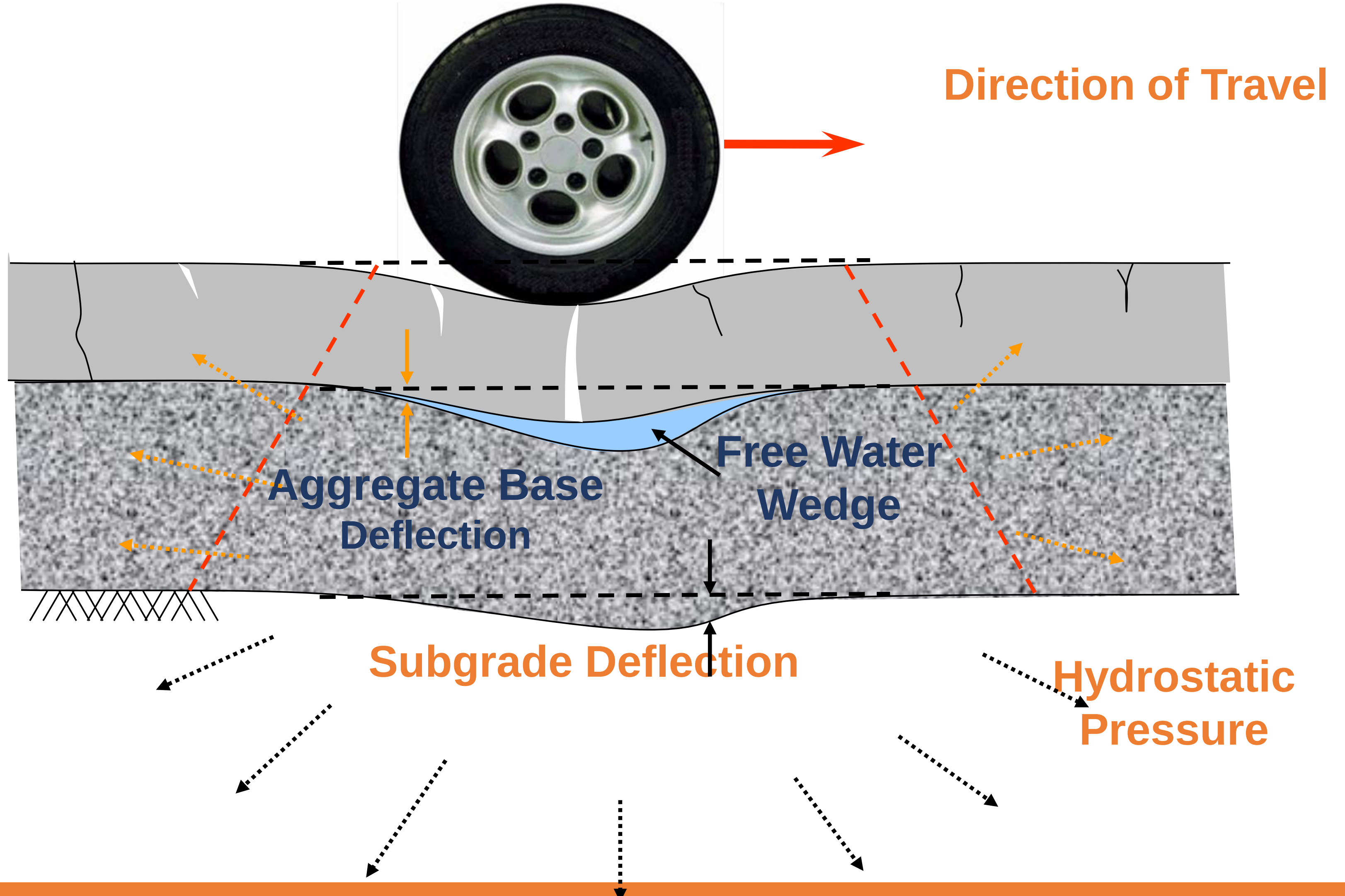
Complete Testing Suite for HMA Performance Prediction



Presenter: Imad L. Al-Qadi, PhD, PE, Dist.M.ASCE

H. Ozer, P. Singhvi, J. Rivera, A. El Khatib, M. Mueller, and J. Trepanier,

Loaded Flexible Pavement



Pavement Distresses

Segregation due to paver operation

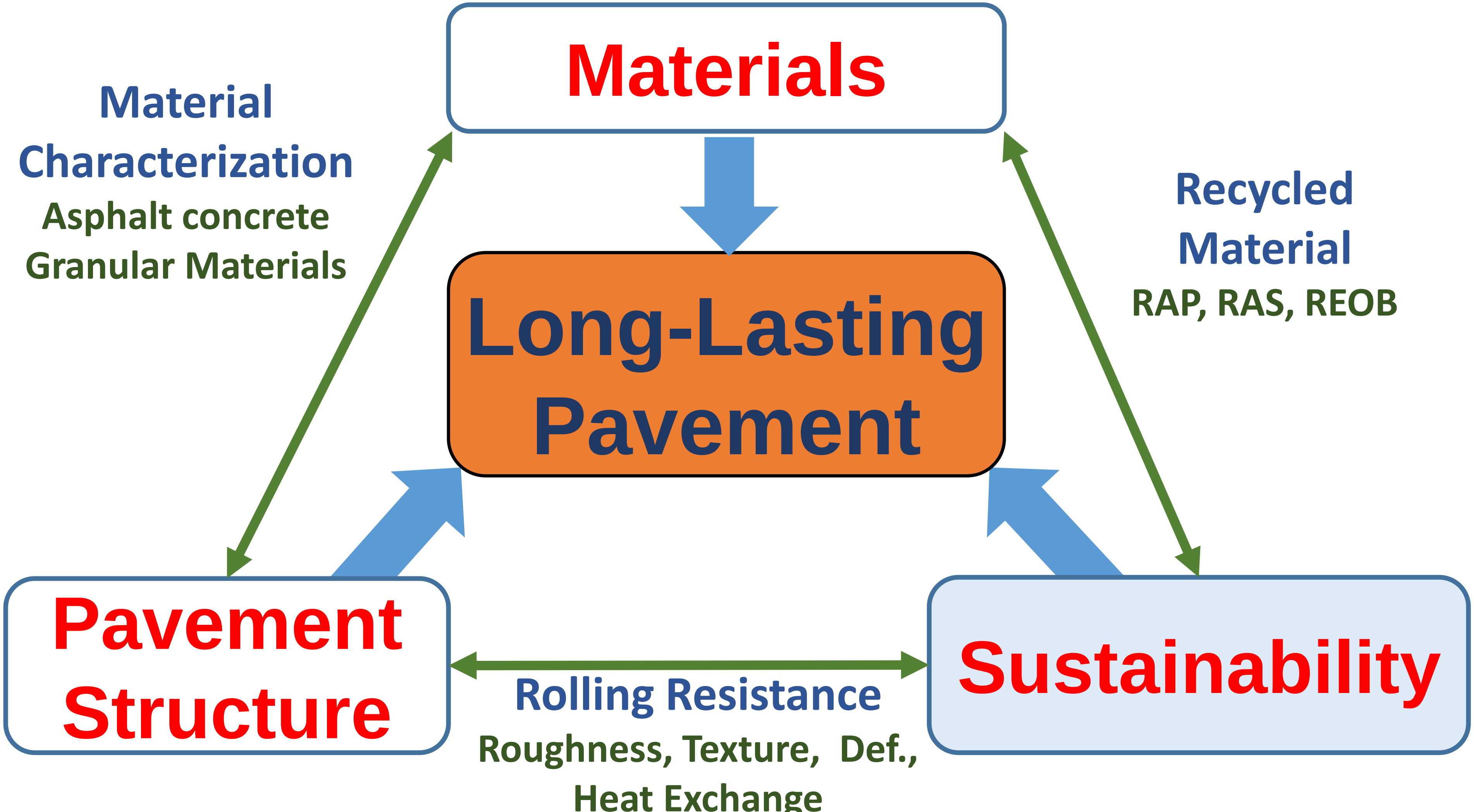
Heavy traffic

Source: Nunn and Ferne (2001)

Aging and thermal loads

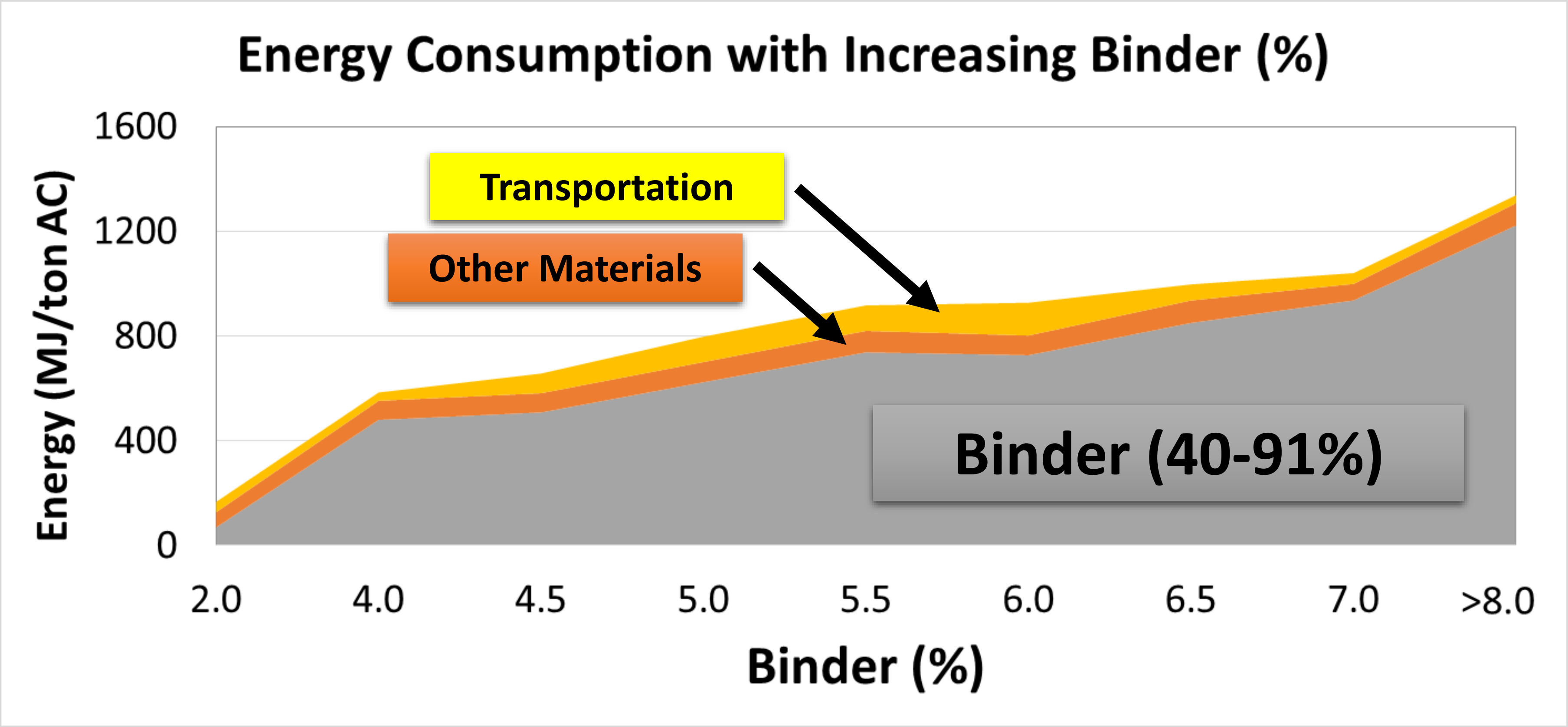
Rutting/ Cracking in HMA

Flexible Pavement System



Contribution of Asphalt Binder

- An analysis of over 1000 mixes shows increased energy with increased binder %

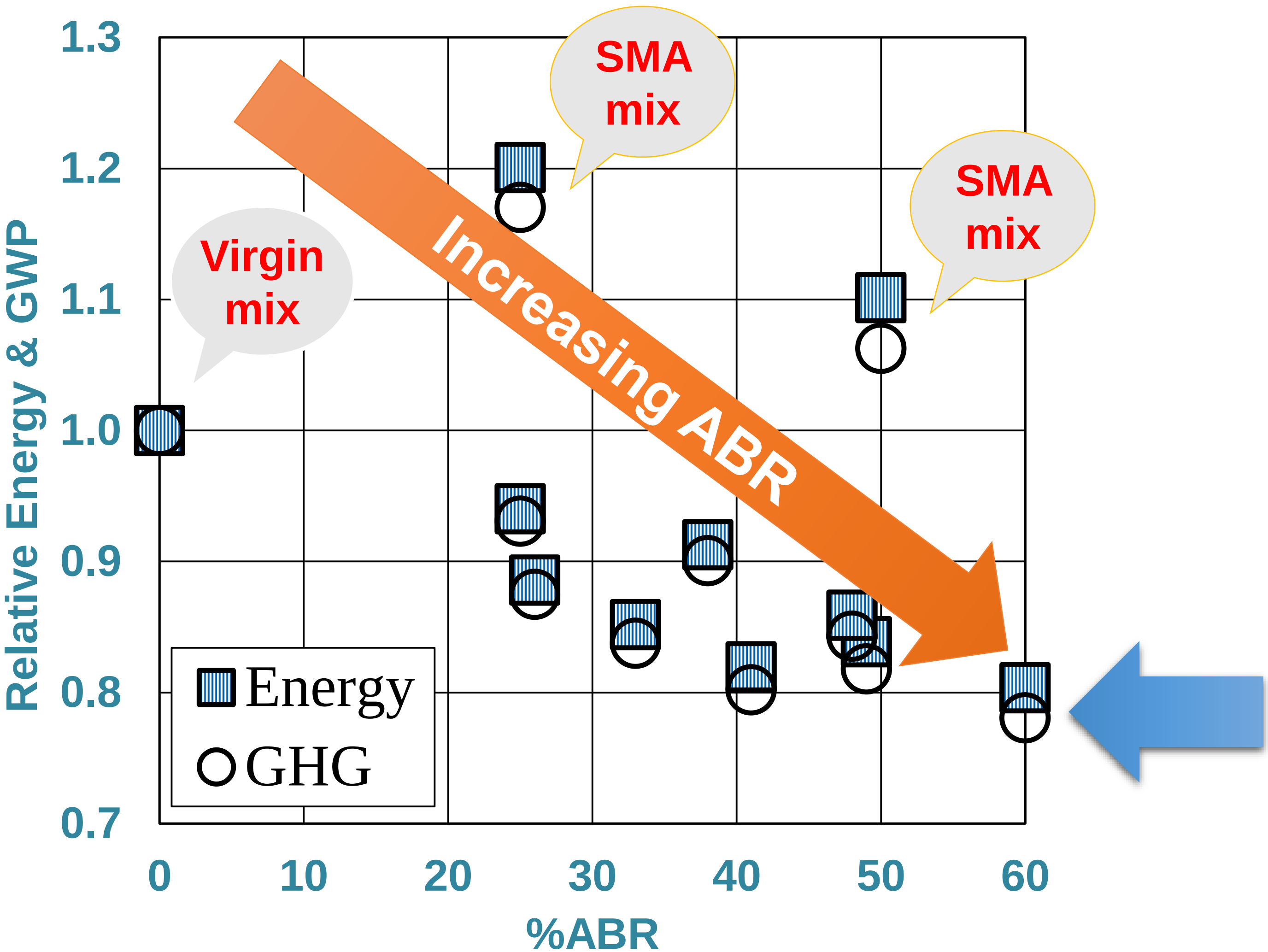


Contribution of Asphalt Binder

- An analysis of over 1000 mixes shows increased energy with increased binder %

Asphalt Binder Replacement (ABR)

Environmental Savings from ABR



60% ABR MIX:

20% Energy Savings

22% CO_2 Savings

Yang et al. (2014). Environmental impacts from producing asphalt mixtures with varying degrees of recycled asphalt materials.

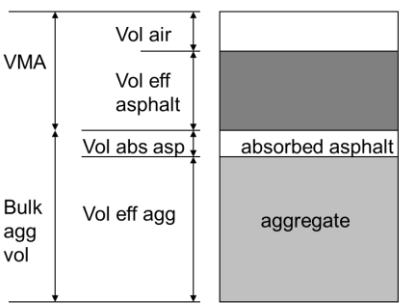
Challenges with RAP/RAS (ABR)

- **Fatigue cracking issue: stiffer mixes with high ABR may exhibit early fatigue cracking**
- **Thermal/Block cracking issue: Stiffer mixes have reduced relaxation potential**
- **Shingle asphalt is air blown to harden asphalt (*PG 112+02*) then additional aging on the roofs**
- **RAP AC can be hard or soft – depends on project(s) milled**
- **Counteracting binder selection of virgin binder becomes arbitrary**

Low Temperature Cracking | **Fatigue/Block/Other Forms of Cracking** | **Permanent Deformation**

-40°C | -20°C | 20°C | 40°C

Superpave™



Volumetrics

\+

Rut Test

\+

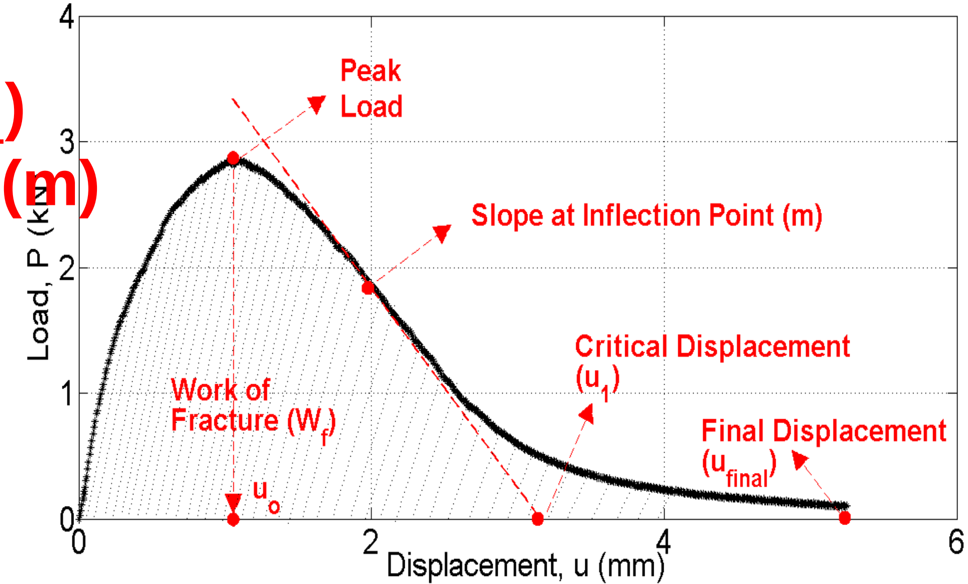
Cracking Test

Pavement Cracking

- Traffic loading, temperature, AC material properties all play a role → **VERY COMPLEX**
- We can't afford running a battery of tests to simulate these conditions → **SUCH TESTS DO NOT EVEN EXIST**
- We need a simple, affordable (money AND time), and meaningful test as a best approximate to overall cracking related damage → **THERMAL, FATIGUE, BLOCK,…**

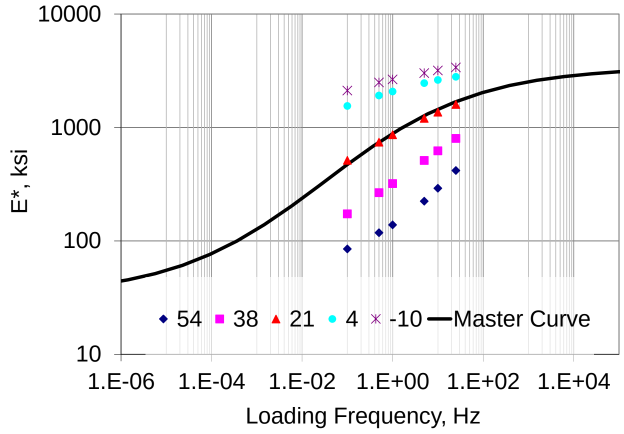
IL-SCB Test

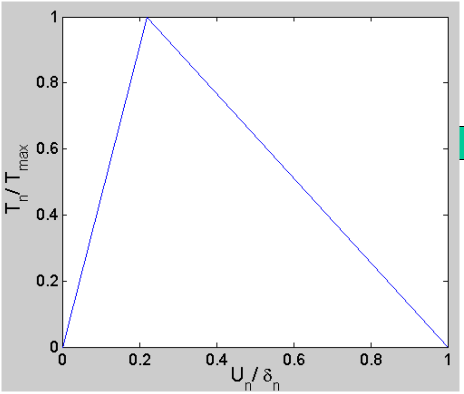
- Modified SCB fracture test conducted at 25˚C
- LVDT control load rate @ 50 mm/min
- Parameters calculated:
  - Fracture energy (G_f)
  - Peak load (P_{max}) & corresponding displacement (u_o)
  - Critical displacement (u_1)
  - Slope at inflection point (m)

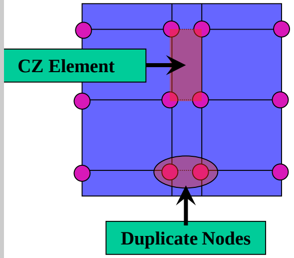


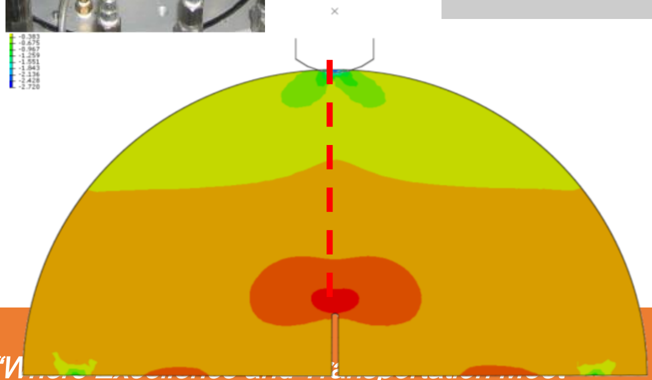
SCB Simulations

- Perform numerical simulations of SCB test with bulk characteristic from complex modulus tests







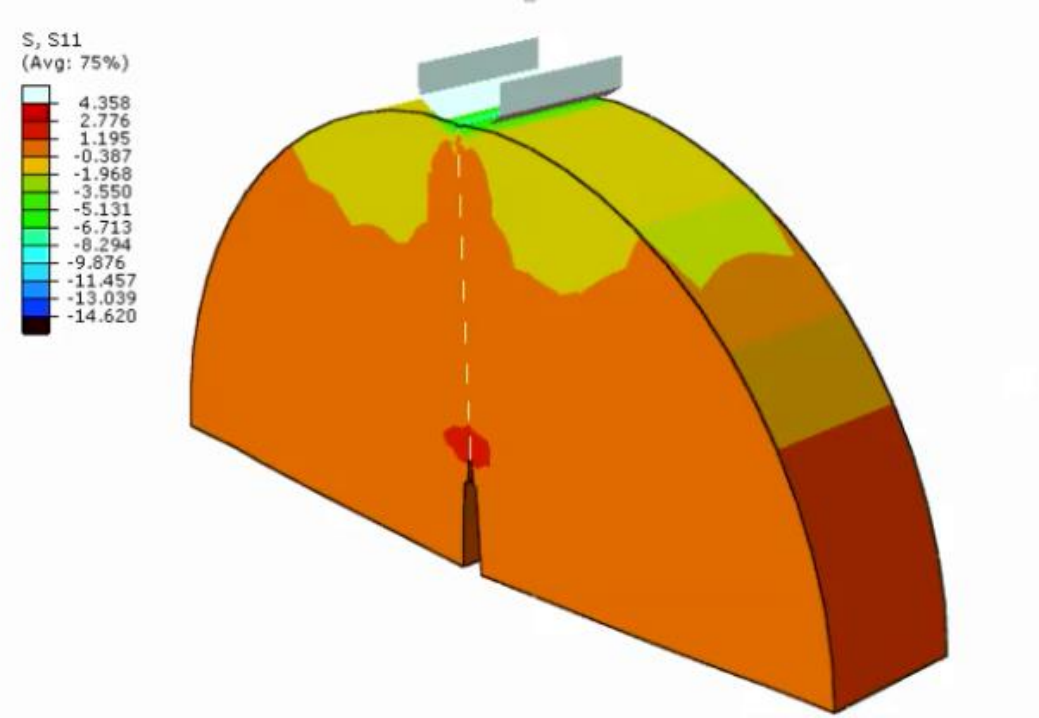


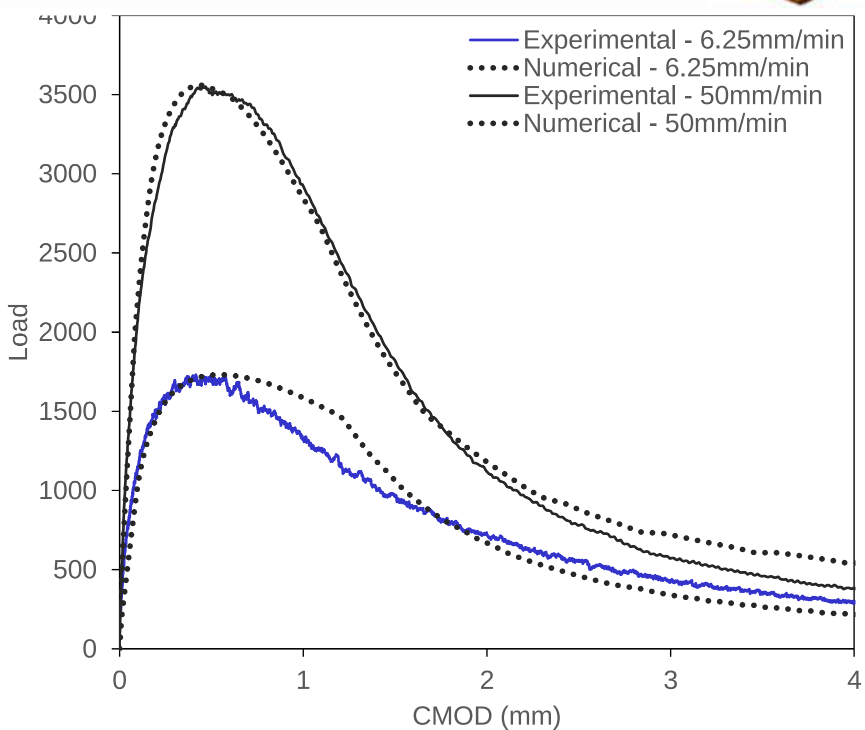
Bulk Properties from Complex Modulus Test

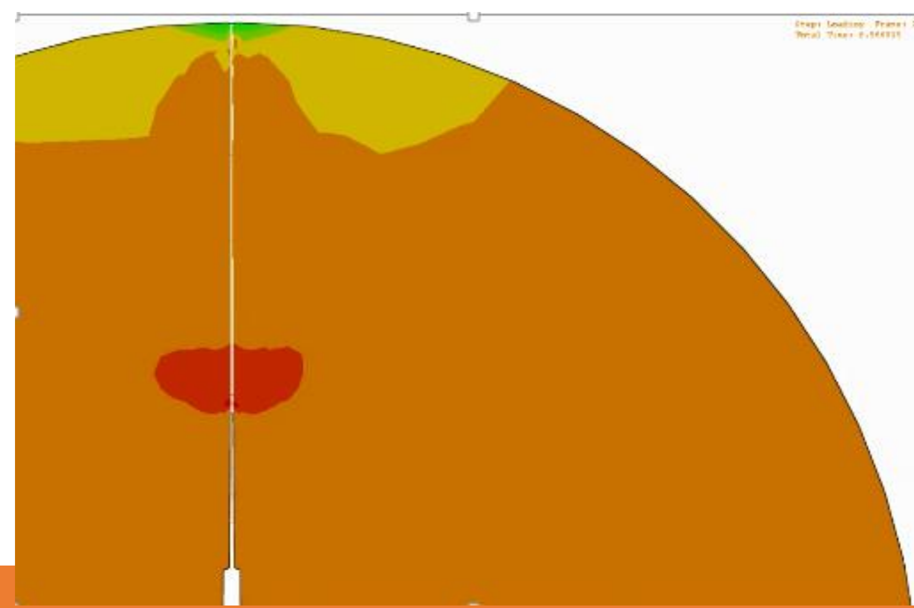
Fracture Properties Using Cohesive Zone Model

FEM Results

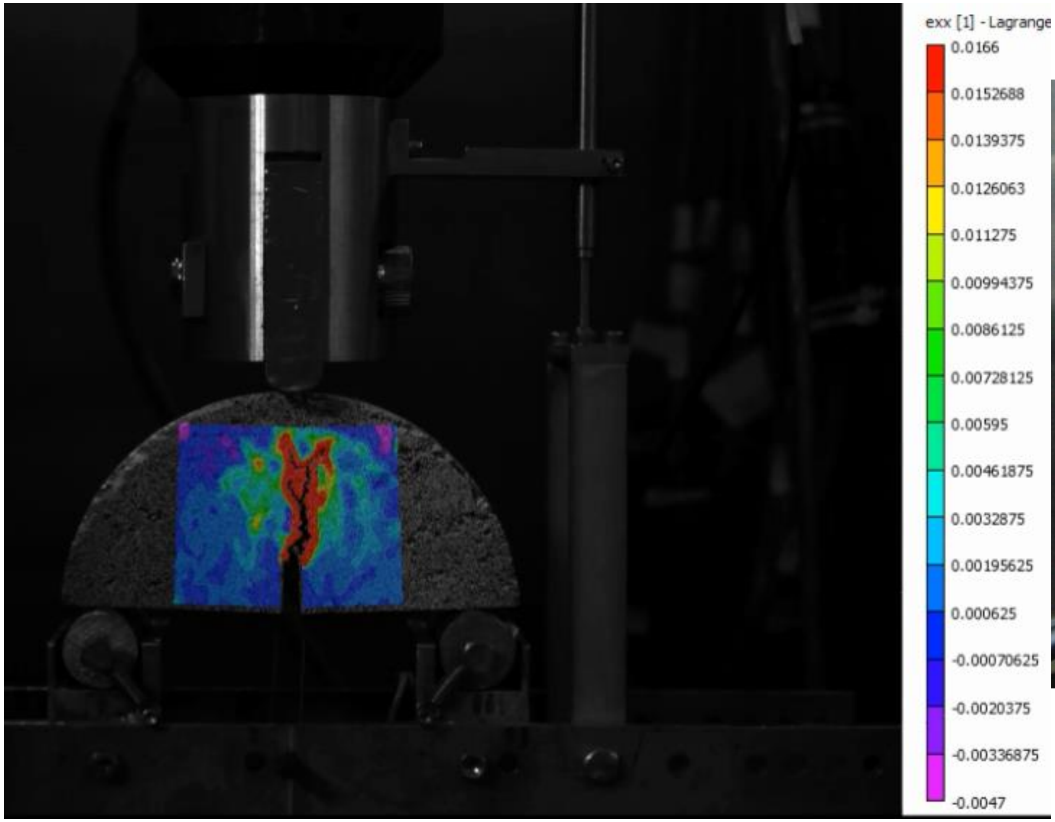
- **FEM simulations of SMA with 25% ABR**

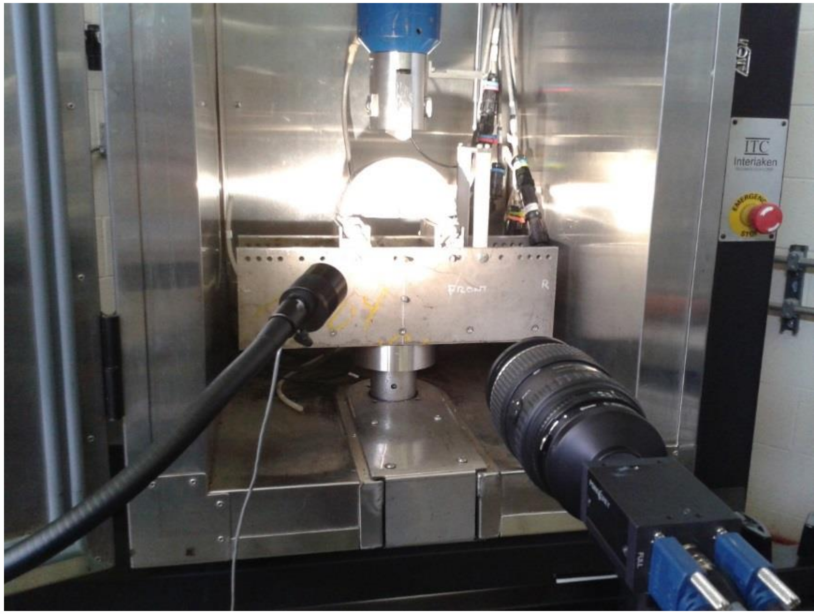




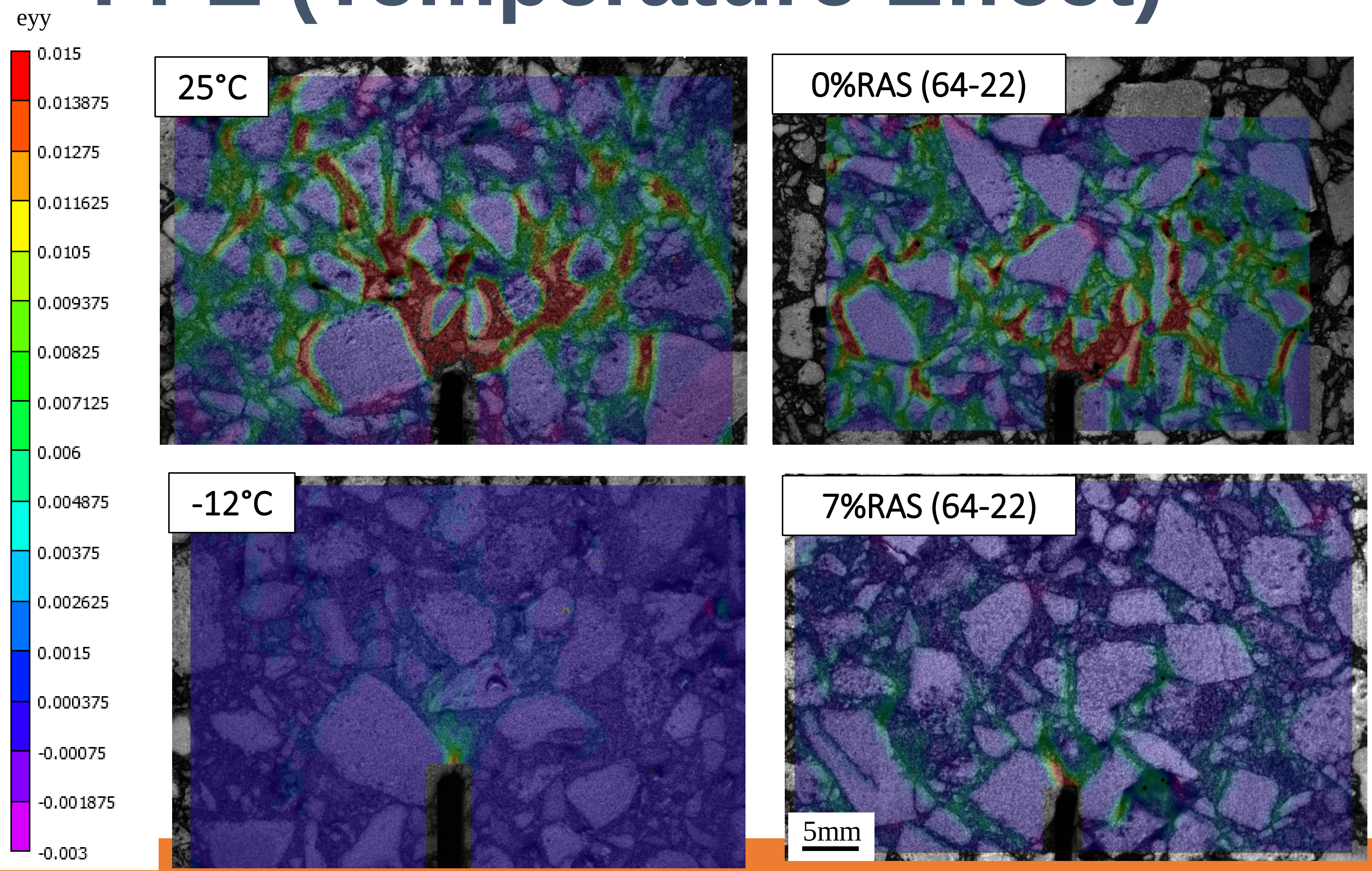


DIC: Full Field Measurements

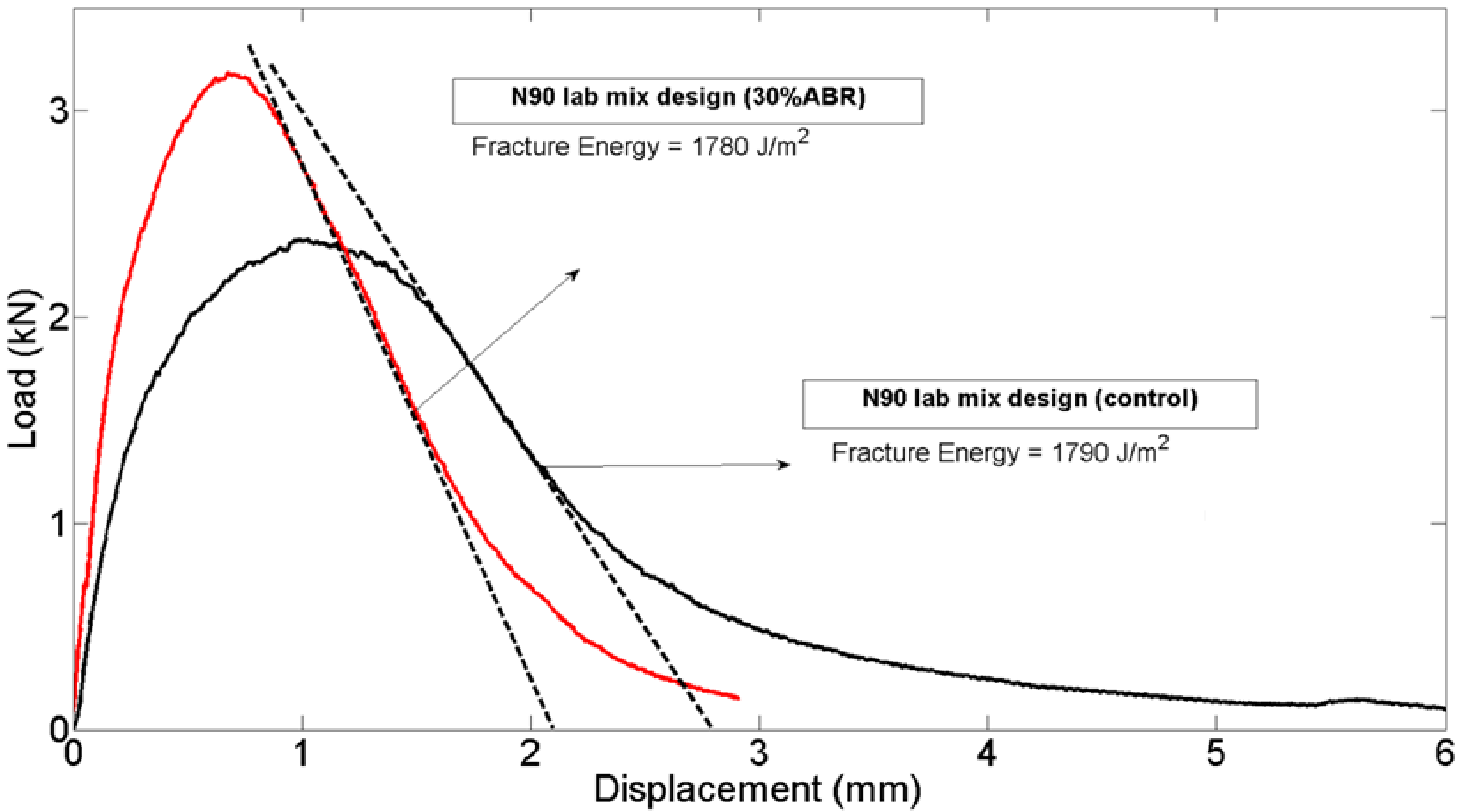




FPZ (Temperature Effect)

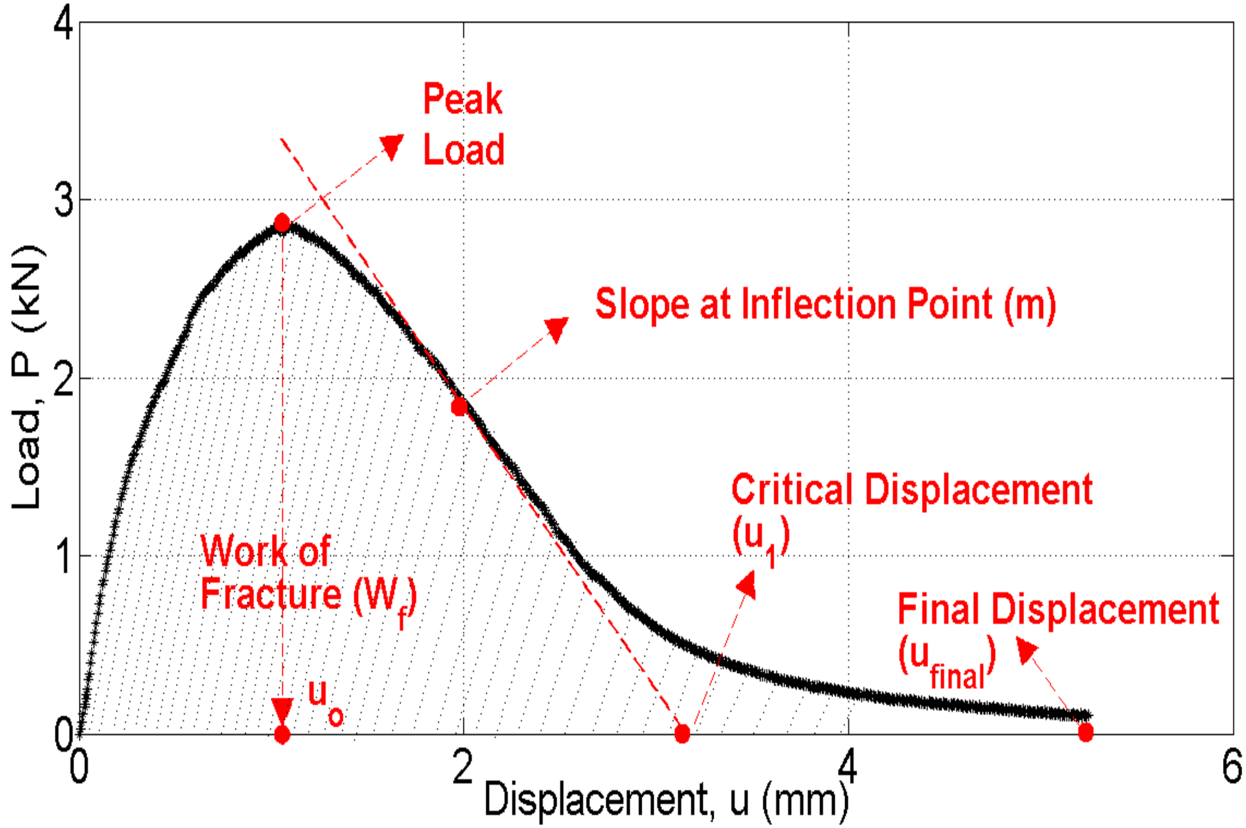


Fracture Energy Ambiguities



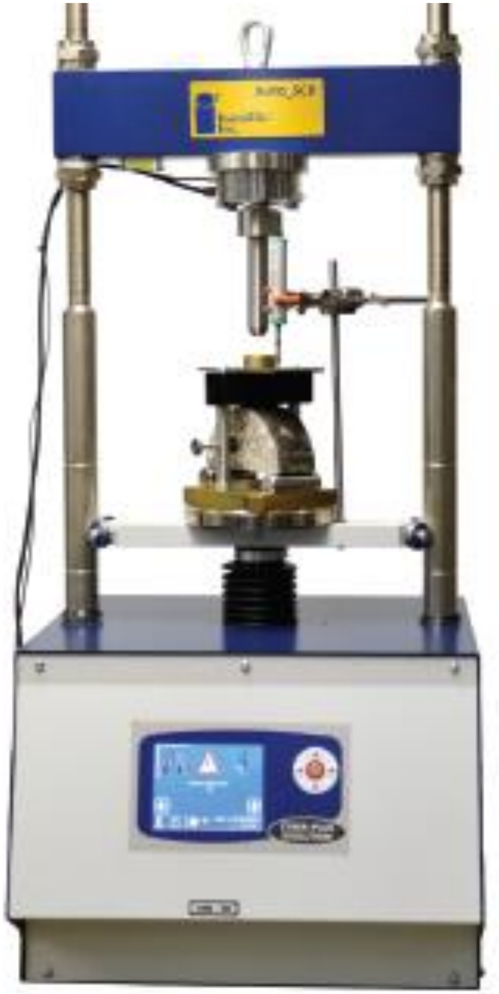
Development of Flexibility Index

Flexibility Index (FI) = $G_F \times \frac{1}{abs(m)}$



Applicability and Seamless Implementation

Applicability and Implementation



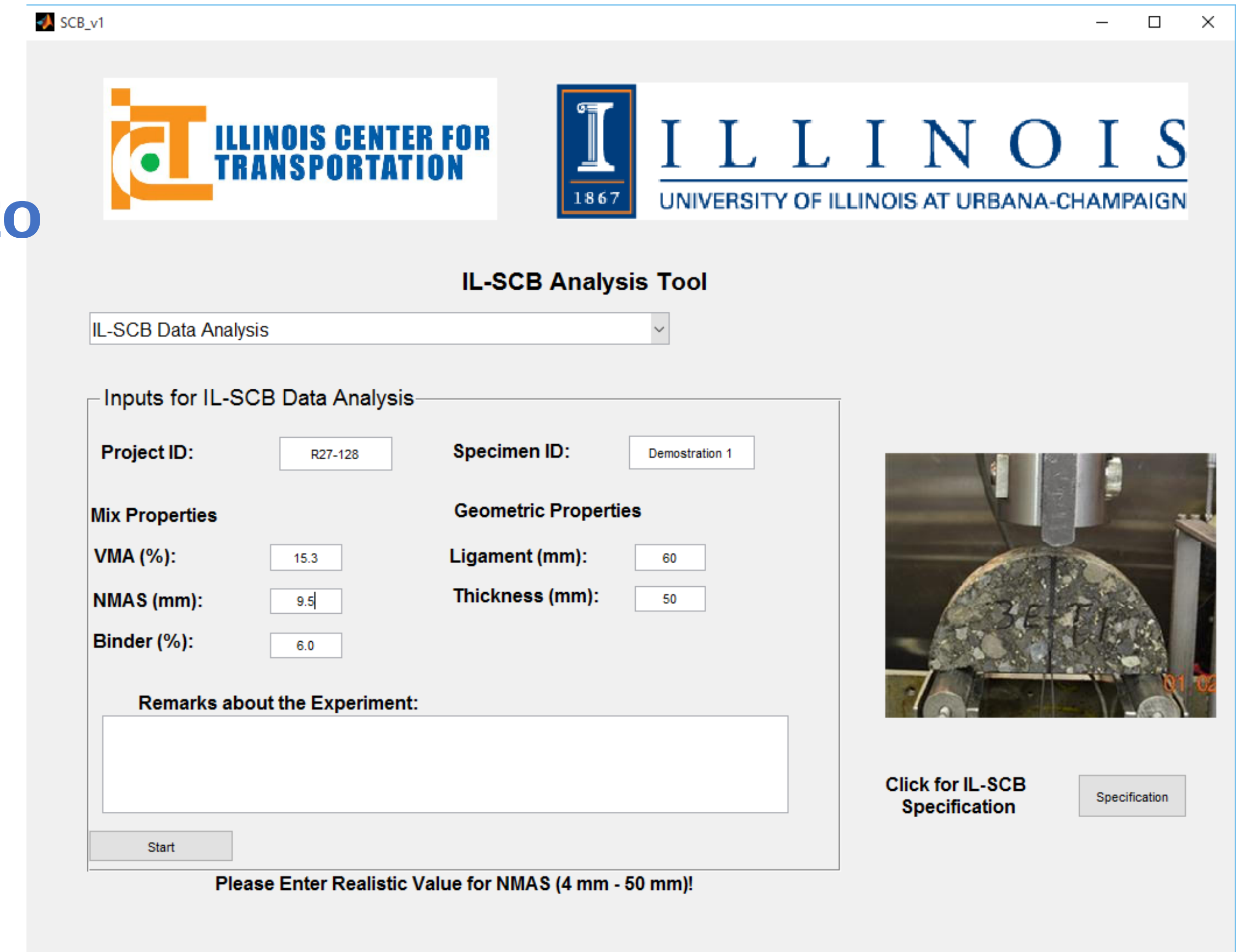
- Can use AASHTO T-283 (TSR) equipment
- Two low-cost prototypes were already manufactured (9-18K)

Conditioning Method

- **Water bath conditioning allows the use of AASHTO T-283 (TSR) set up**

IL-SCB Tool

- A software tool was developed to process IL-SCB results



Provide a Significant and Meaningful Spread in Test Output

Case Study: High ABR Mixes

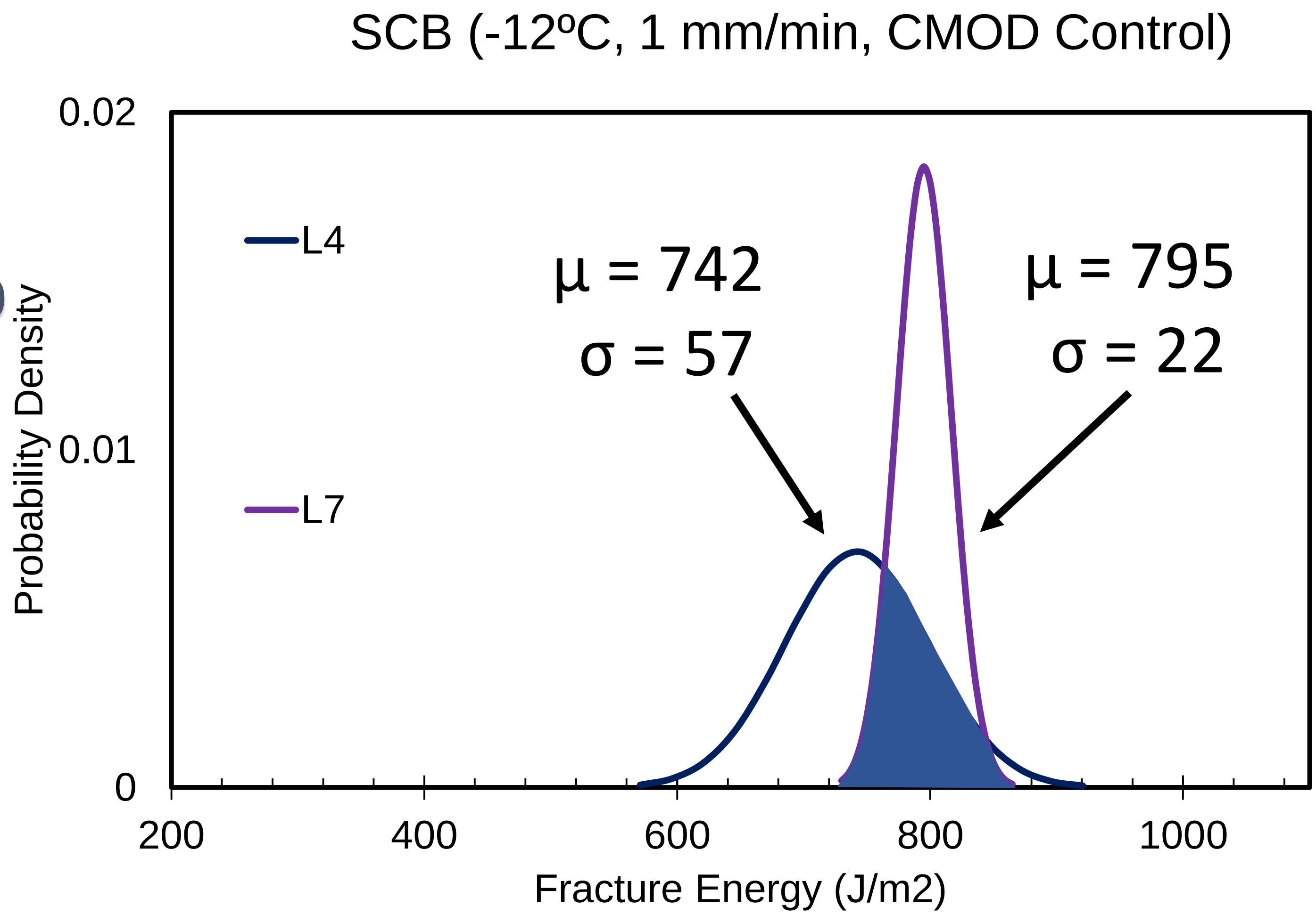
- **Goal: Identify a difference in the performance of:**

Mix	ABR	Binder	Constant Properties	Expected Behavior
L4	0%	64-22	AC (%): 6 VMA (%): 15.3	Increment in ABR Decreases Toughness
L7	20%	58-28		
L9	30%	58-28		
L10	60%	52-34		

Low Temperature SCB (-12ºC):

ABR
0% vs 20%

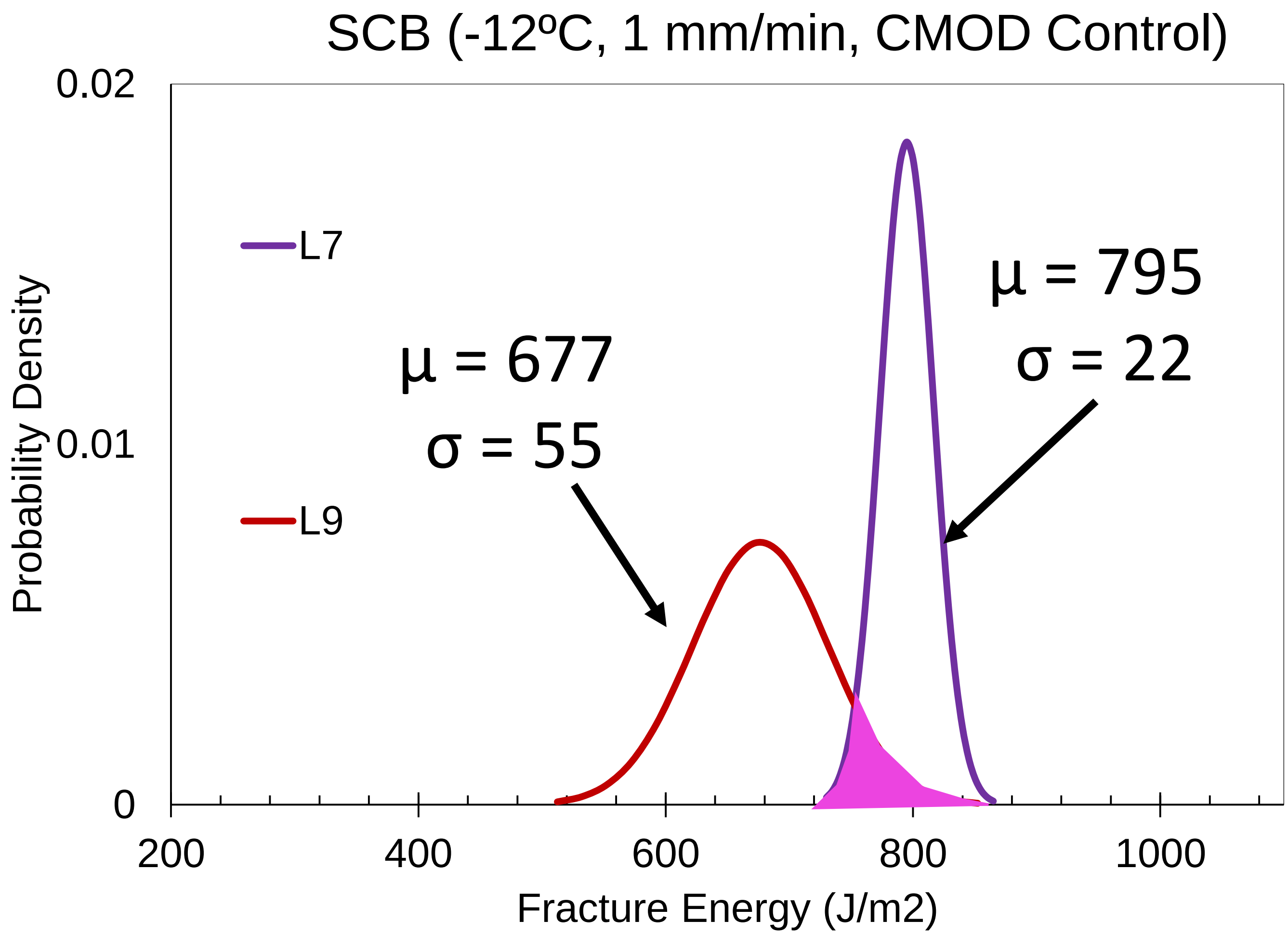
Overlap:
43%



Low Temperature SCB (-12ºC):

ABR
20% vs 30%

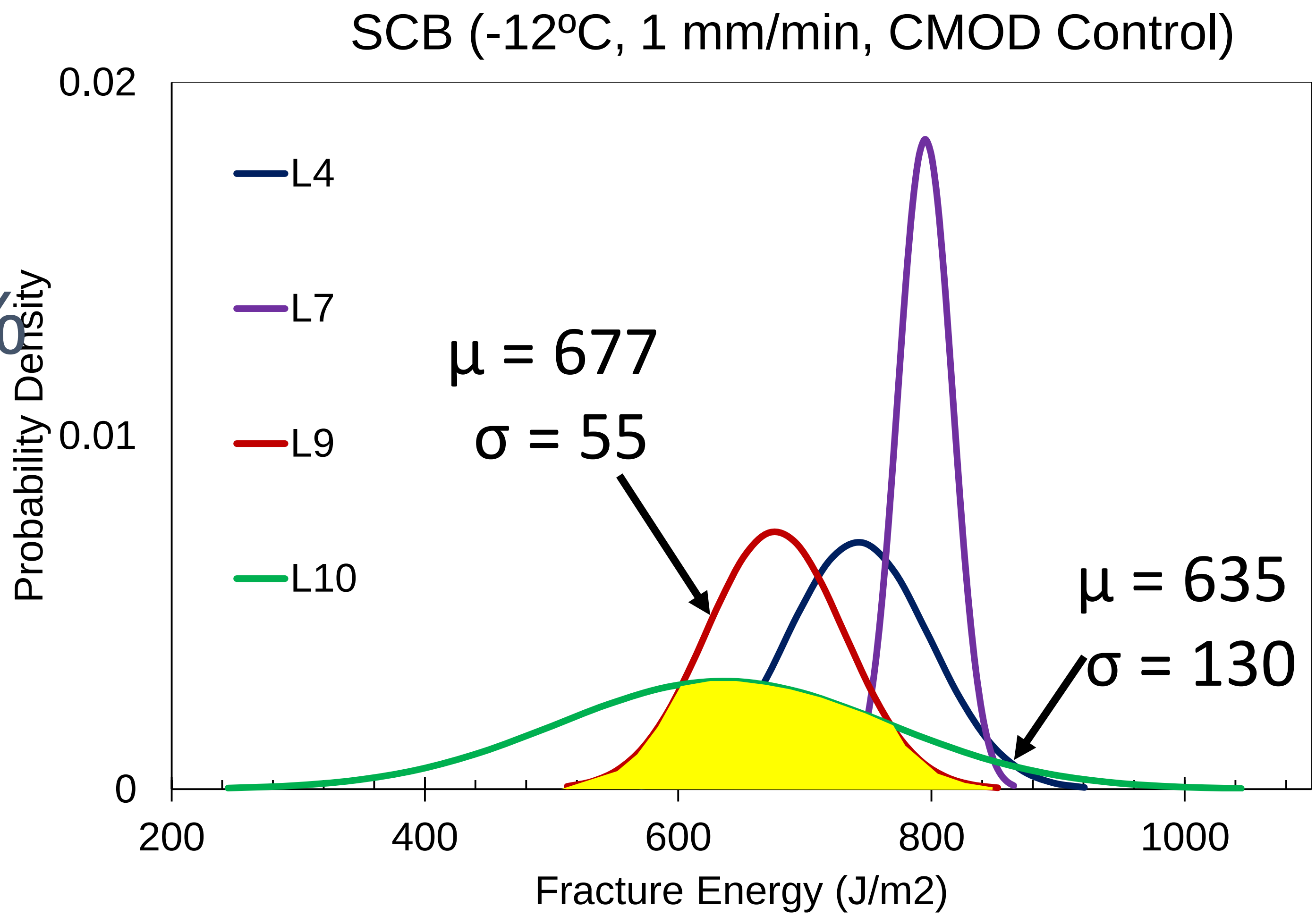
Overlap:
11%



Low Temperature SCB (-12ºC):

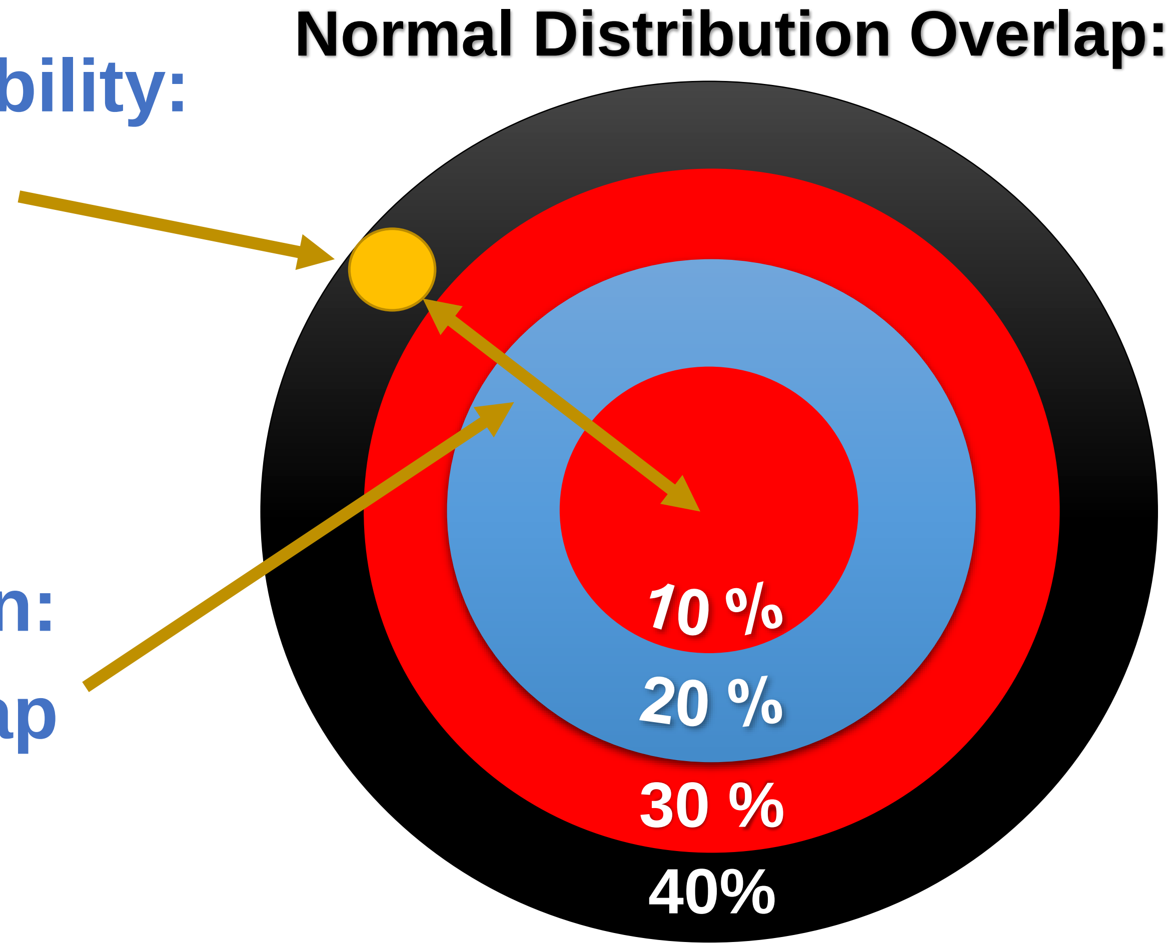
ABR
30% vs 60%

Overlap:
58%



Low Temperature SCB:

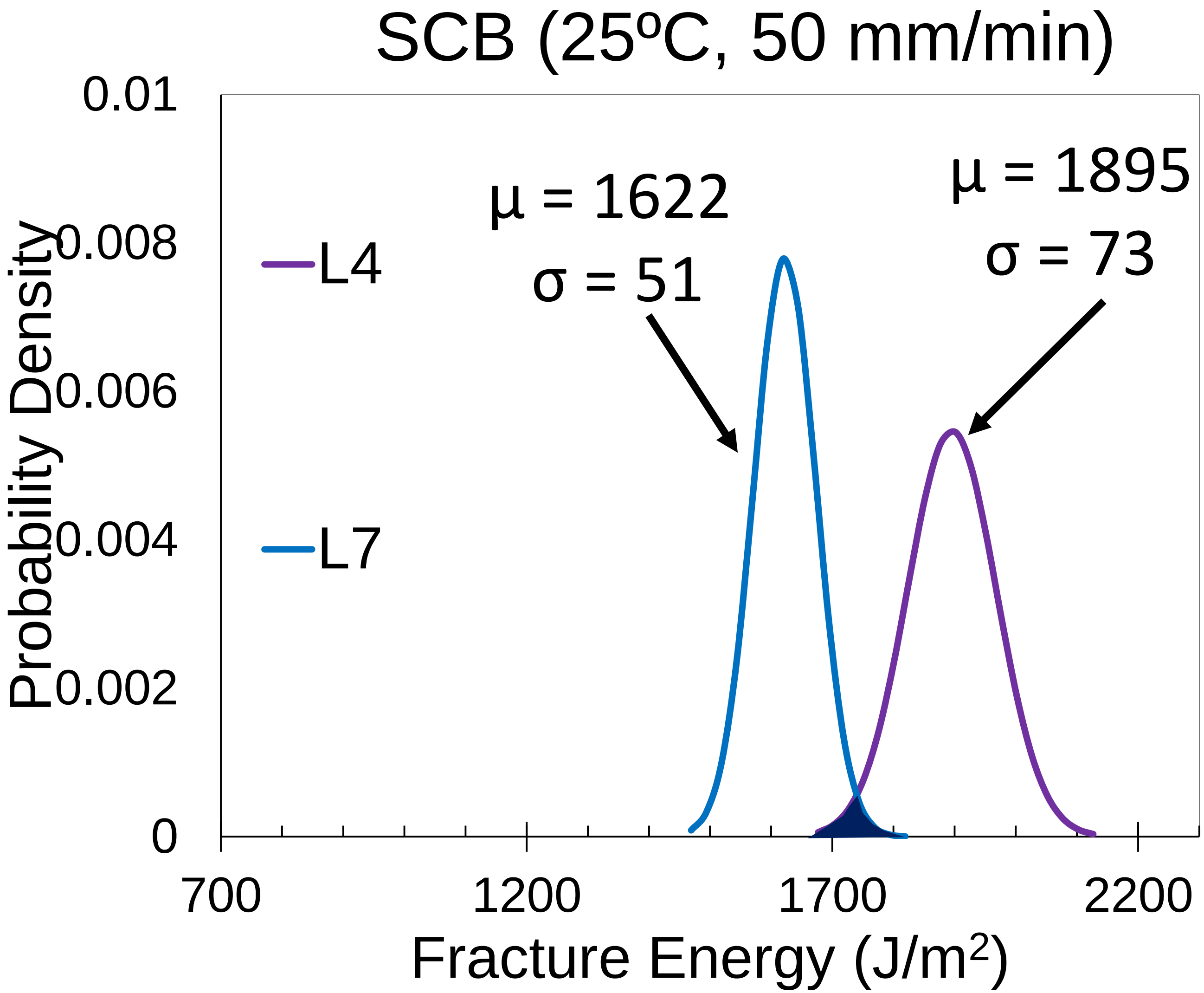
- High Repeatability:
  - ~ 9% COV
- Low Discrimination:
  - 40% Overlap



Intermediate Temperature SCB (25 ºC):

ABR
0% vs 20%

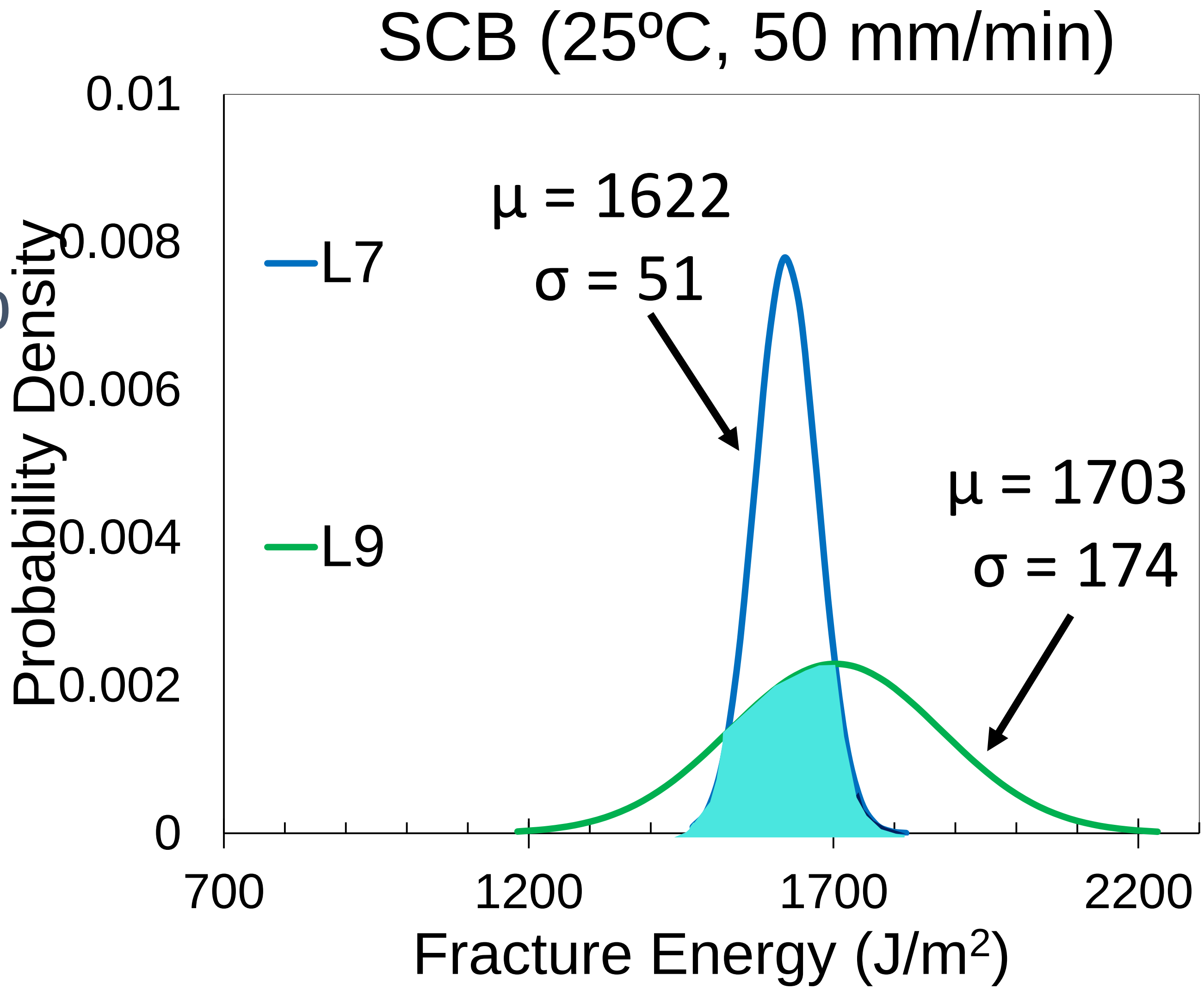
Overlap:
3%



Intermediate Temperature SCB (25 ºC):

ABR
20% vs 30%

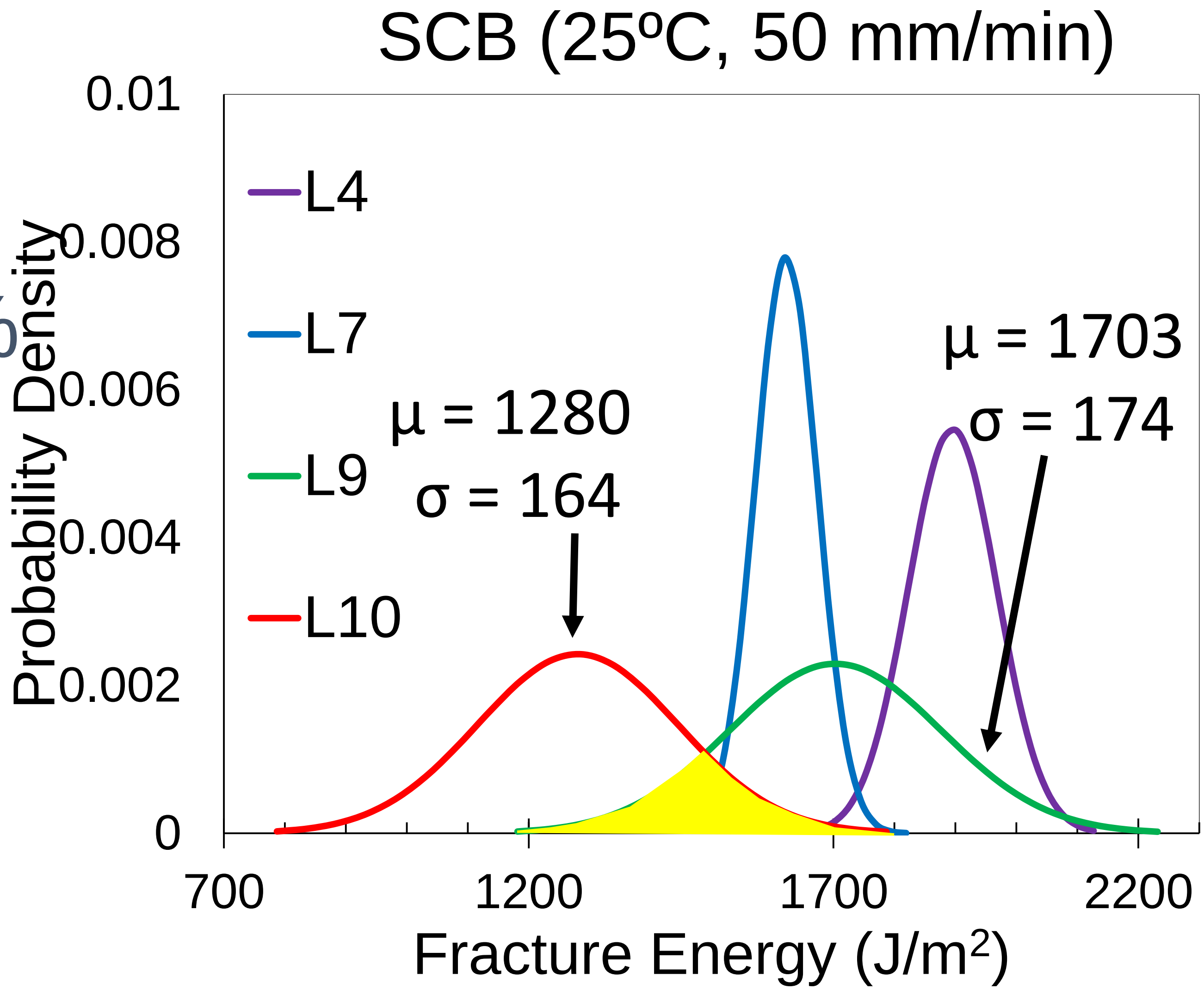
Overlap:
37%



Intermediate Temperature SCB (25 ºC):

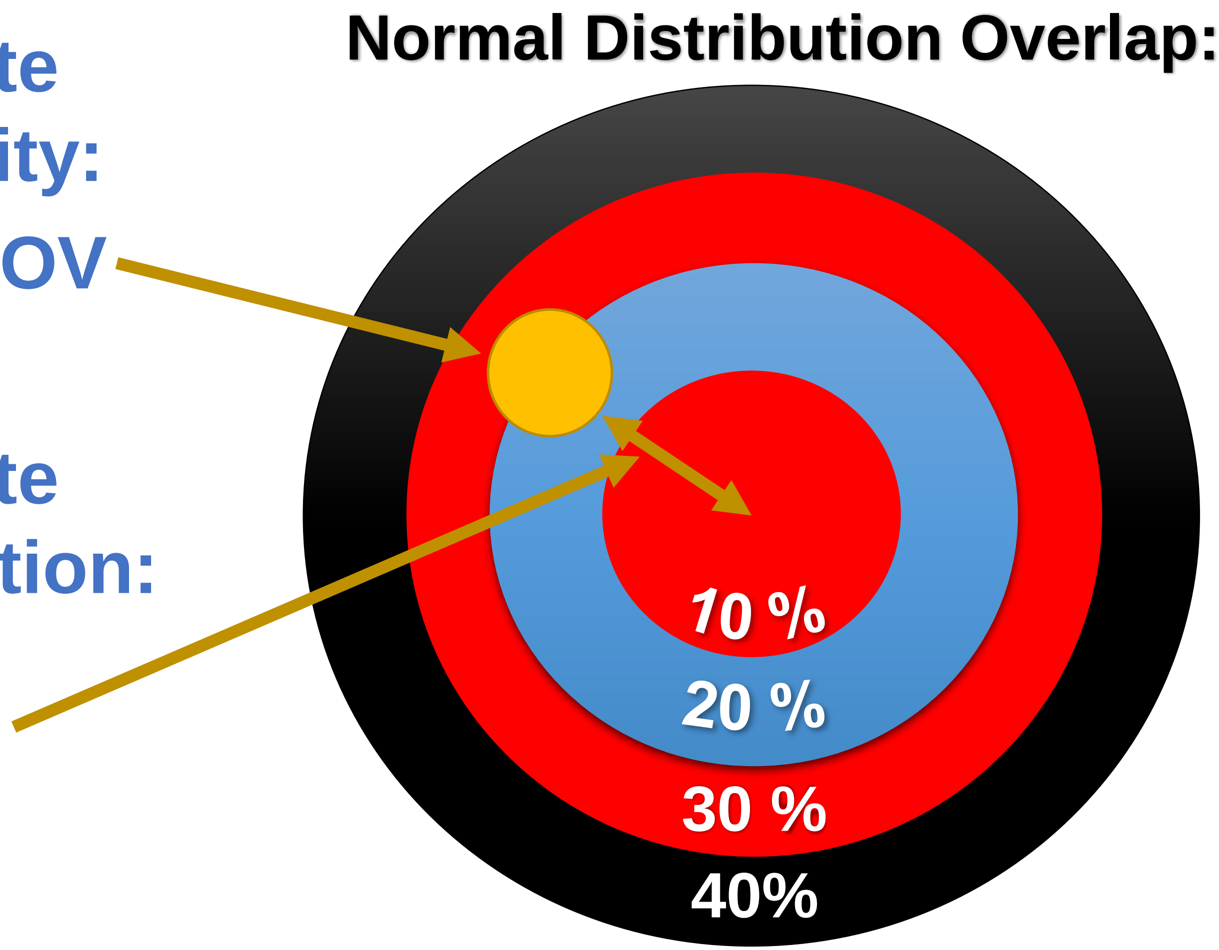
ABR
30% vs 60%

Overlap:
21%



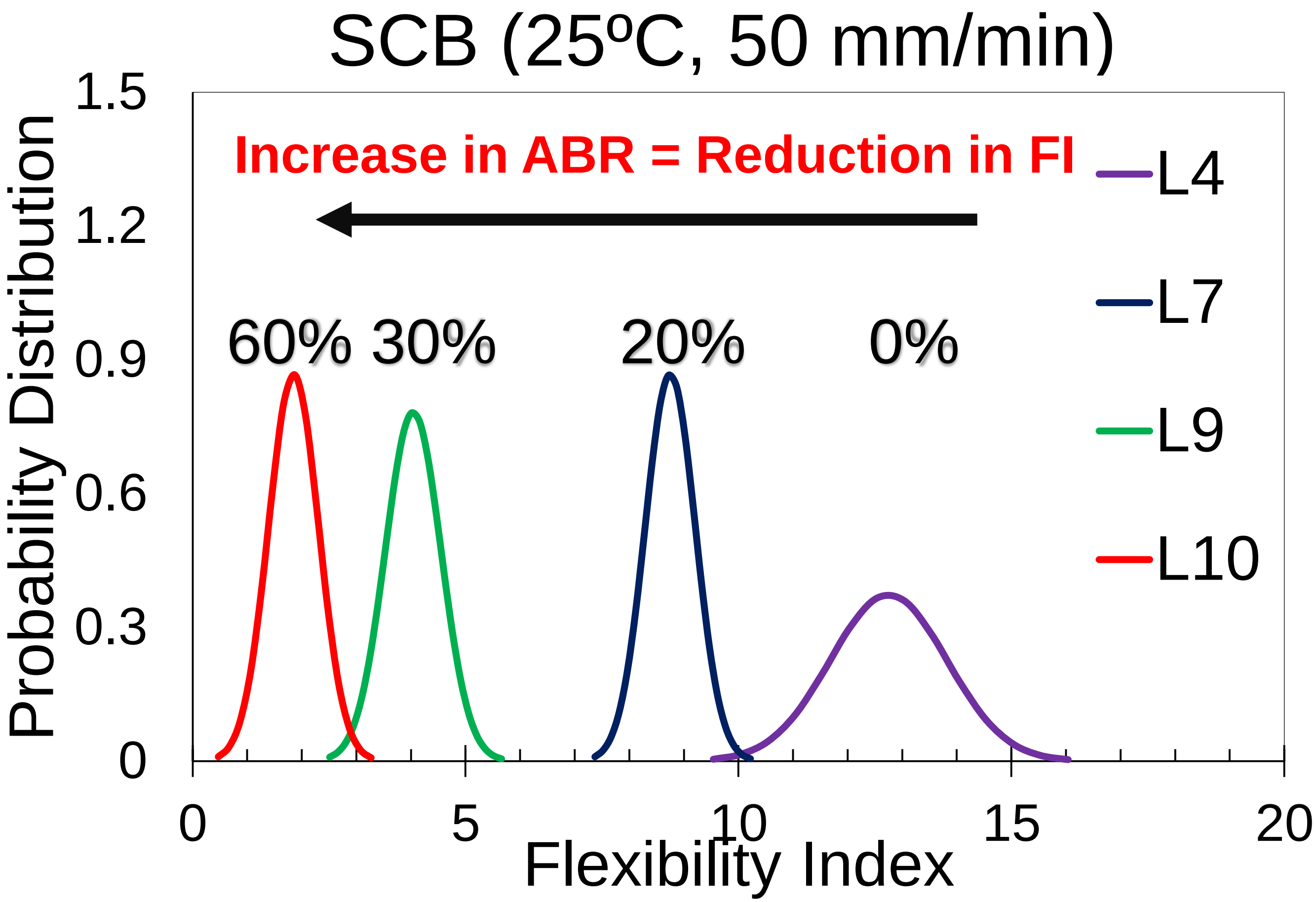
Intermediate Temperature SCB:

- Intermediate Repeatability:
  - ~ 10% COV
- Intermediate Discrimination:
  - ~ 25% Overlap



Flexibility Index SCB (25 ºC):

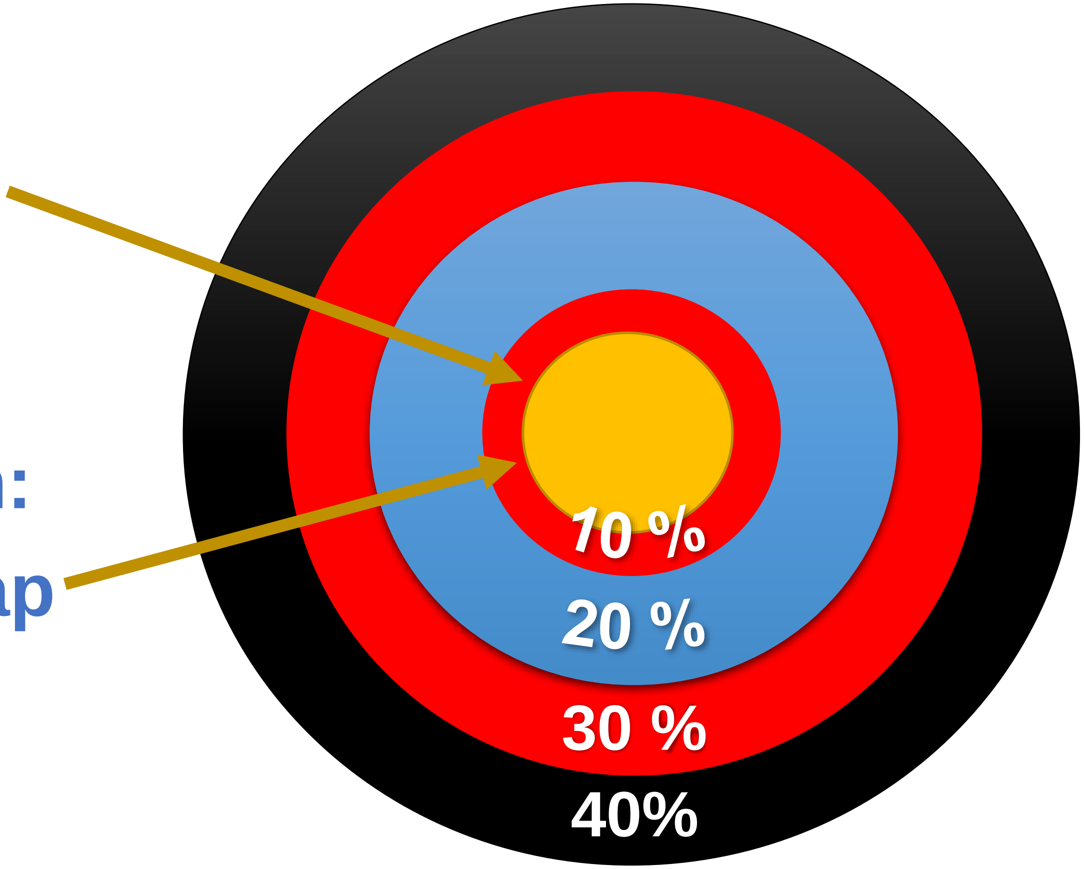
Overlaps: < 3%



Flexibility Index SCB (25 ºC):

- Reduced Repeatability:
  - ~ 15% COV
- High Discrimination:
  - ~ 3% Overlap

Normal Distribution Overlap:



Correlation to Field Performance

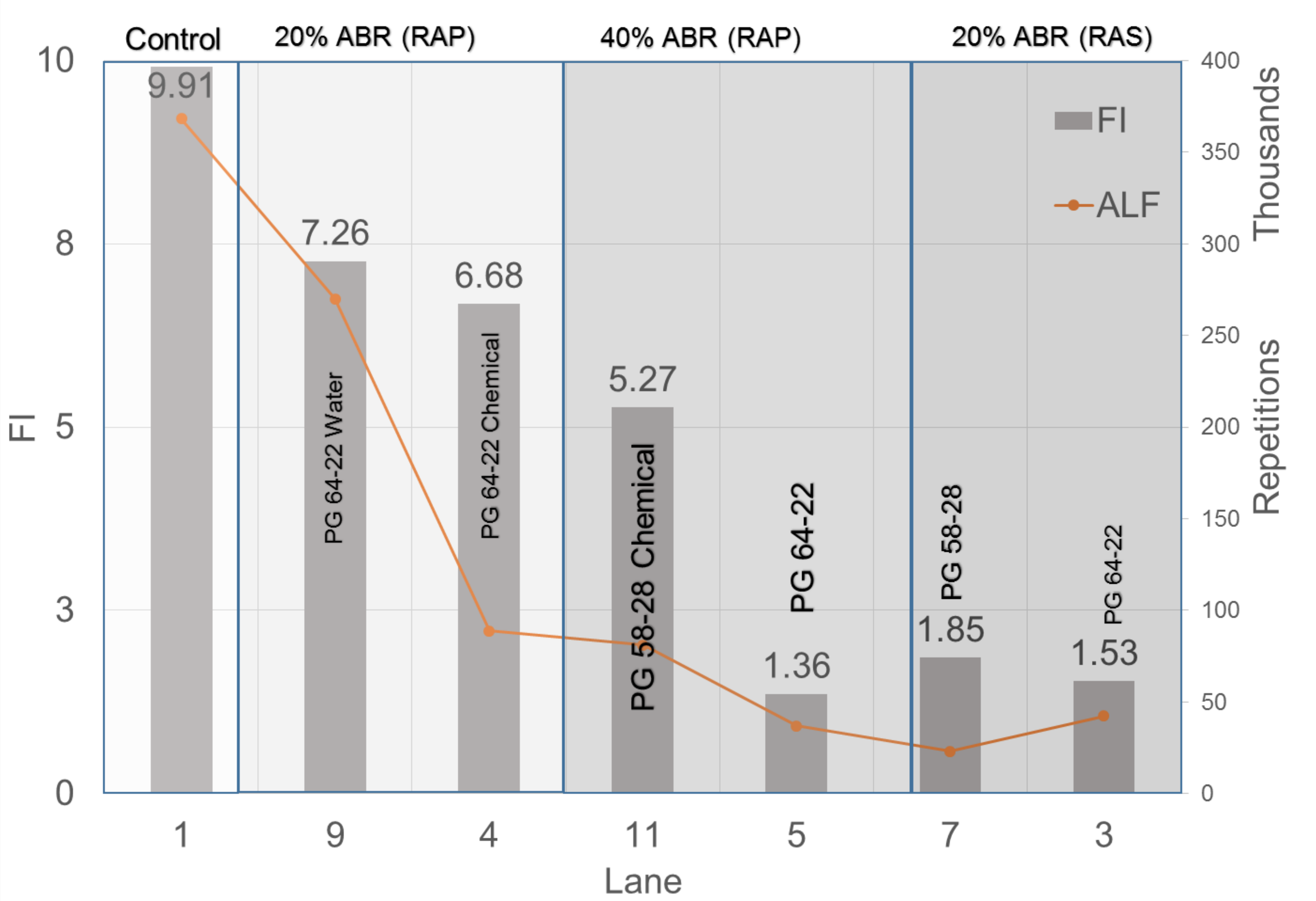
Accelerated Loading Facility

- Simulates truck traffic with controlled loading and pavement temperatures.
- Up to 35,000 cycles can be applied per week.
- Wheel load can be varied from 33 kN (7,500 lb) representing a light truck to 84 kN (19,000 lb) simulating a heavy axle.

Lane Properties

ABR Group	Lane	WMA	Binder Grade
Control	1	-	PG64-22
20% (w/ RAP)	9	Water	PG64-22
	4	Chemical	PG64-22
40% (RAP)	8	-	PG58-28
	11	Chemical	PG58-28
	5	-	PG64-22
20% (w/ RAS)	7	-	PG58-28
	3	-	PG64-22

IL-SCB vs. Fatigue Cracking



Field Cores

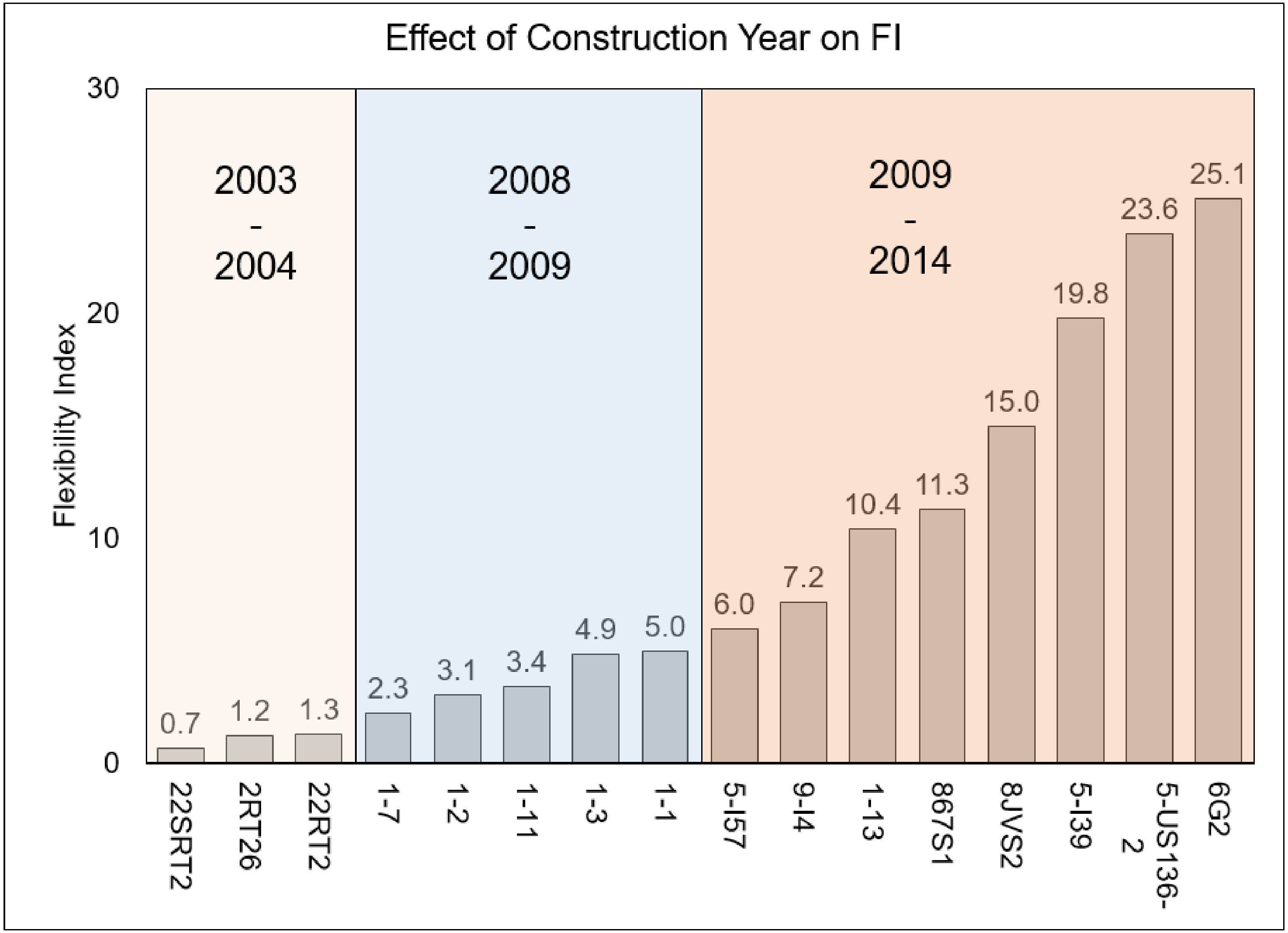
- Field cores were obtained from nine IDOT districts
- Flexibility index values were compared to field performance data obtained from districts

Field Correlation (D1)

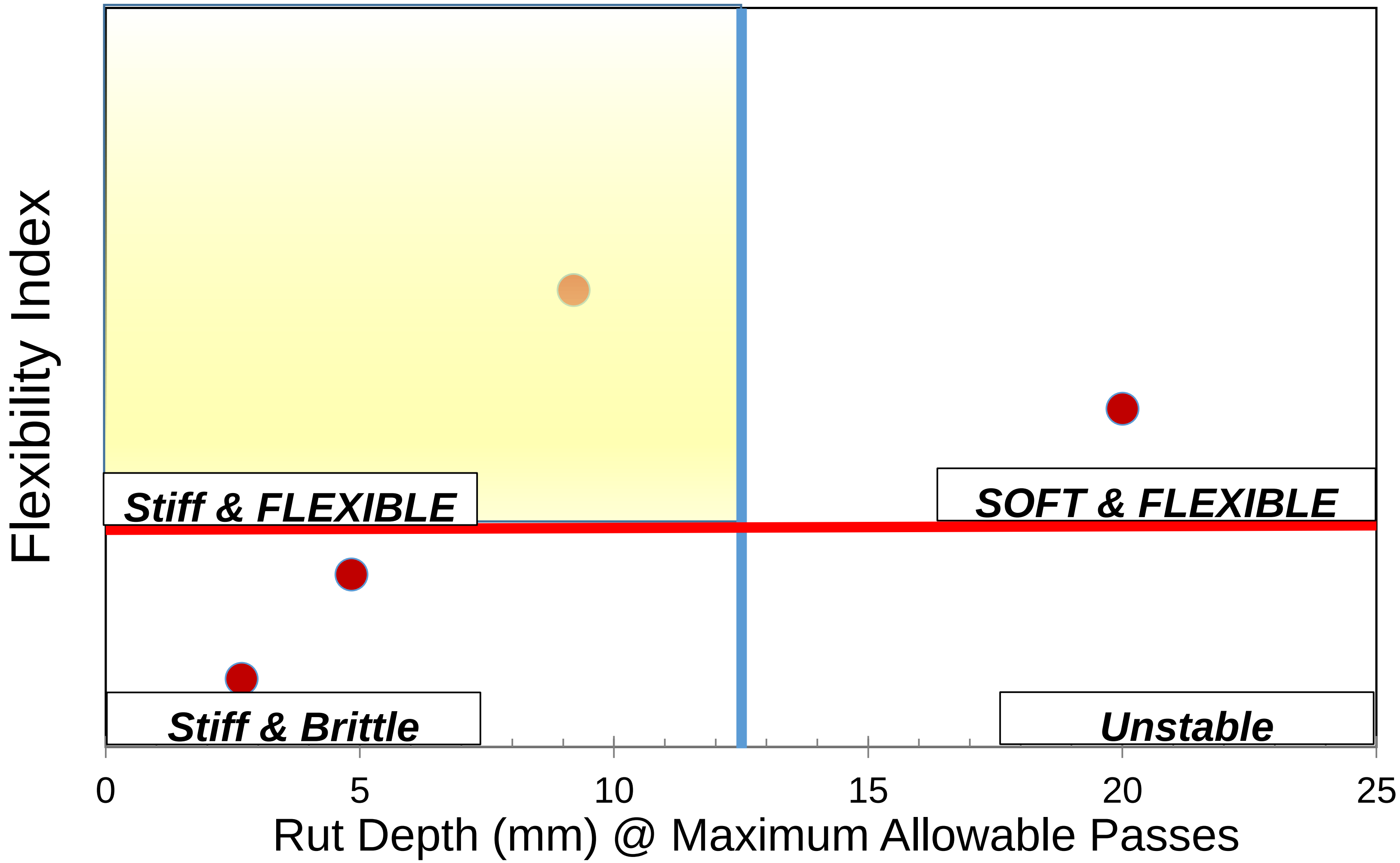
District 1 Section #	Field Perf.	FI	Thickness (mm)
5	Bad	1.3	40
10	Bad	1.4	41
4	Bad	1.8	41
7	Good	2.3	38
6	Bad	2.9	38
2	Bad	3.1	38
11	Good	3.4	26
12	Bad	3.9	38
3	Good	4.9	41
1	Good	5.0	37
8	Good	6.0	25
13	Bad	10.4	41
9	Good	10.9	26

Increasing FI

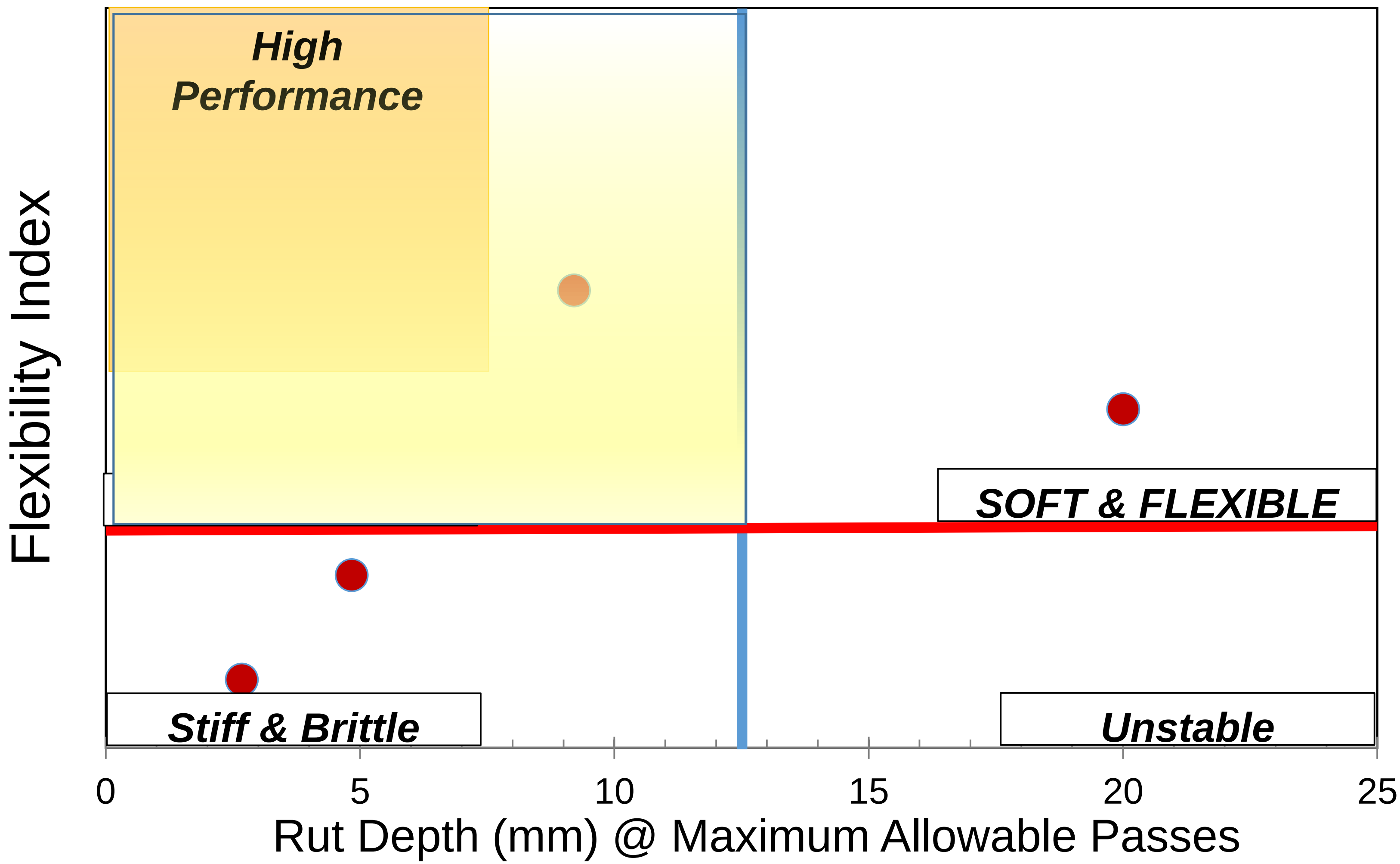
Effect of Construction Year



Balanced Mix



Balanced Mix



Final Remarks

- Asphalt mixture brittleness can result from **mixture volumetrics** as well as adding **recycled materials** (RAP and RAS)
- **Low temperature** fracture tests **could not distinguish** between AC mixes
- **IL-SCB test** is a practical, affordable, and reliable test to distinguish between mixes' cracking resistance
- The **method is supported** by extensive lab and field testing, theoretical, and numerical methods, and DIC technique

Findings and Remarks

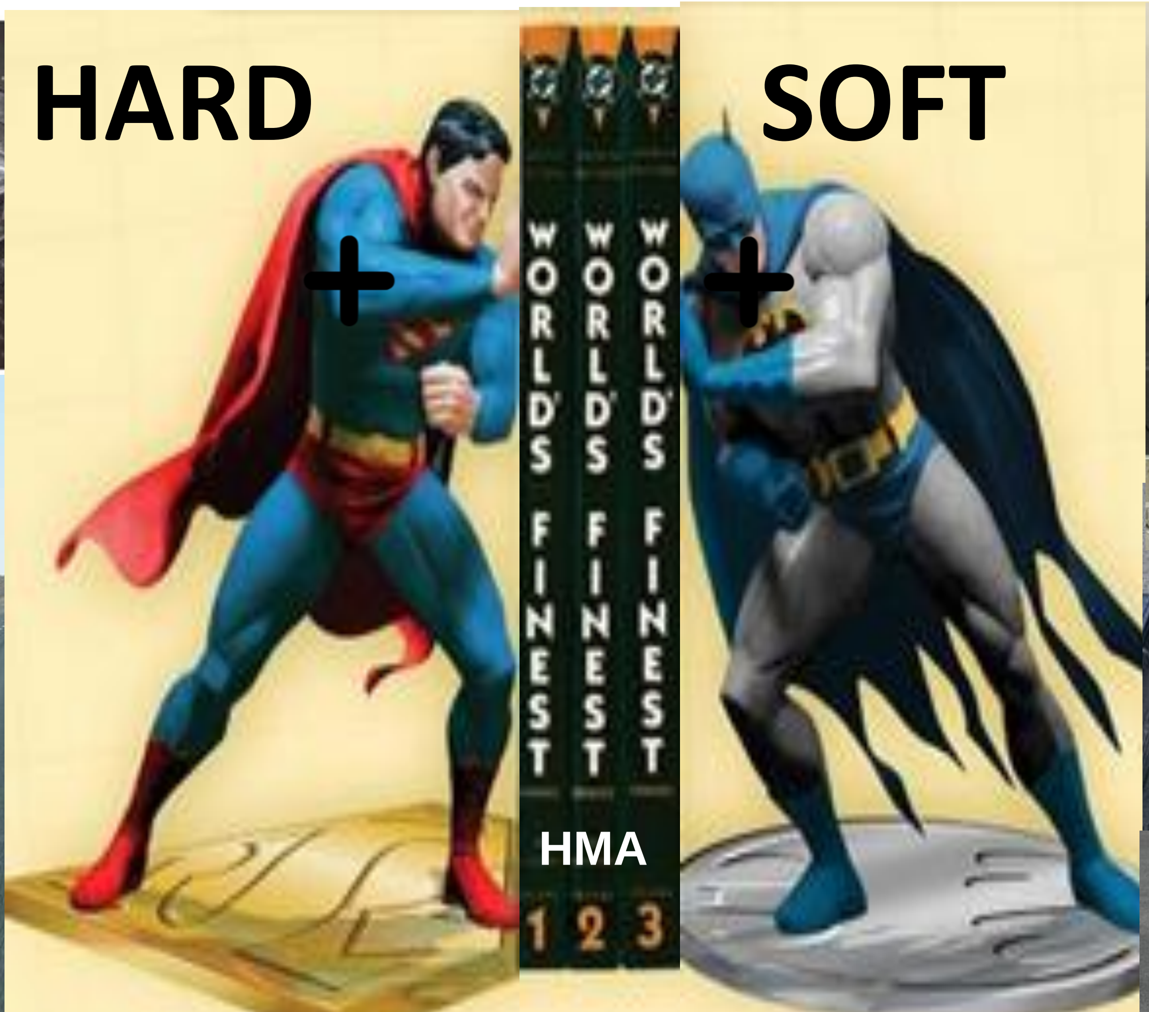
- **IL-SCB test method and the proposed Flexibility Index have successfully screened hundreds of AC mixes for changes in brittleness**
- **Implementation of a balanced mix design and field performance validation is underway**
  - **Simple interaction plots combining Hamburg and IL-SCB tests**
- **A life-cycle approach is needed to assess sustainability impact of recycled materials**
  - **Pavement performance and traffic volumes are critical**

Acknowledgements

- ICT R27-128 Project Technical Review Panel
- Undergrad and graduate students involved
- ICT research engineers

ICT.illinois.edu

HMA Testing “Book Ends”



Courtesy of David Lippert