Characteristics of Illinois Flexibility Index Test

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

ILLINOIS BITUMINOUS PAVING CONFERENCE
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Toughness (Strength)

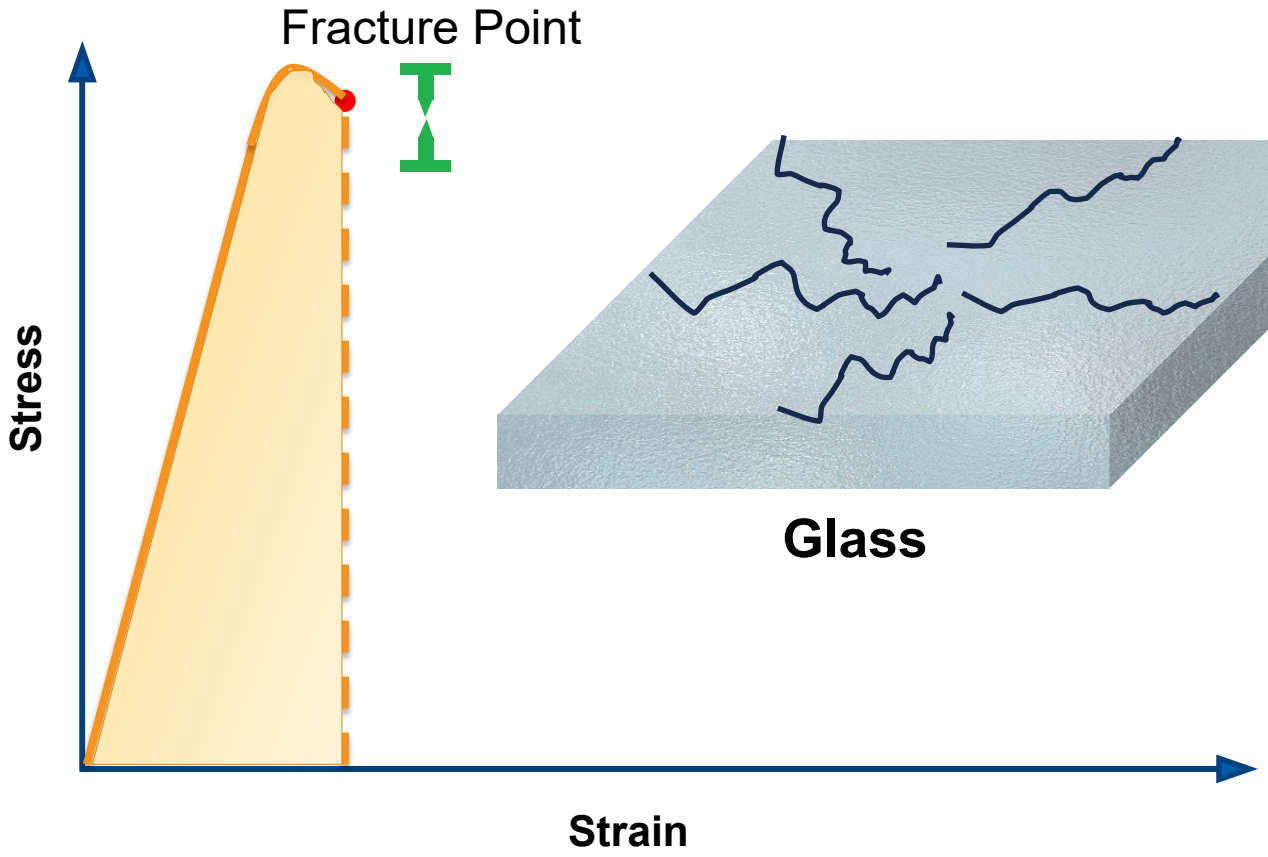
- Ability of the material to absorb the impact and plastically deform without fracturing
- Includes plastic deformation

Fracture Toughness

- Ability of the materials to resist the fracture when crack is already present
- Zero or negligible plastic deformation

$$Energy_{absorbed} = Energy_{Cracks} + Energy_{plastic}$$

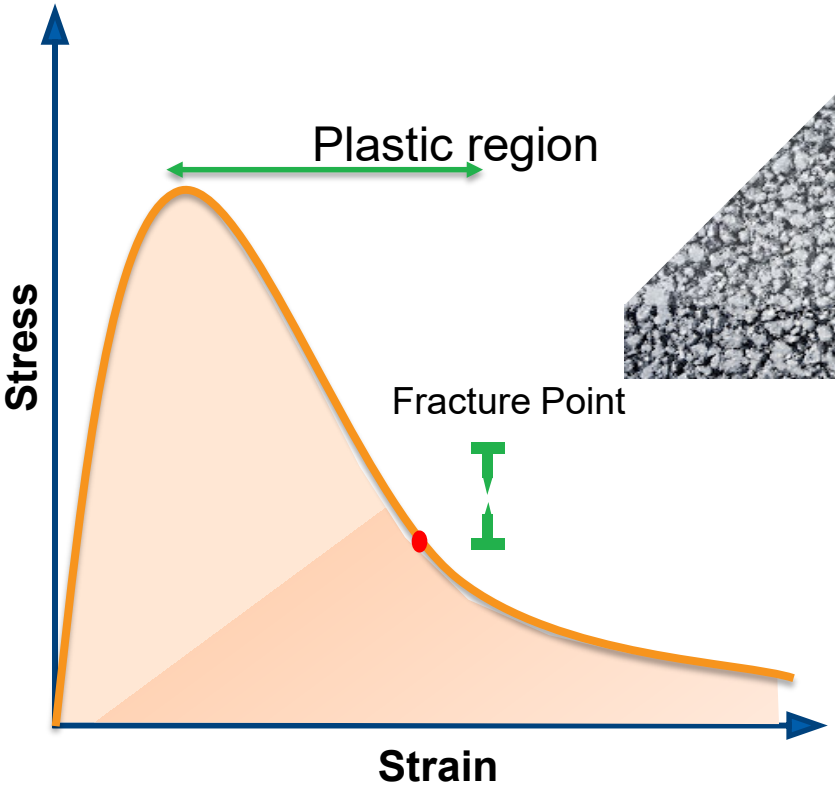
Illustration – Brittle Material

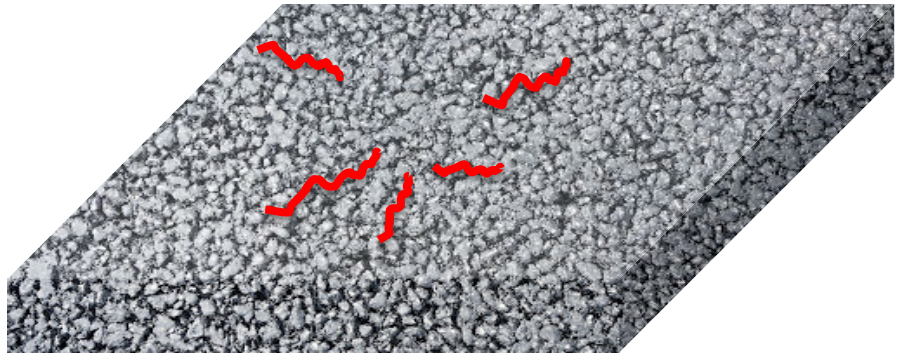


Glass

- Fracture occurs immediately after yield point and is catastrophic
- Most of energy absorbed is used for crack propagation
  $Energy_{plastic} \approx 0$
- Hence, $Toughness \equiv Fracture\ Toughness$

Illustration – Ductile Material

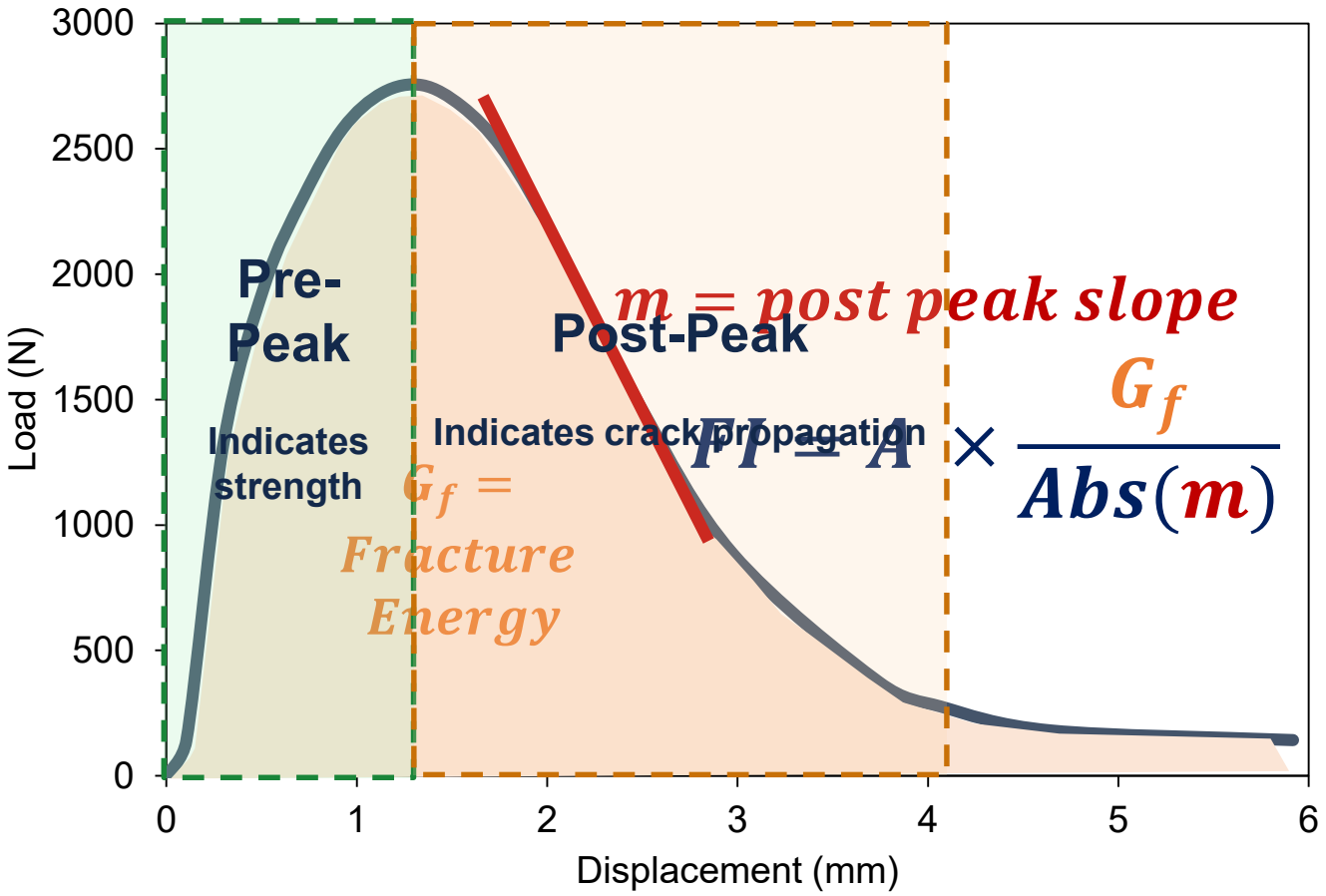


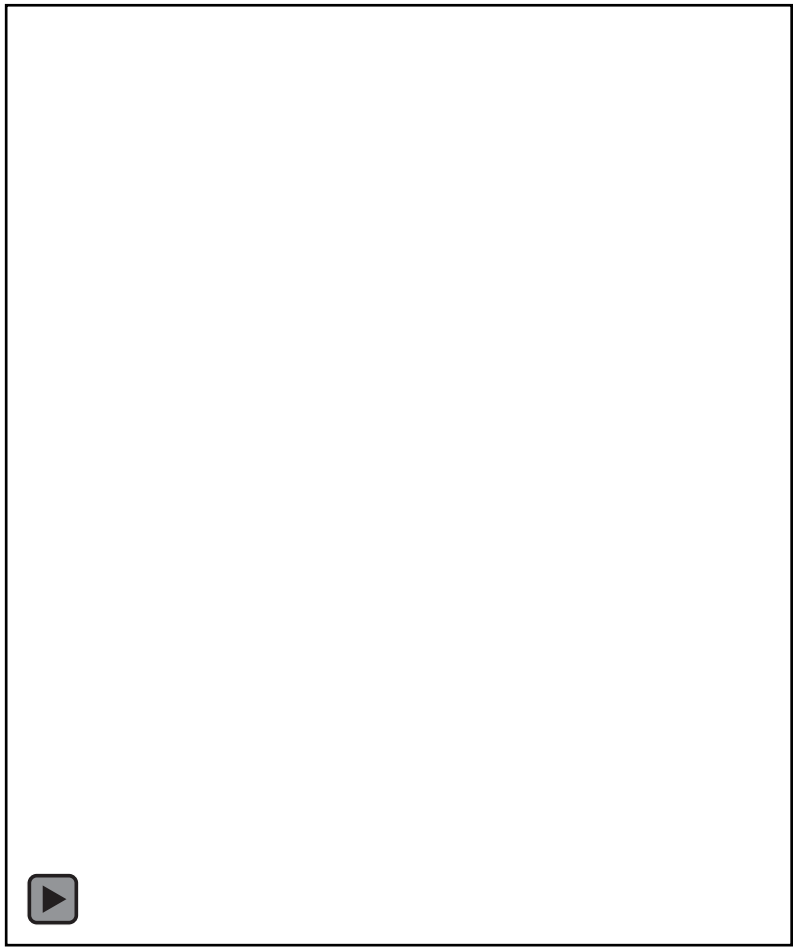


HMA

- Fracture occurs slowly after yield point and is stable
- Energy absorbed is used for 1) plastic deformation and ii) crack propagation $Energy_{plastic} > 0$
- Hence, $Toughness \not\equiv Fracture\ Toughness$

Illinois Flexibility Index Test (I-FIT)

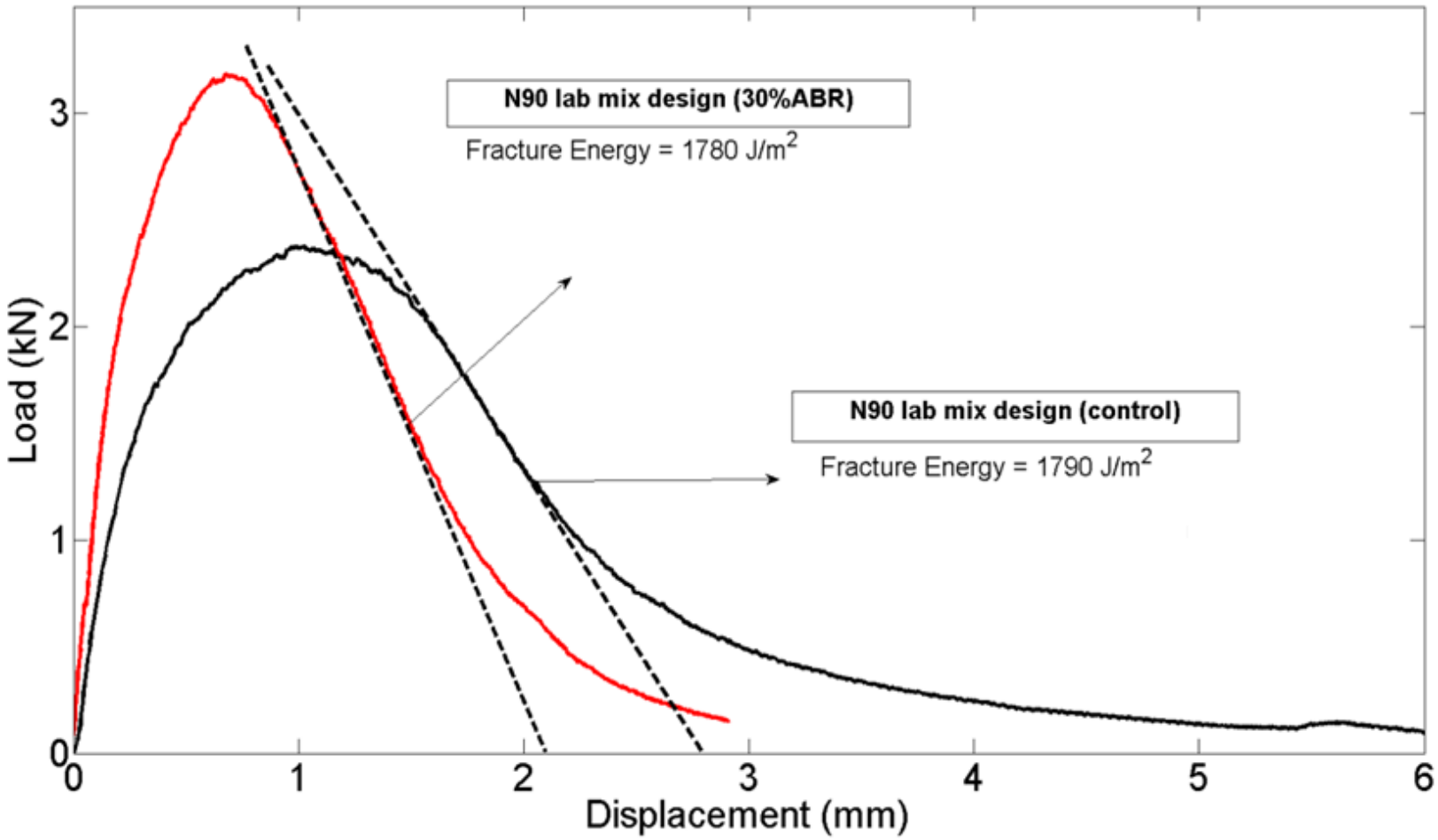




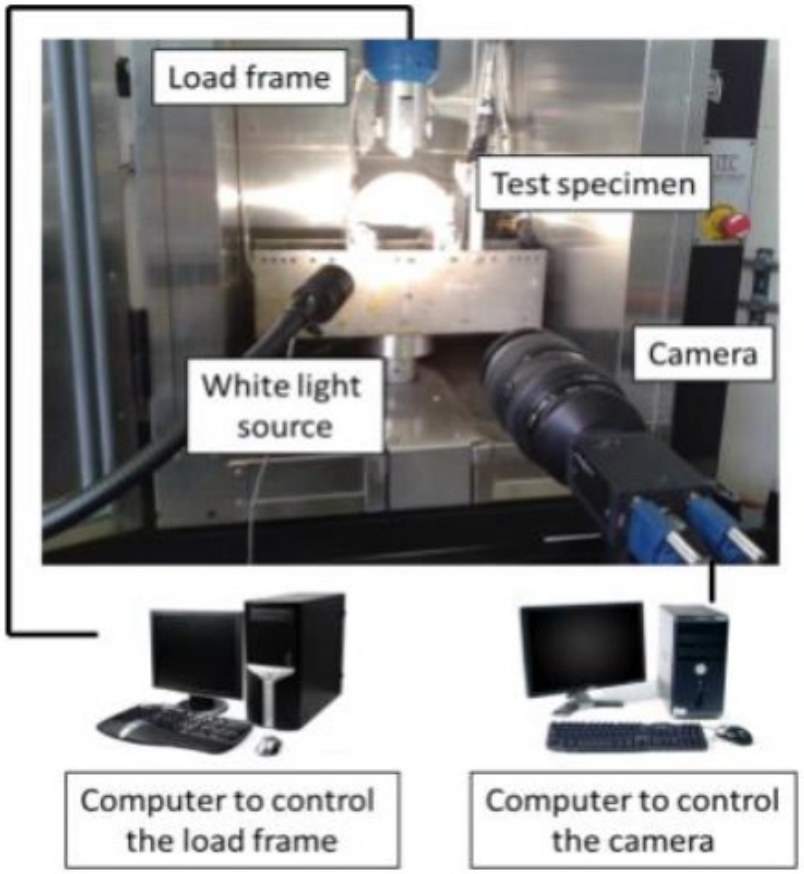
Fracture Energy (G_f) = W_f/ Ligament Area

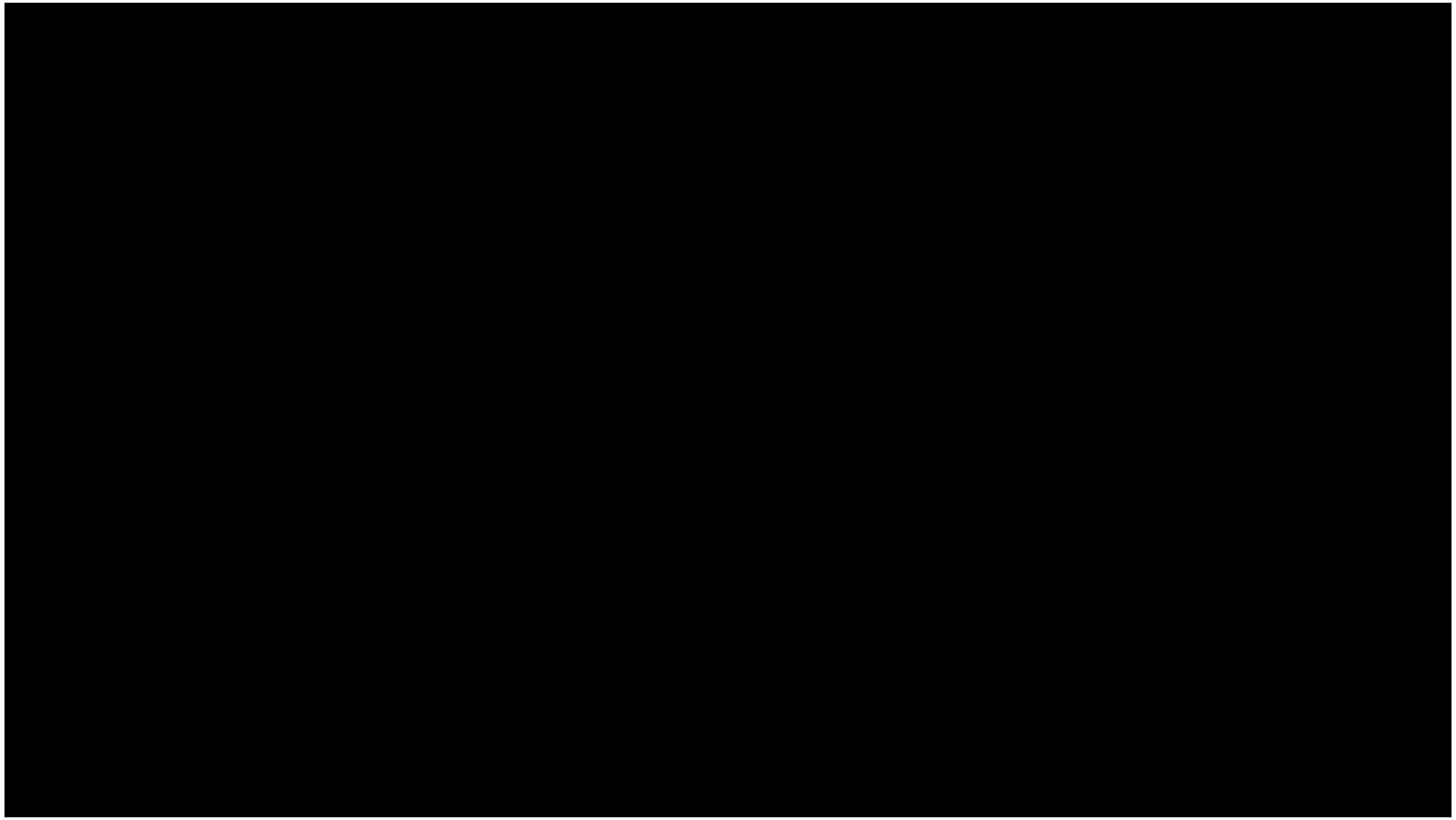
I-FIT Distinguishes between AC Mixes!

- Different AC may have **similar Fracture Energy**
- **Distinguish** between AC mixes with different **cracking susceptibility**

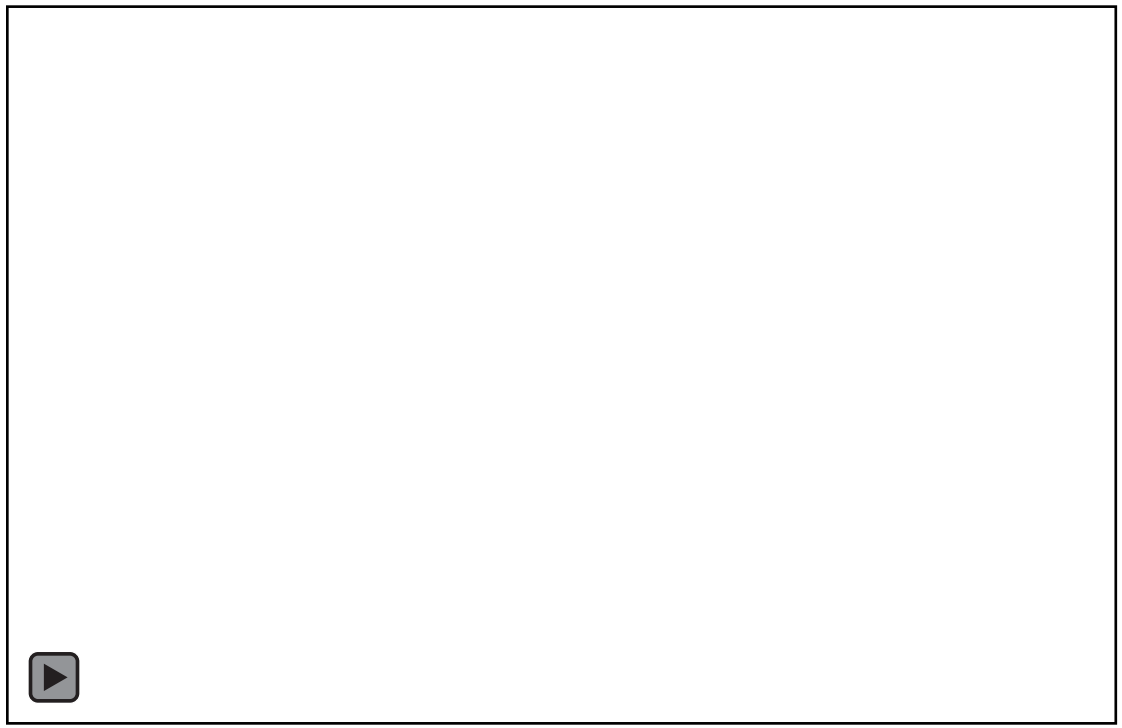


Fracture Characterization Using DIC





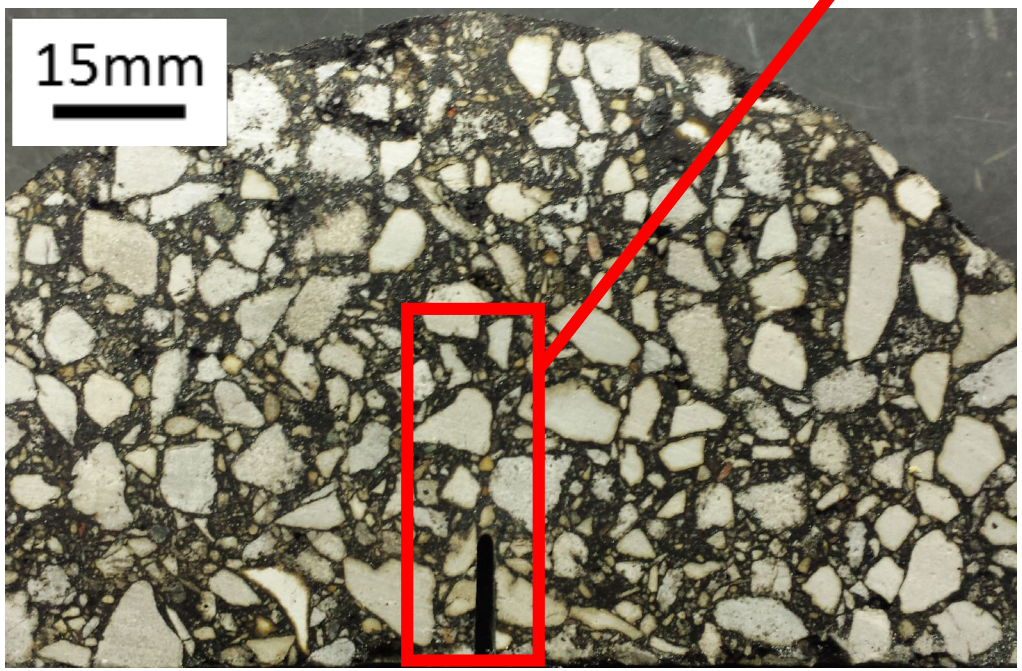
Importance of Notch in I-FIT

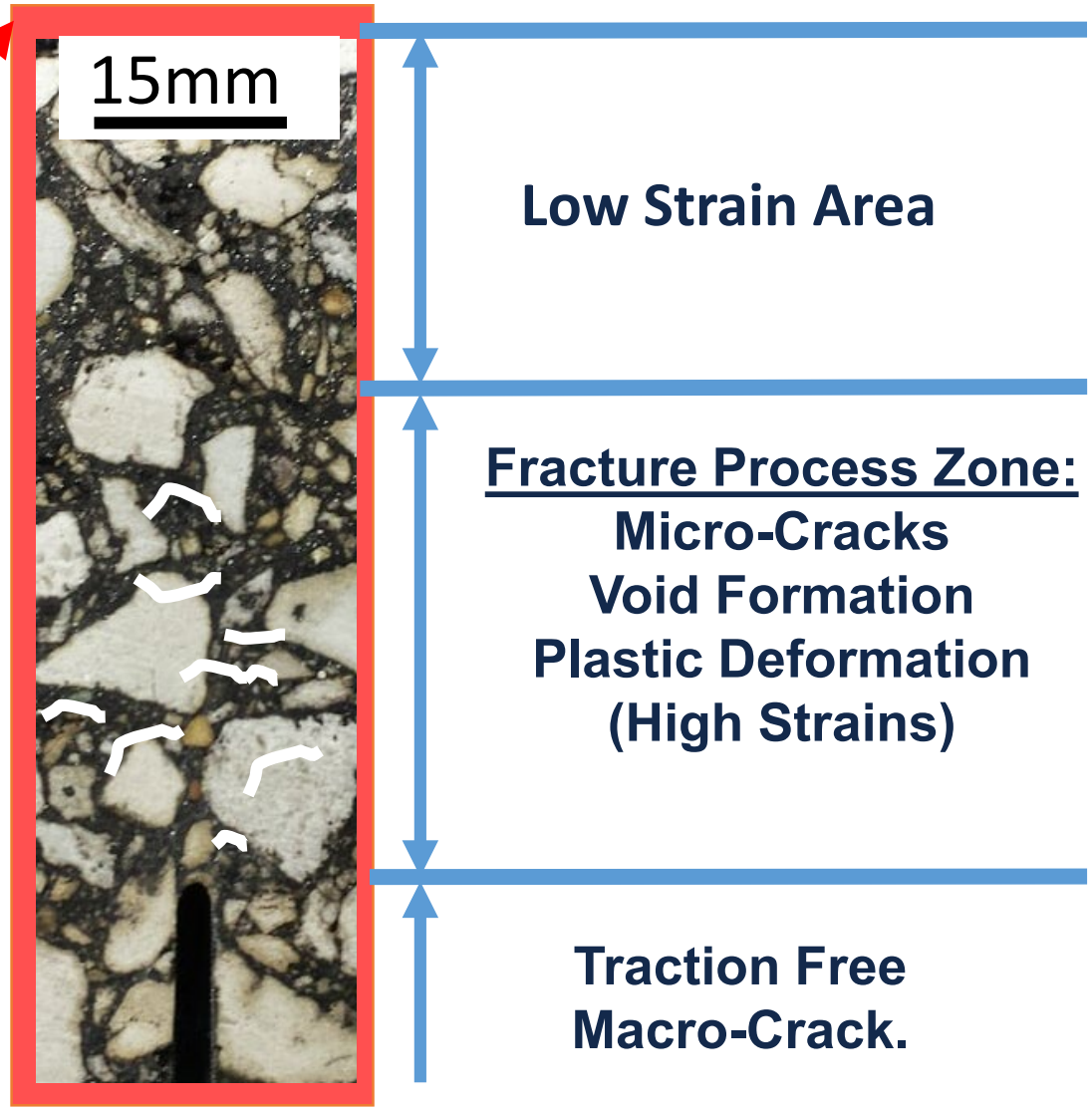


- Notch in the I-FIT specimen is necessary for fracture mechanics principles to be applicable

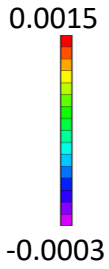
Fracture Process Zone

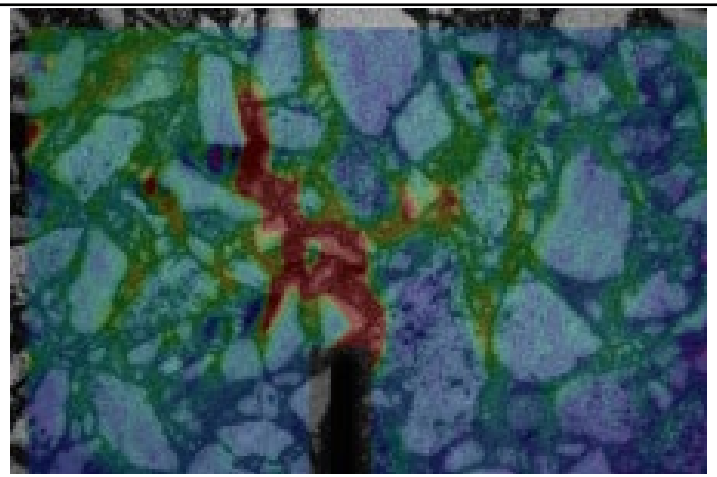
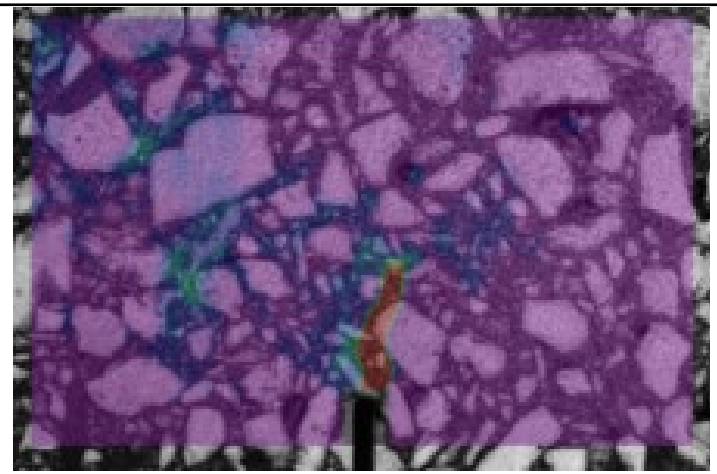
Zone near and around the crack tip where the material is experiencing damage.





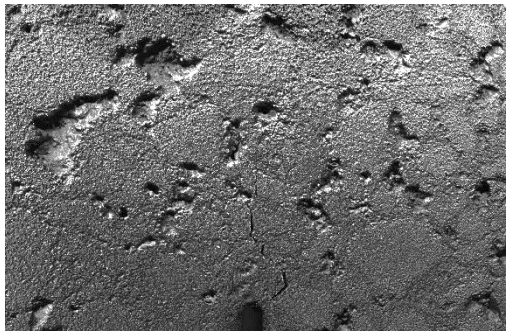
Effect of RAS Using DIC



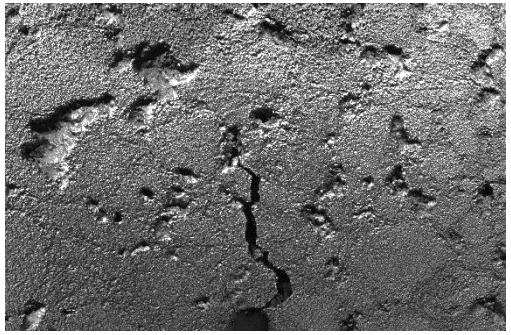
Mix / Test Condition	0%RAS	7%RAS
-12°C, 0.7mm/min		

Variability in HMA Cracking

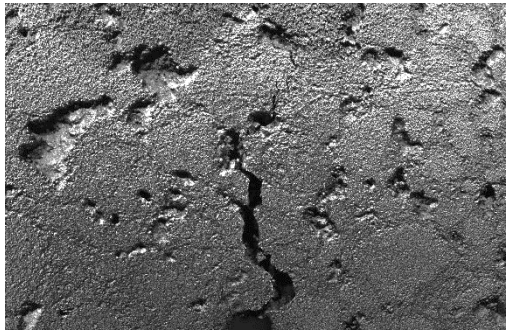
t_1 = 0.33s (following peak load)



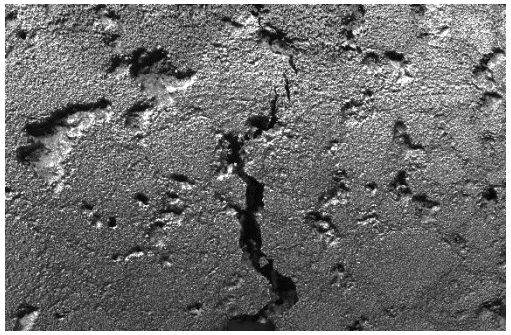
t_2 = 1.0s



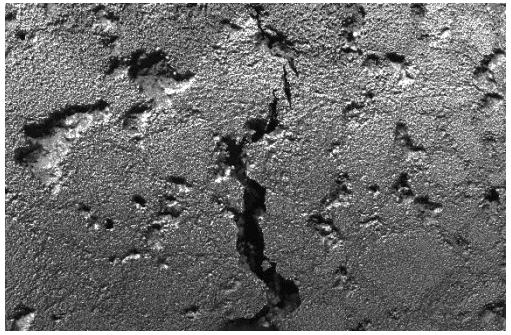
t_3 = 1.66s



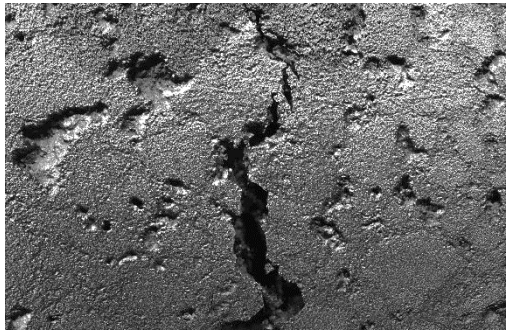
t_4 = 2.33s

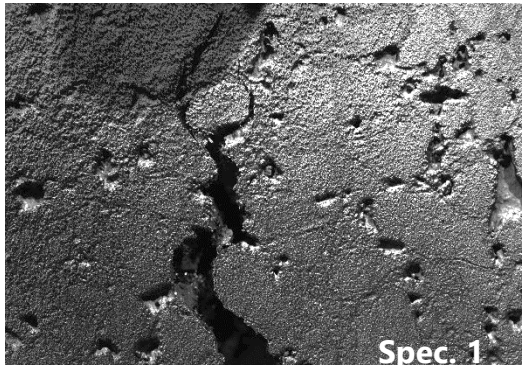


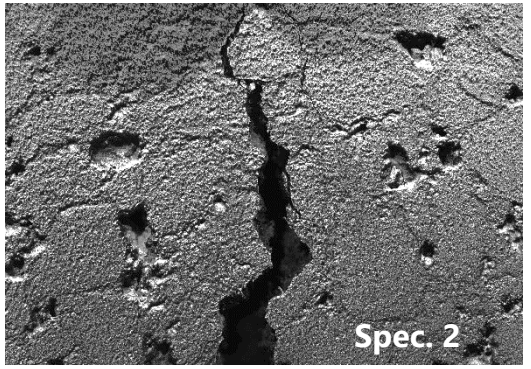
t_5 = 3.0s

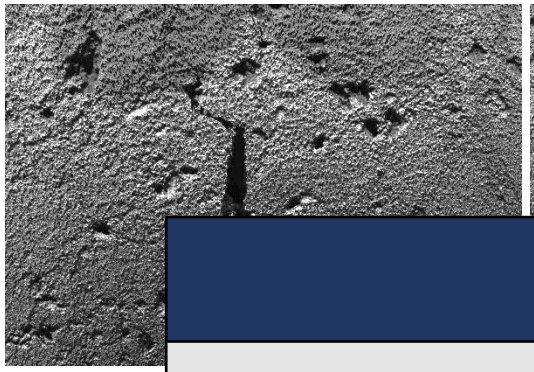


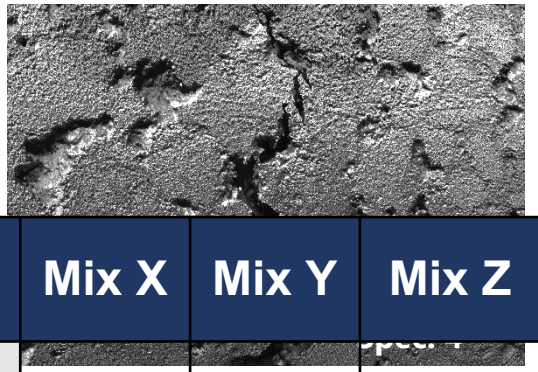
t_6 = 3.66s







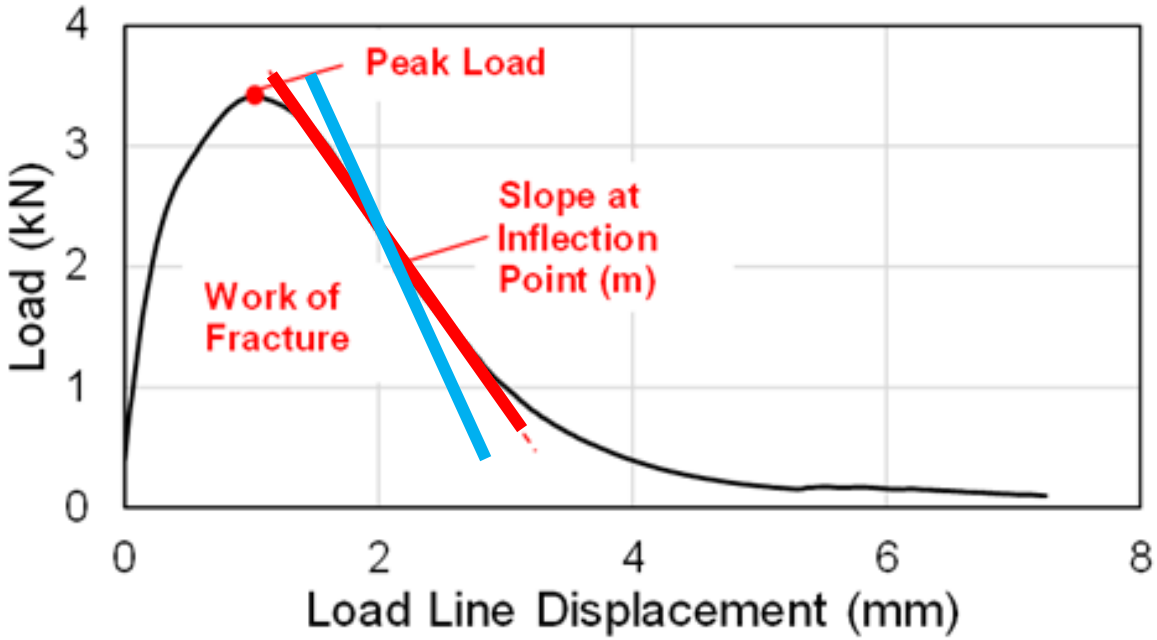


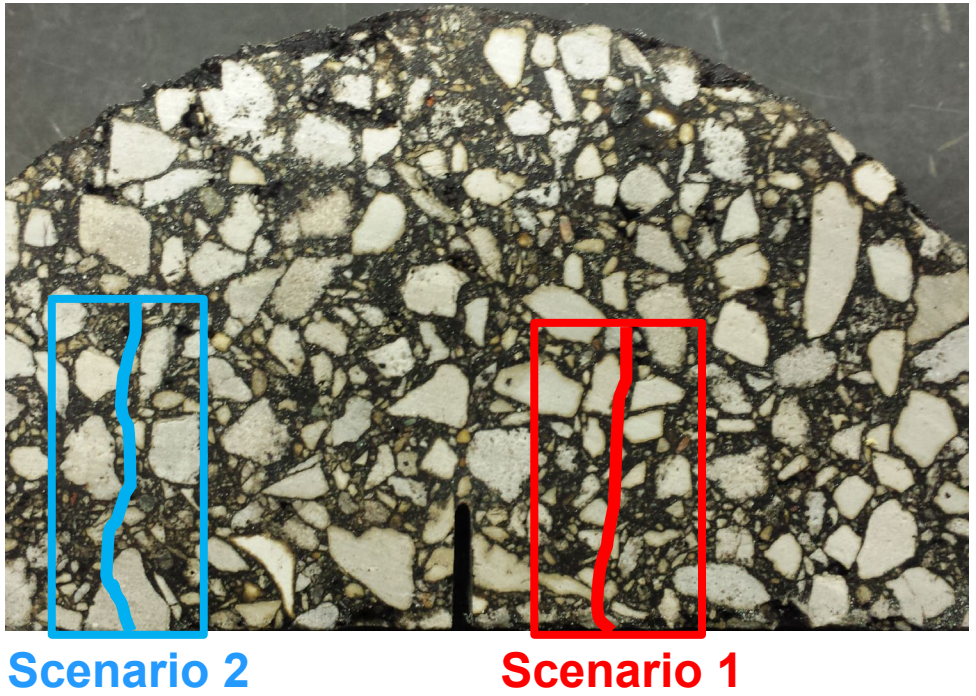


	Mix X	Mix Y	Mix Z
FI	8.9	5.9	2.2
FI CoV	12.4	28.1	28.7
Crack Speed CoV	17.5	29.8	30.3

Reason for High Variability!

- Crack propagation depends on aggregate size, orientation, and distribution





In the field, aggregate distribution varies throughout the project; hence, inherent variability exists, FI captures this variability while discriminates between mixes.

Stages of Fracture vs. Strength Tests

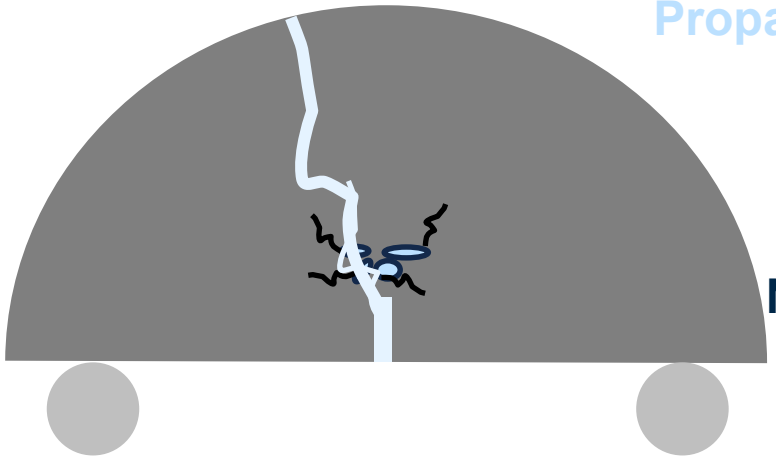
I-FIT

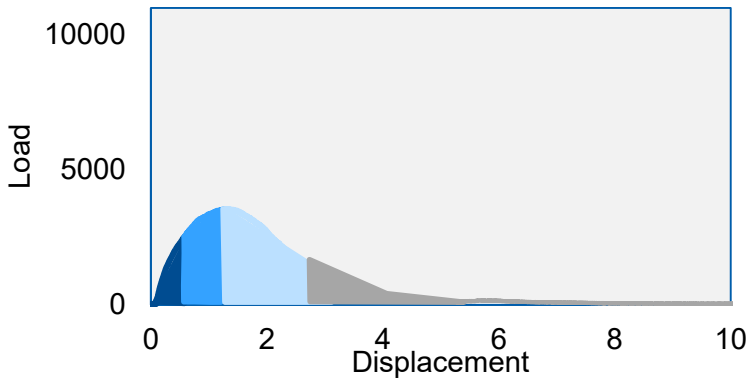
Failure

Crack Propagation

Crack Initiation

Void Nucleation





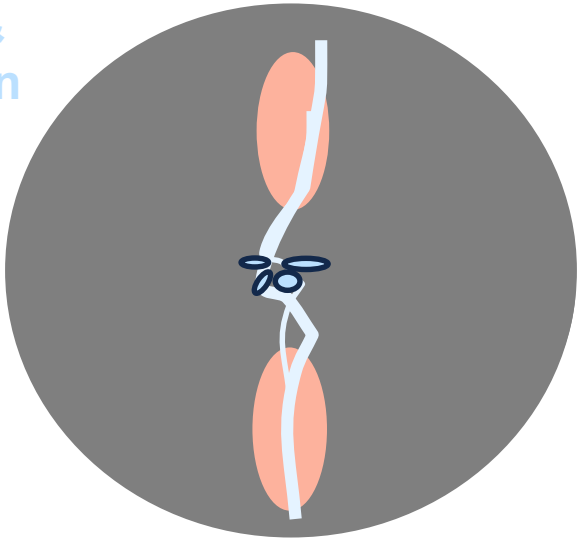
IDEAL-CT

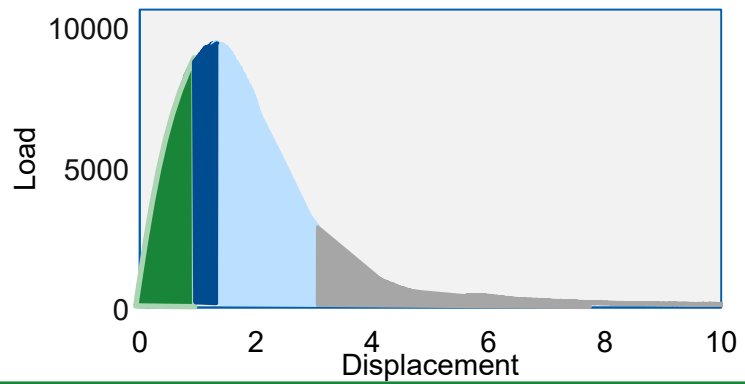
Cracks initiation & Propagation

Plastic Deformation

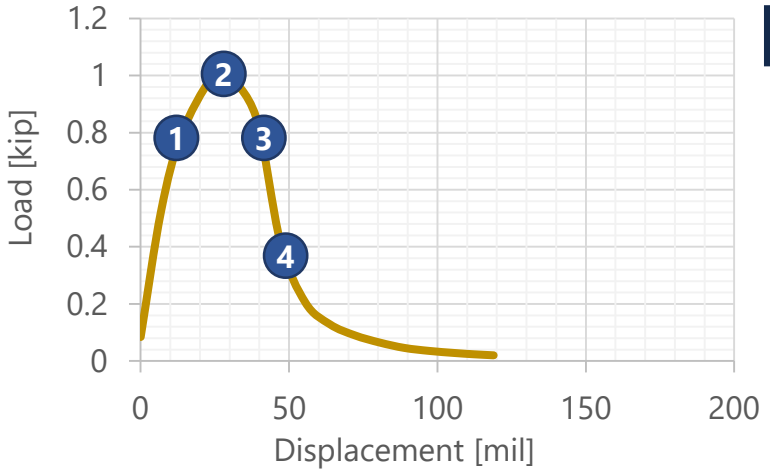
Void Nucleation

Failure

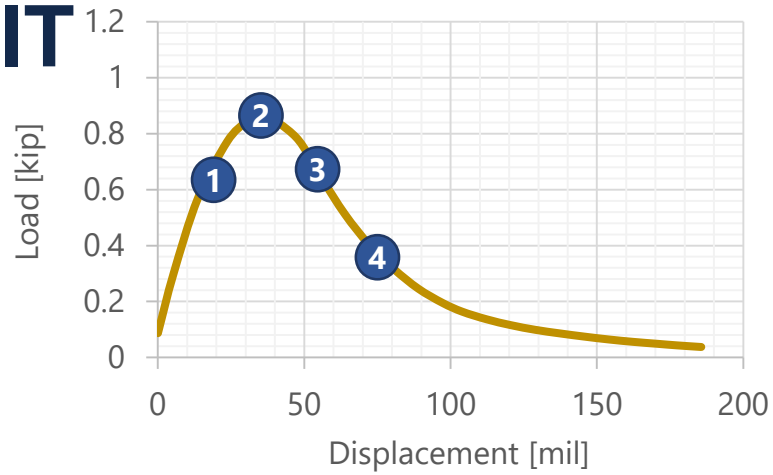




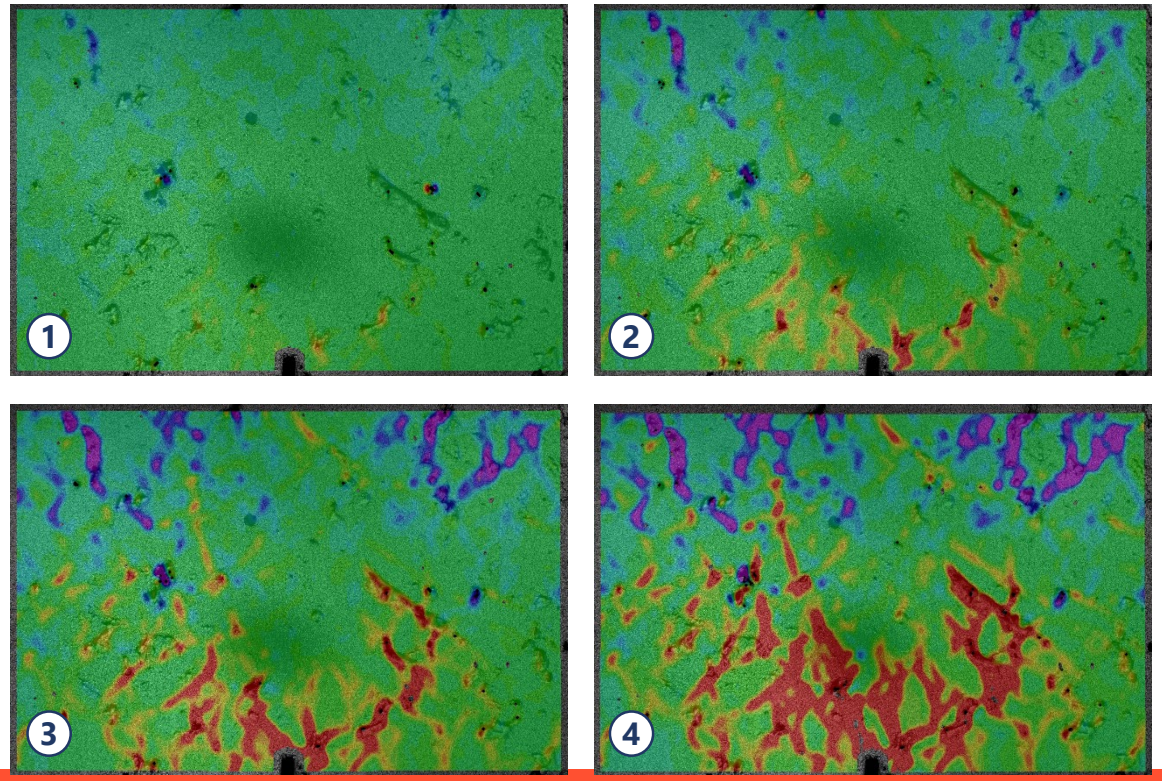
DIC on I-FIT

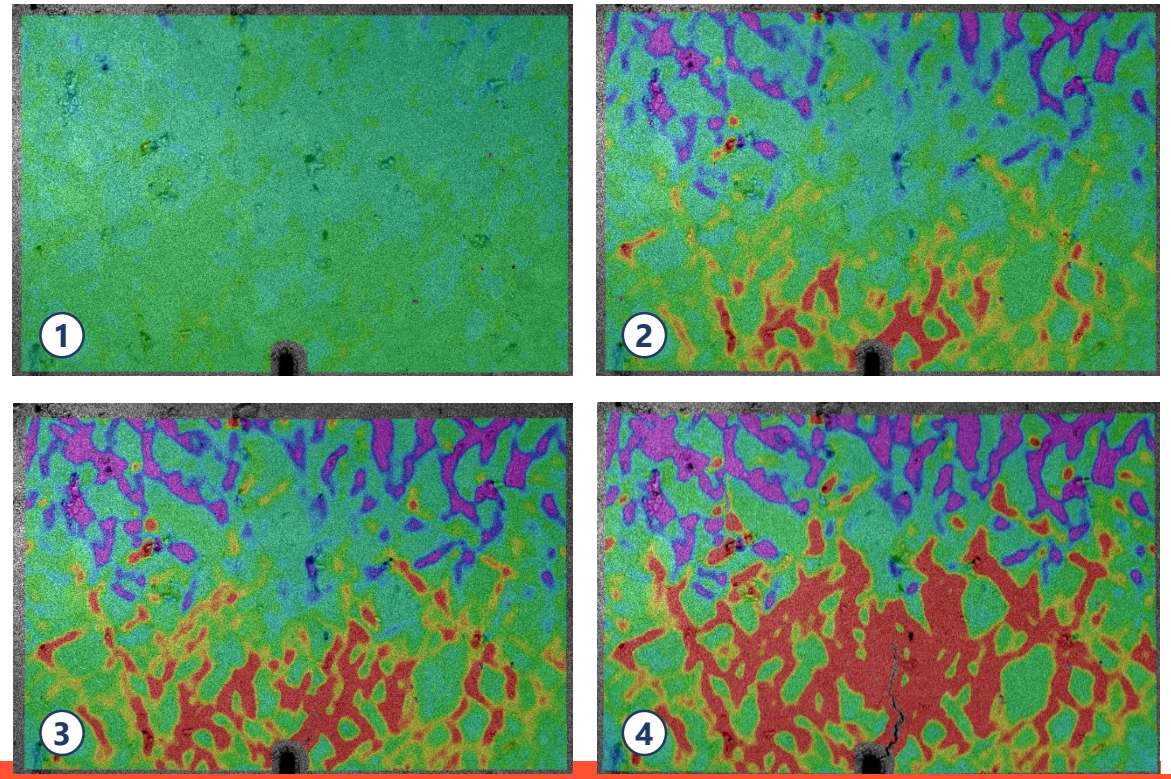


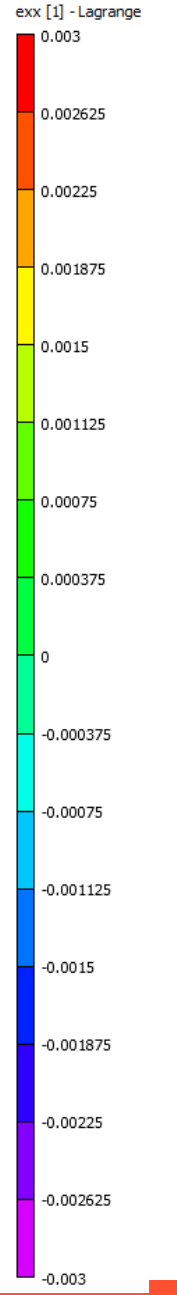
Mix 1
Brittle mix



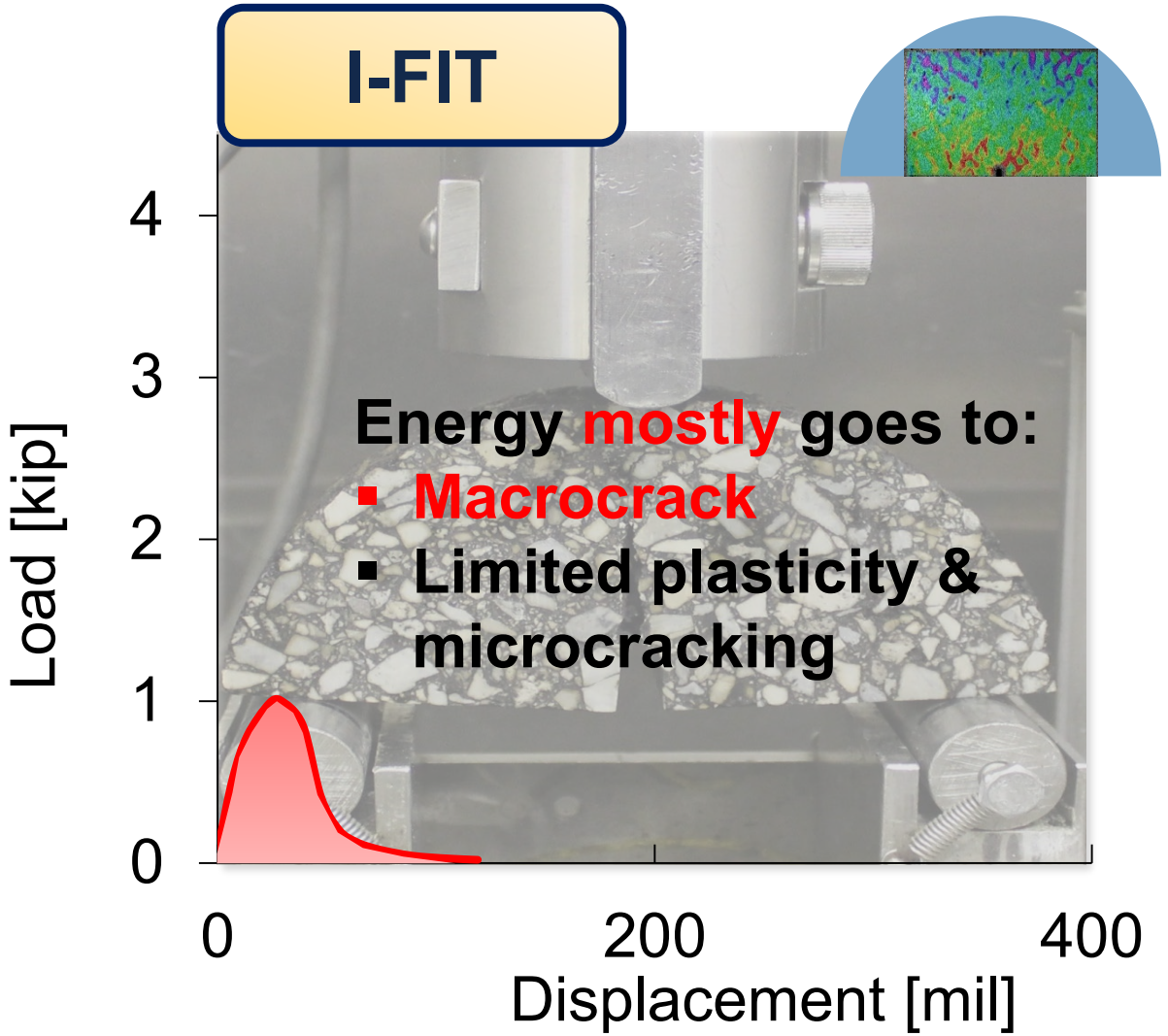
Mix 2
Ductile mix



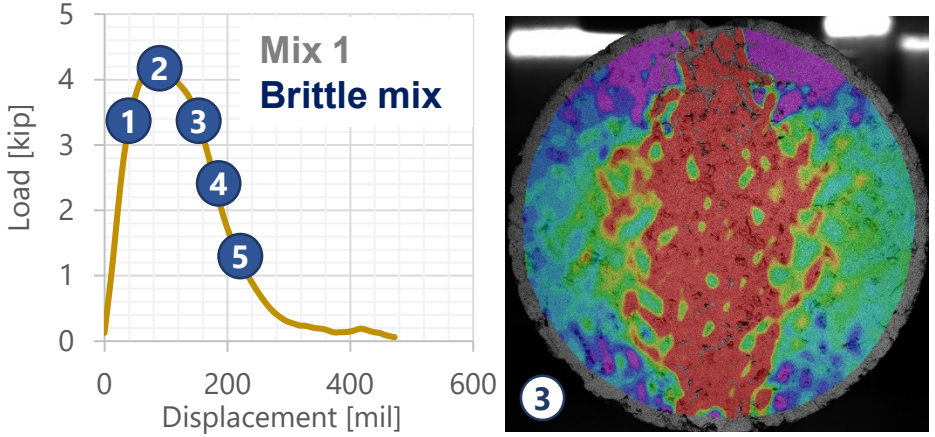


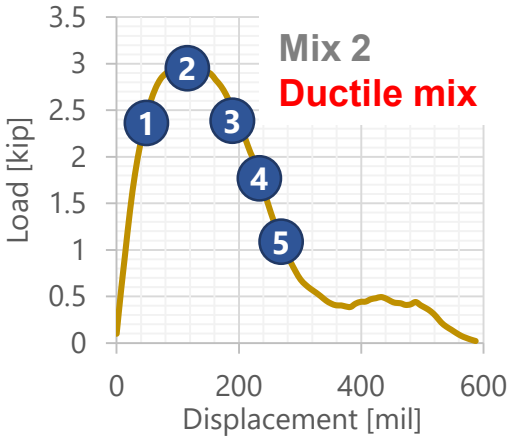


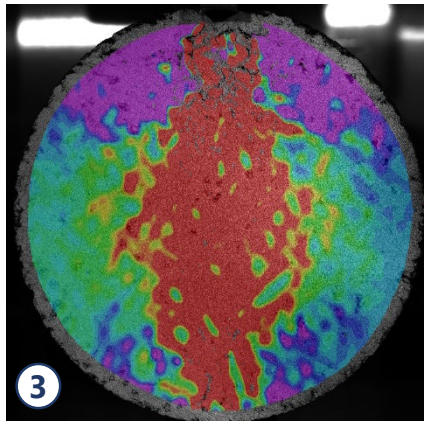
Fracture Test

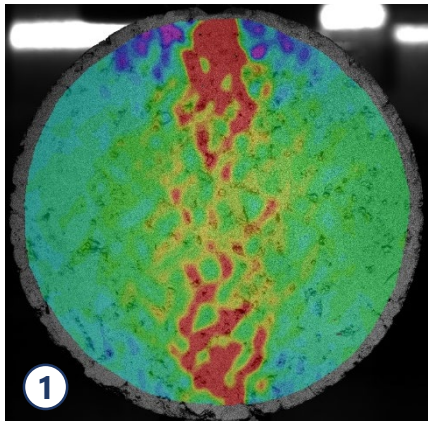


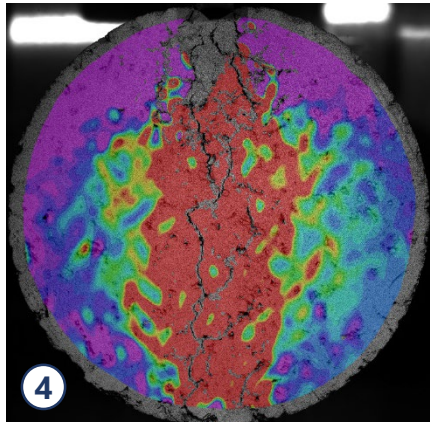
DIC on IDT/IDEAL

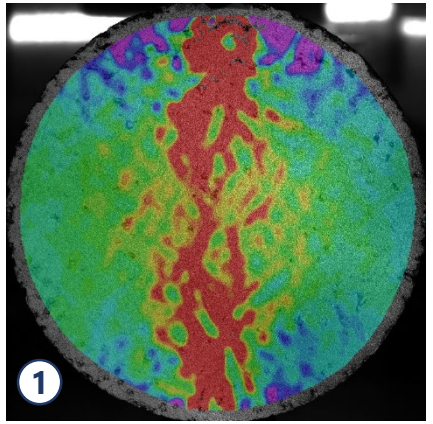


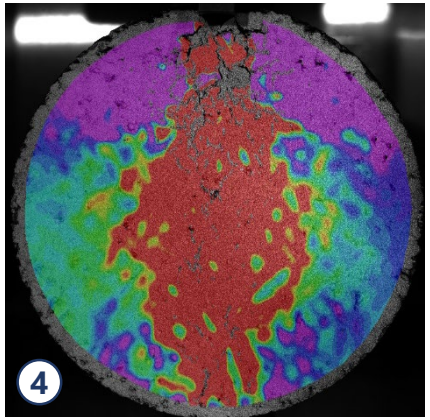


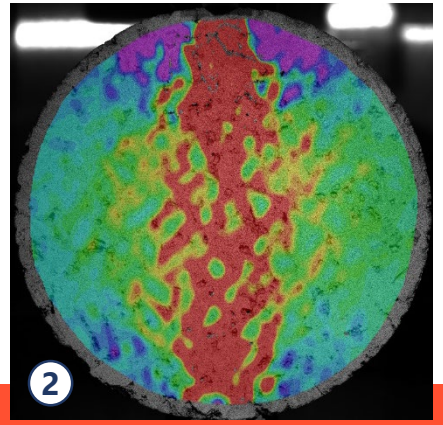


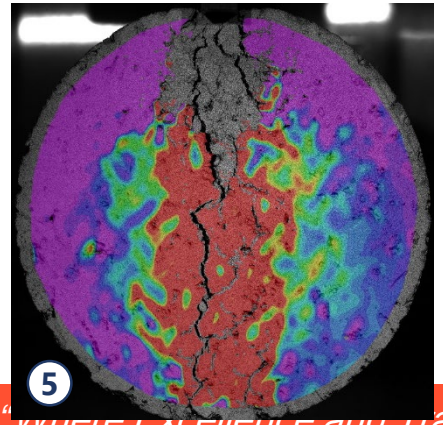


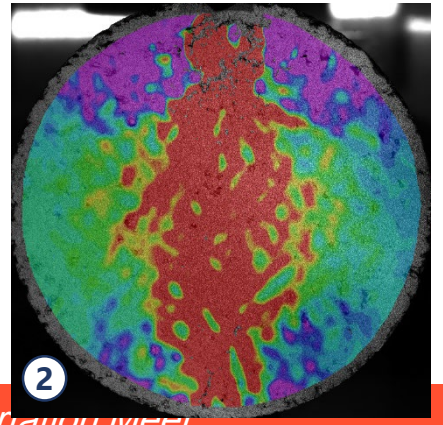


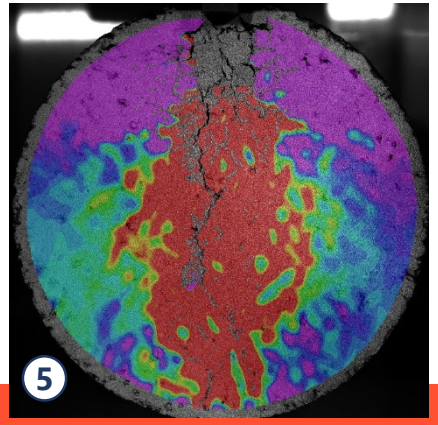


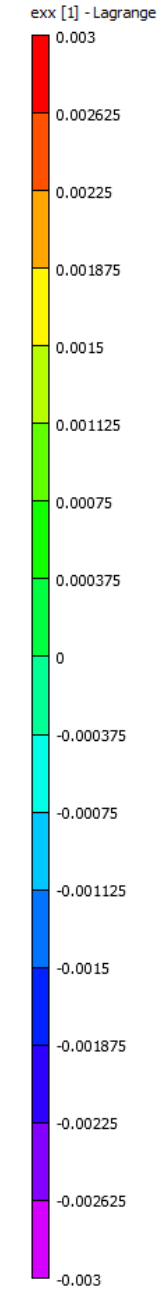






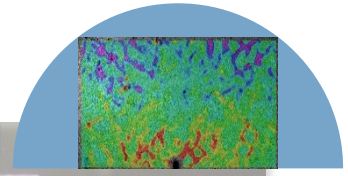




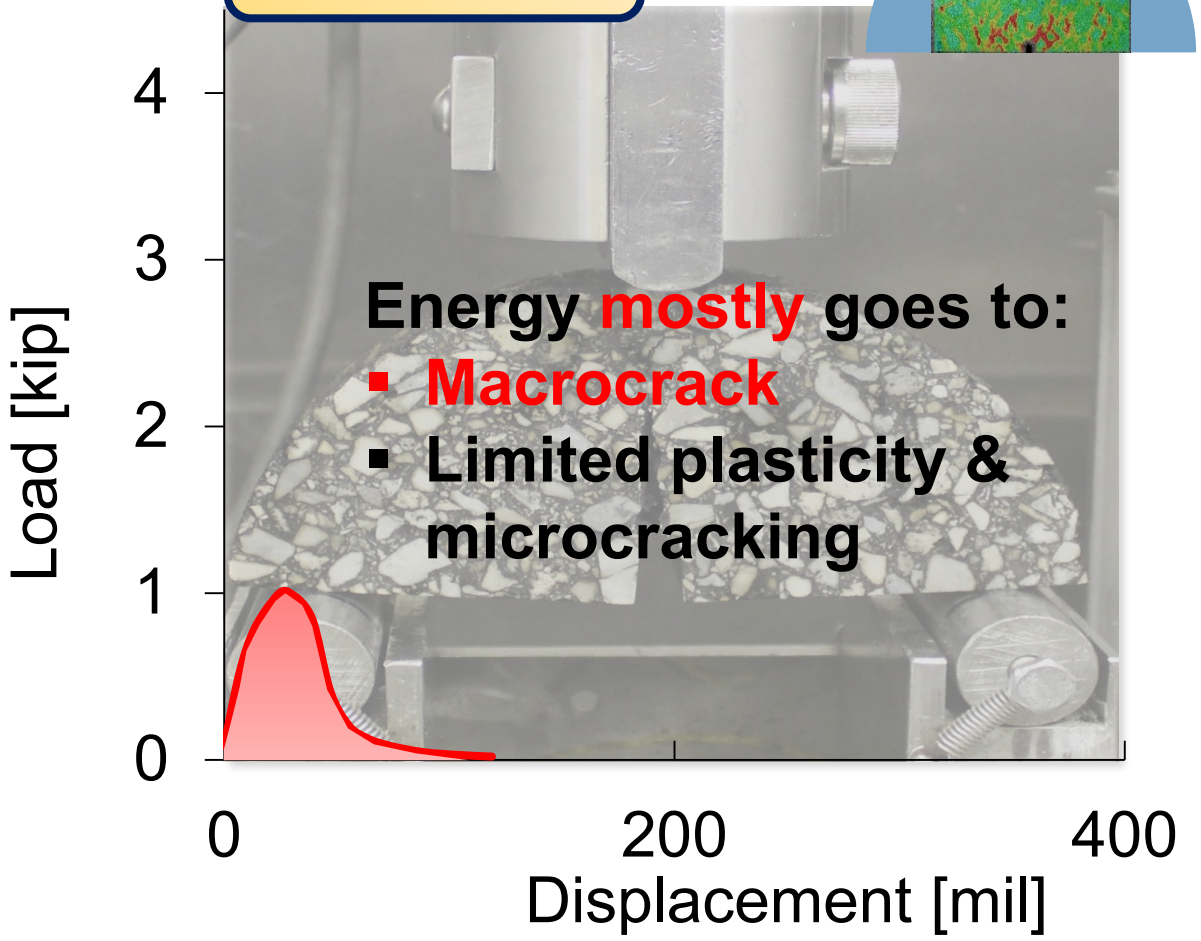


Fracture vs Strength Tests

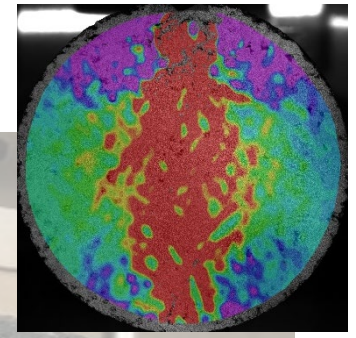
I-FIT



Energy **mostly** goes to:
- **Macrocrack**
- **Limited plasticity & microcracking**



IDEAL CT



Energy goes into:
- **Plastic deformation**
- **Microcracks**
- **Macrocracks**

Significance of Variability

- **An agency requires an HMA average FI = 8; the selected HMA has an FI = 8. The variability in the fracture properties of the HMA herein would help in quantifying the risk of HMA (due to cracking).**

FI_{max} = 9.5

FI_{avg} = 8.0

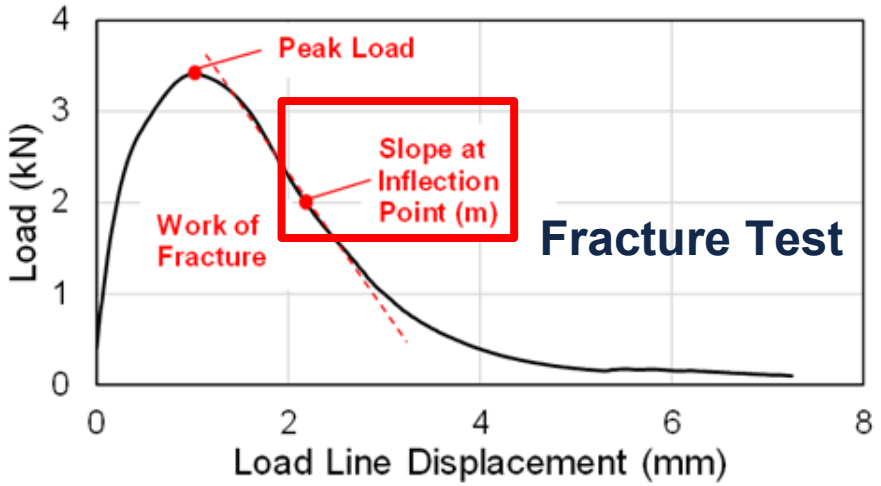
FI_{min} = 6.5

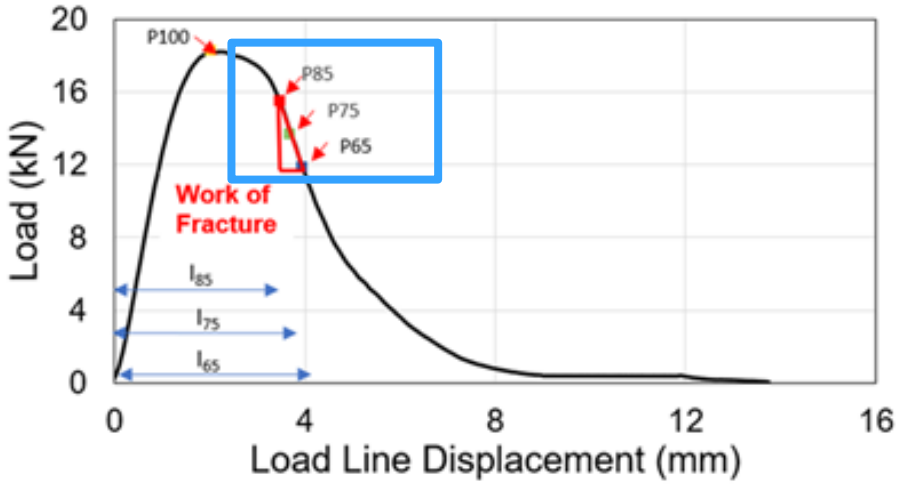
FI_{avg}= 8.0

FI_{max} = 8.2

FI_{min} =7.8

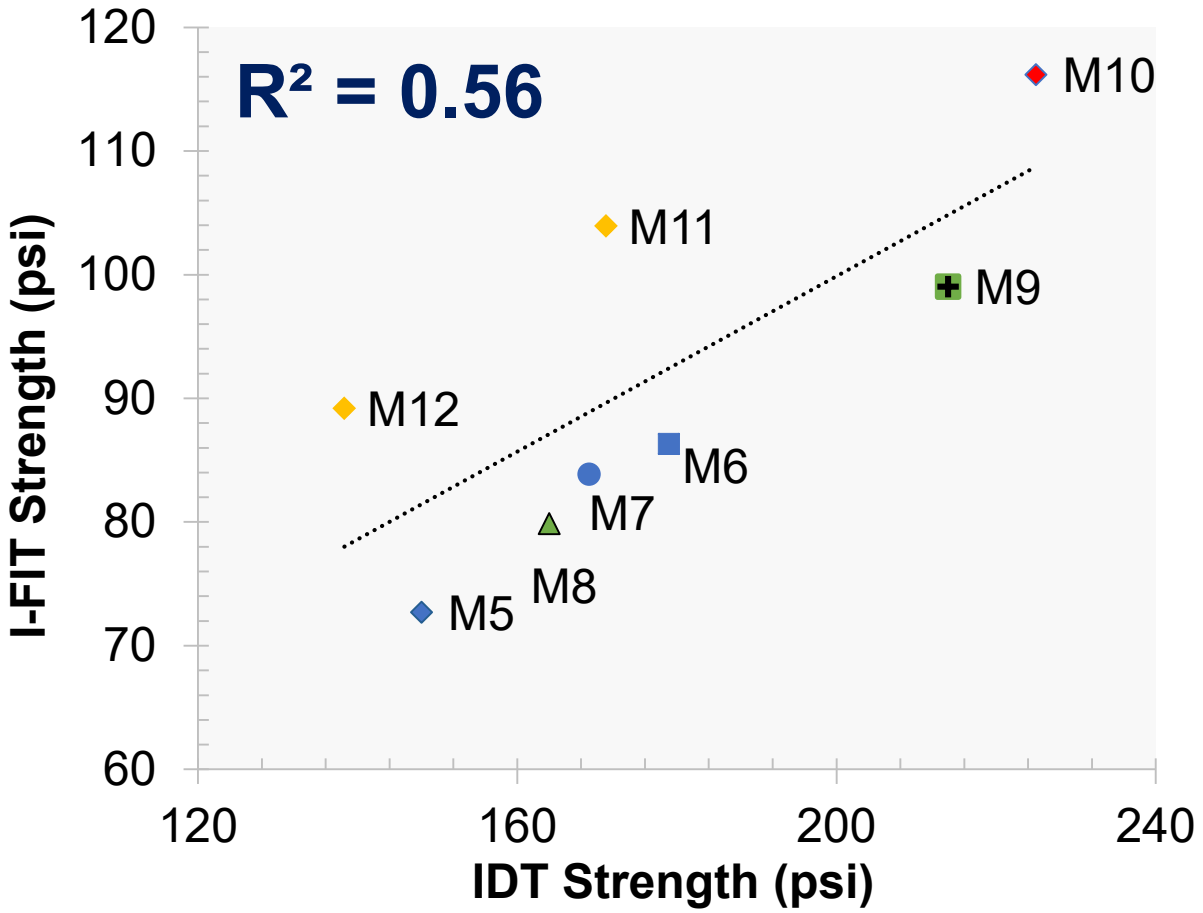
- **Variability is partially masked when using average post peak slope**



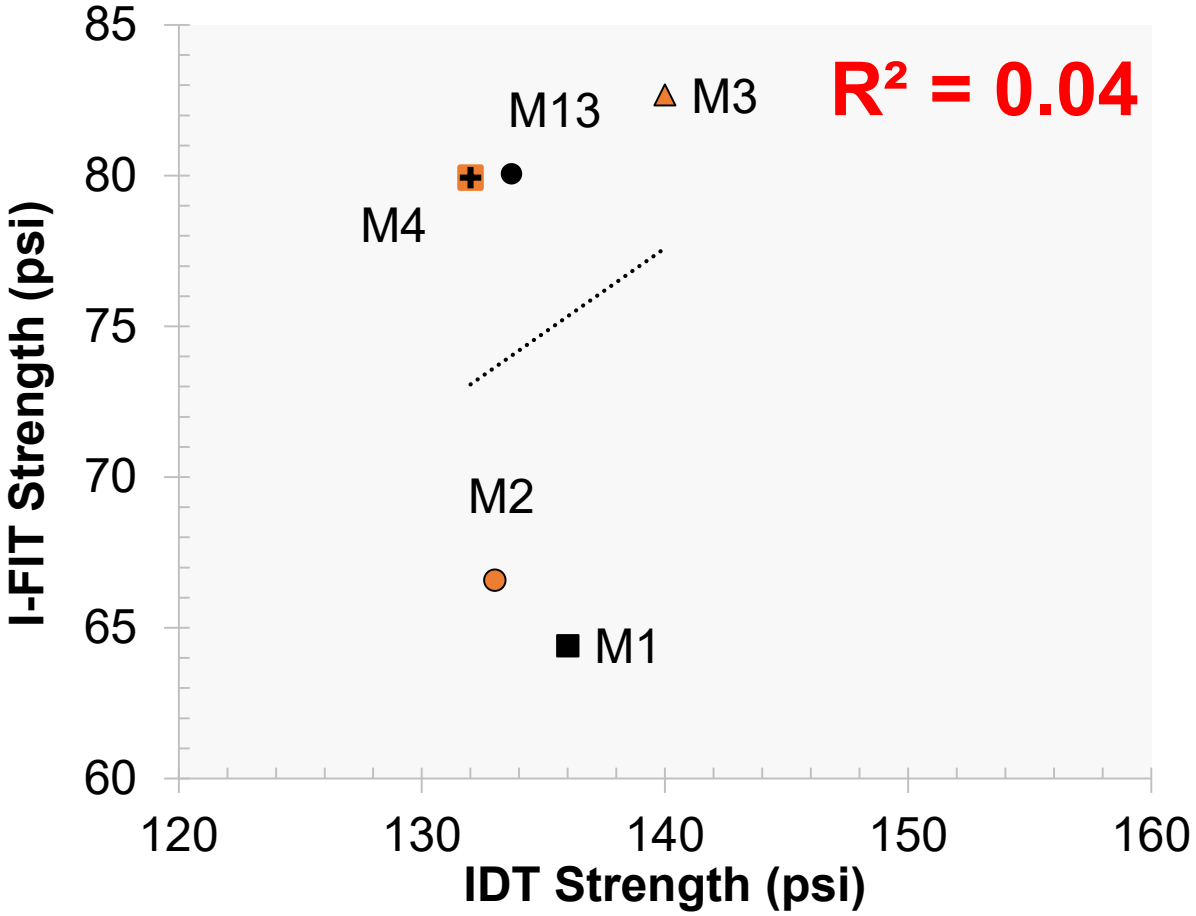


I-FIT and IDT/IDEAL Correlations for Brittle & Ductile Mixes

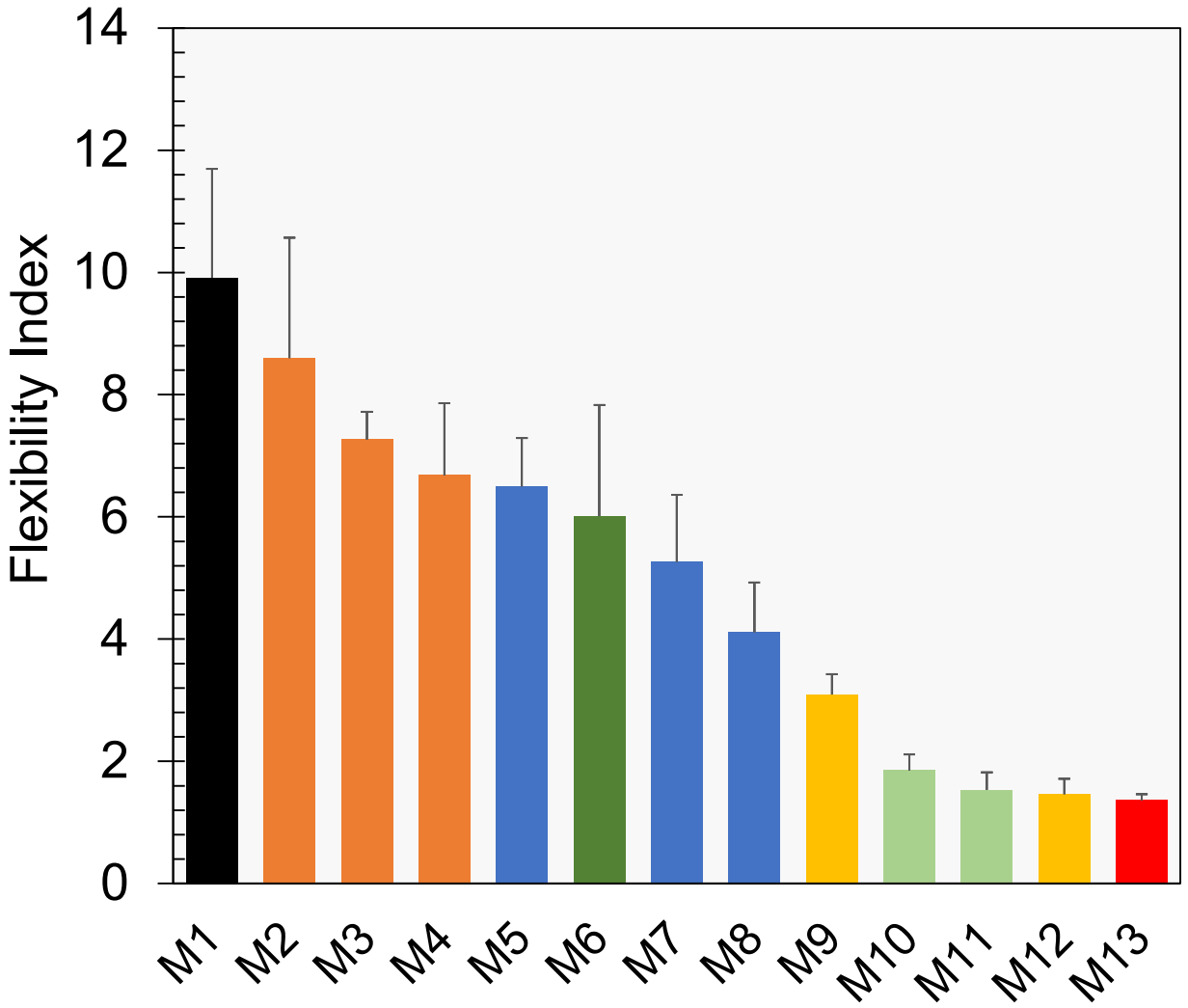
Brittle Mixes

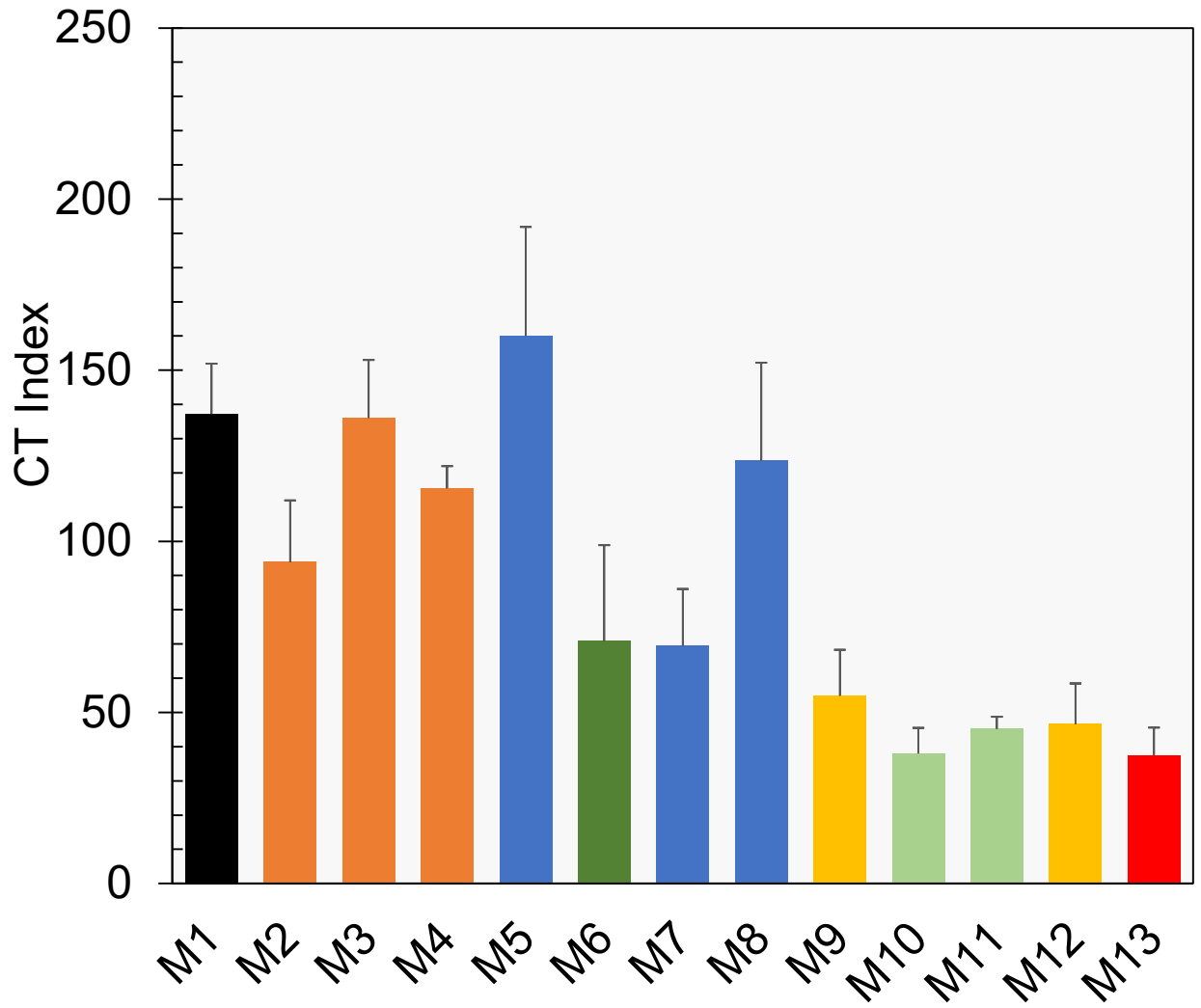


Ductile Mixes



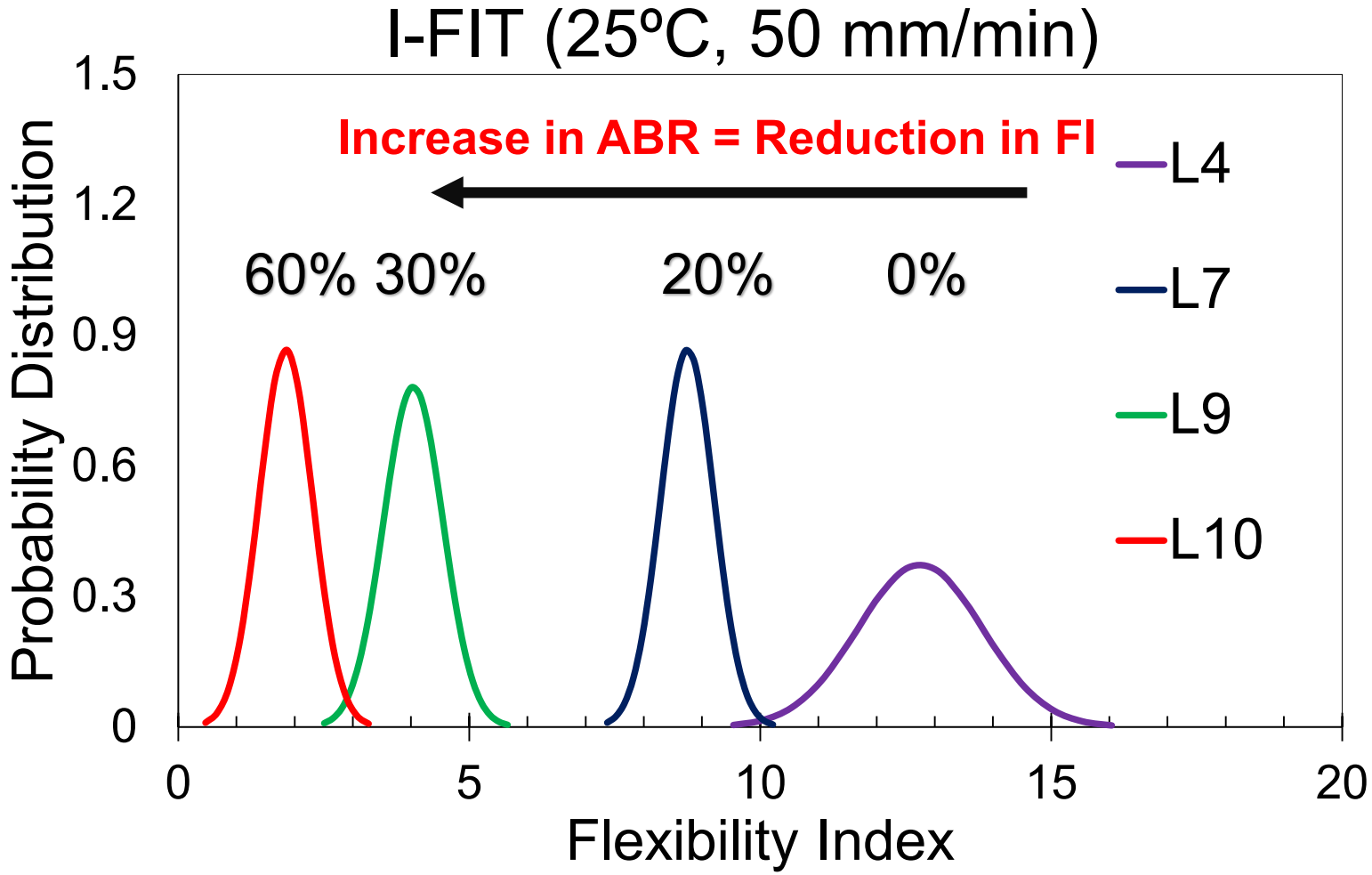
Correlation of FI vs CT Index





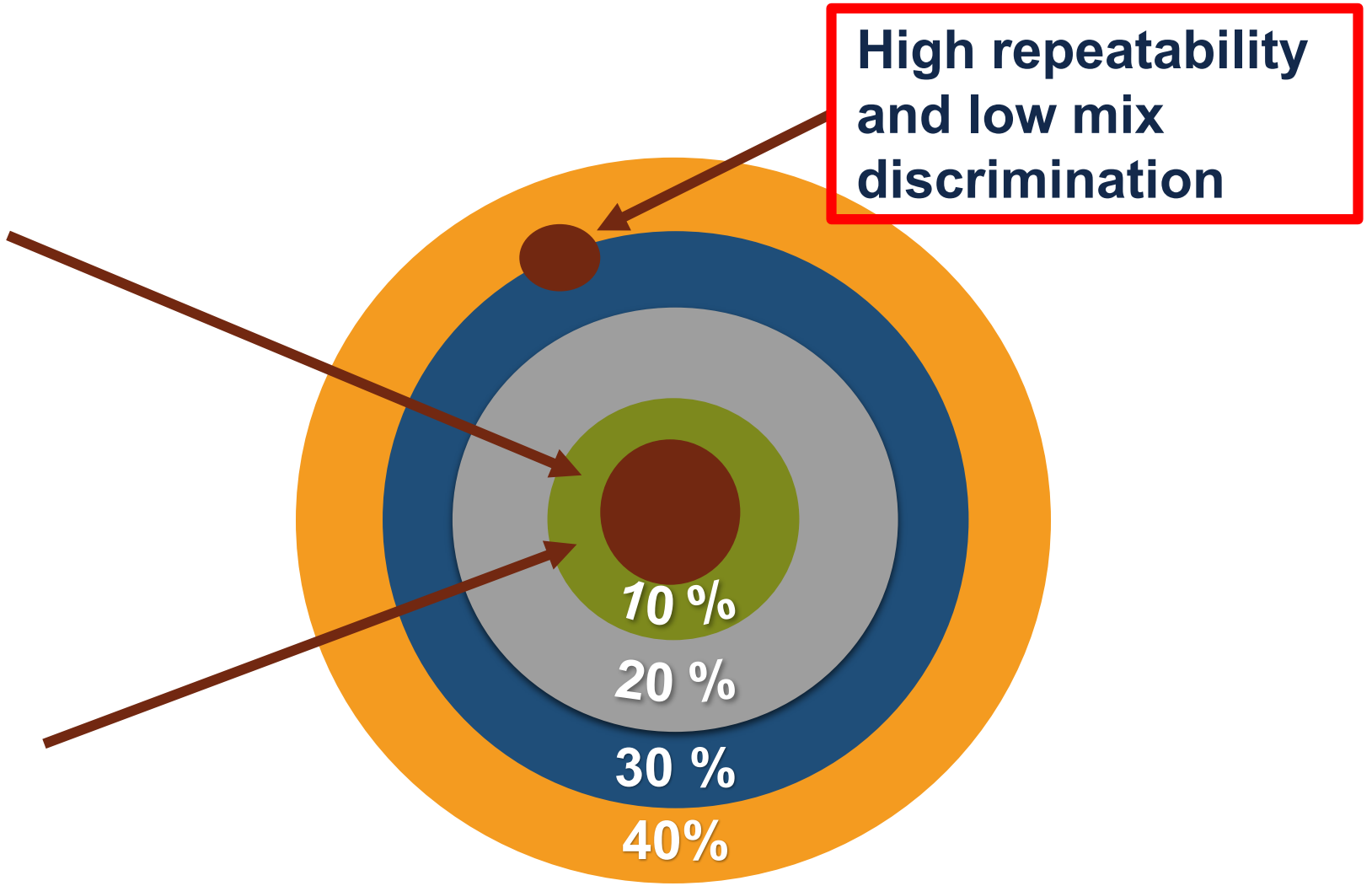
Flexibility Index

Overlaps: < 3%



What Does Work: Fracture Test or Strength Test

- Reduced Repeatability:
  - ~ 20% COV
- High Discrimination:
  - ~3% Overlap



Summary

- **I-FIT is a simple, practical, reliable, and meaningful test**
  - Principles of fracture mechanics are applied and validated
- **It can discriminate between mixes having various cracking susceptibility**
  - Flexibility Index (FI) indicates HMA cracking susceptibility
  - FI correlates with cracking potential (from lab to field)
- **The variability in FI is related to cracking phenomenon, which is highly variable in the field due to the inhomogeneousity of HMA and the crack path**
  - Masking variability may mislead the AC quality control process.

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THANK YOU

Any Questions?

Presenter: Imad L. Al-Qadi
Email: alqadi@illinois.edu

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