Mitigating Top-Down Cracking in Asphalt Pavements

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Outline

- Introduction
- Scope of Study
- Volumetric Properties
- Material Properties
- Energy Ratio
- Summary & Conclusions

Focus on the Energy Ratio Concept, Development & Results

Introduction

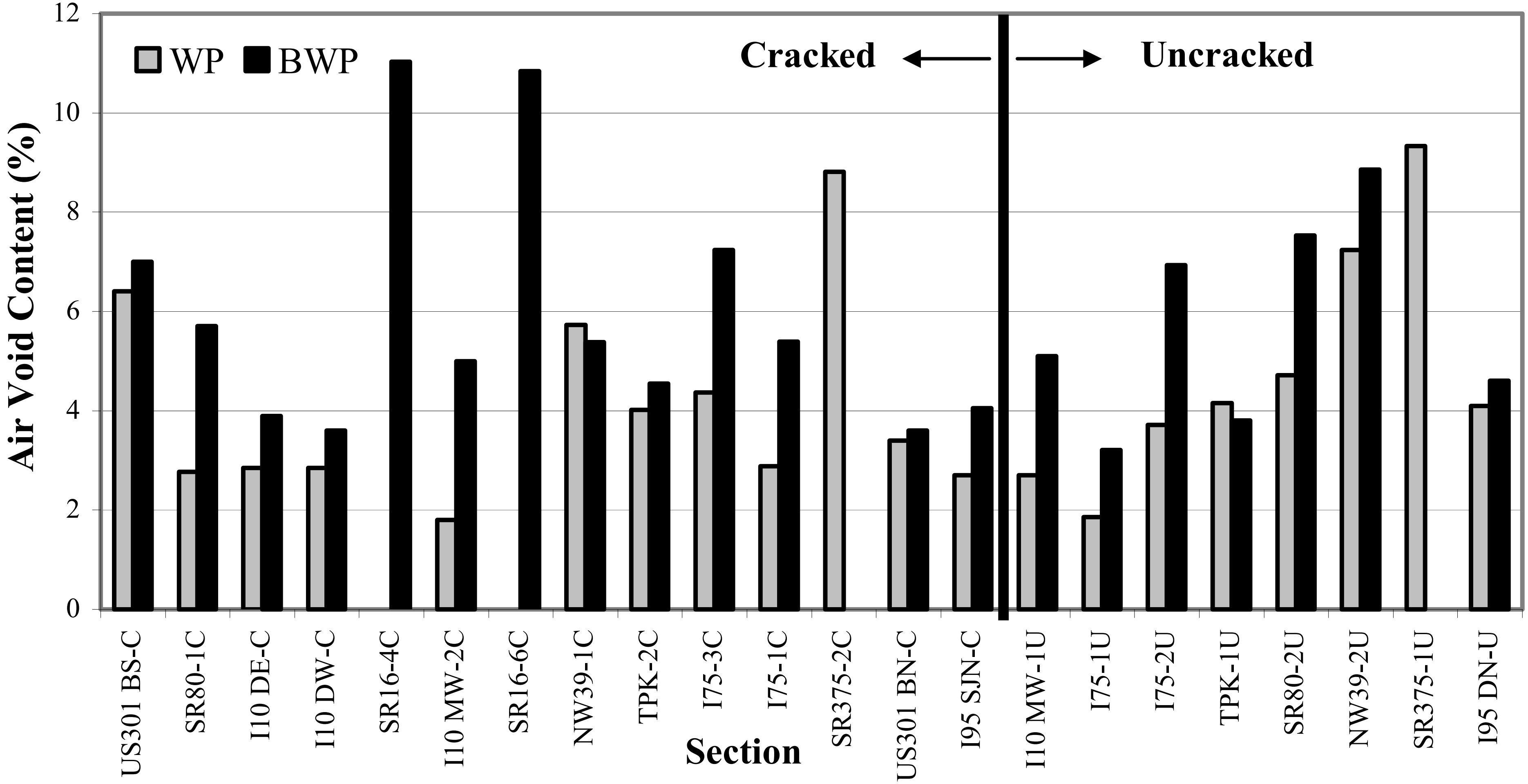
- Top-down cracking is recognized as a major form of distress in HMA.
- 90% of pavements scheduled for rehab:
  - Deficient crack rating
  - Top-down cracking
- FDOT - UF embarked on a multi-year study to identify causes and solutions.

Scope of Study

- 25 field test sections to-date
  - Continuing study w/ 12 additional planned
- Comprehensive evaluation:
  - Volumetric properties
  - Material properties
  - Effect of traffic loads and tires
  - Pavement structure (pavement design)

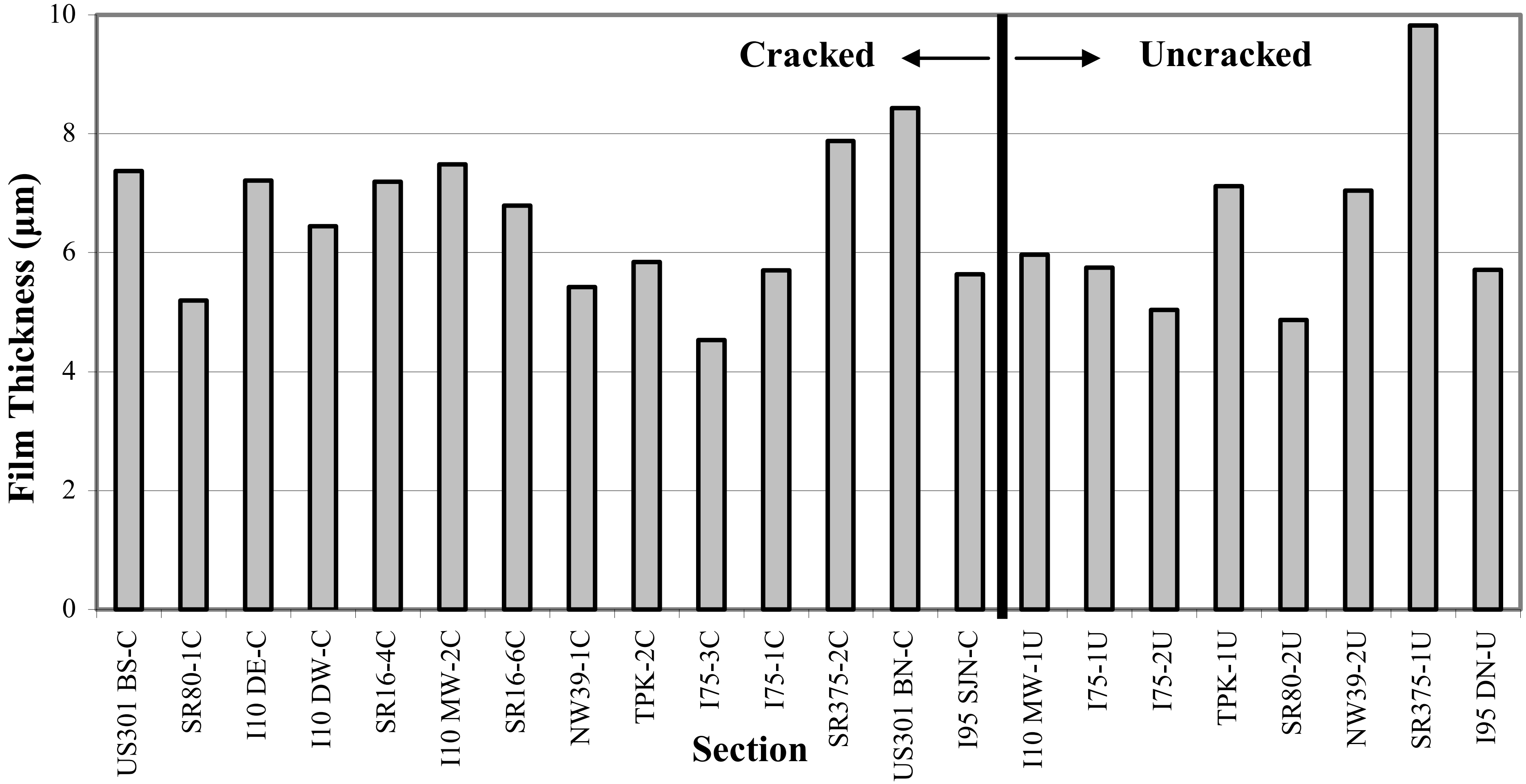
Air Voids

- WP cores showed lower AV% than BWP



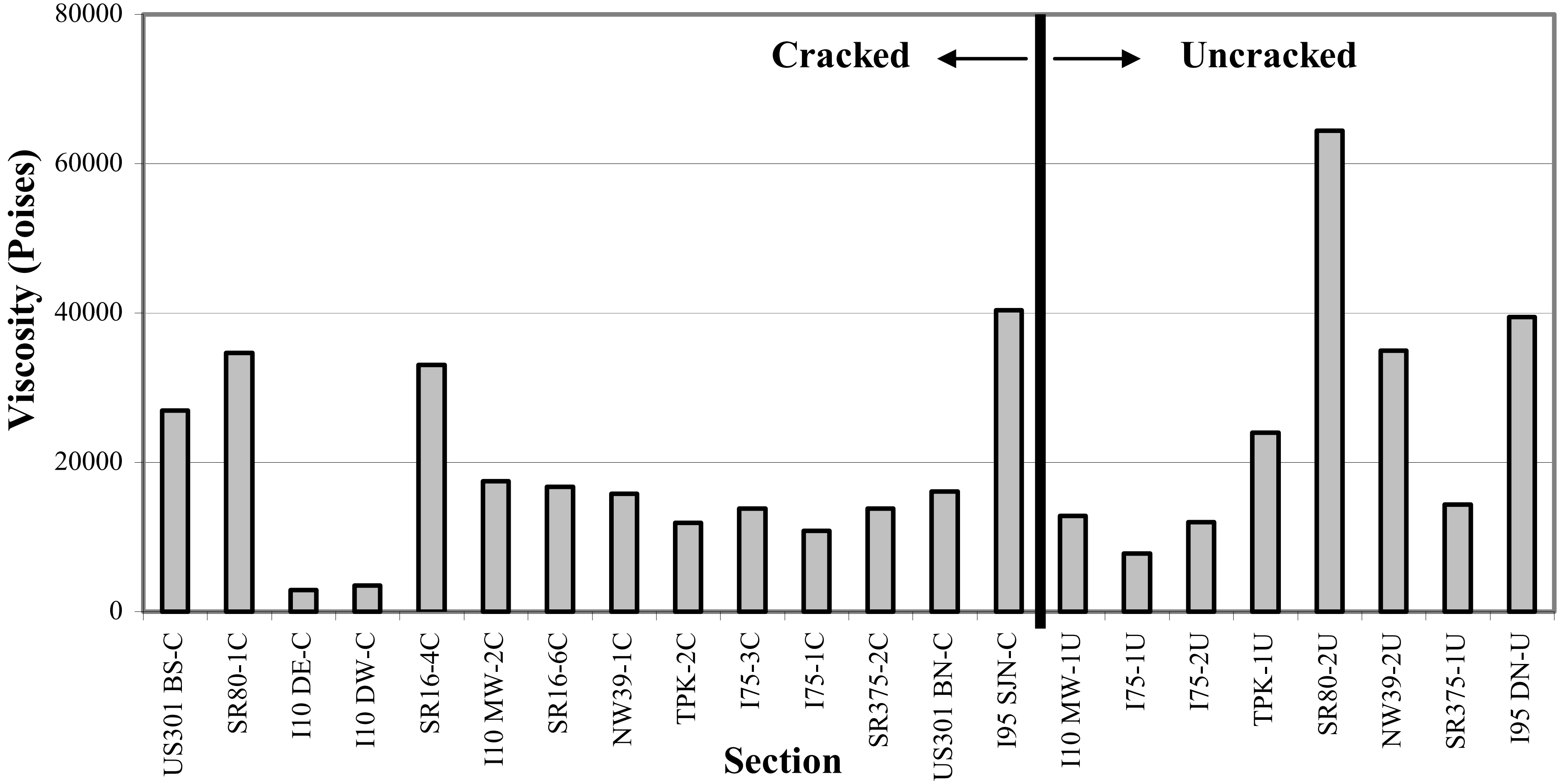
Theoretical Film Thickness

- Proposed minimum 9-10 µm [Kandhal]



Binder Viscosity

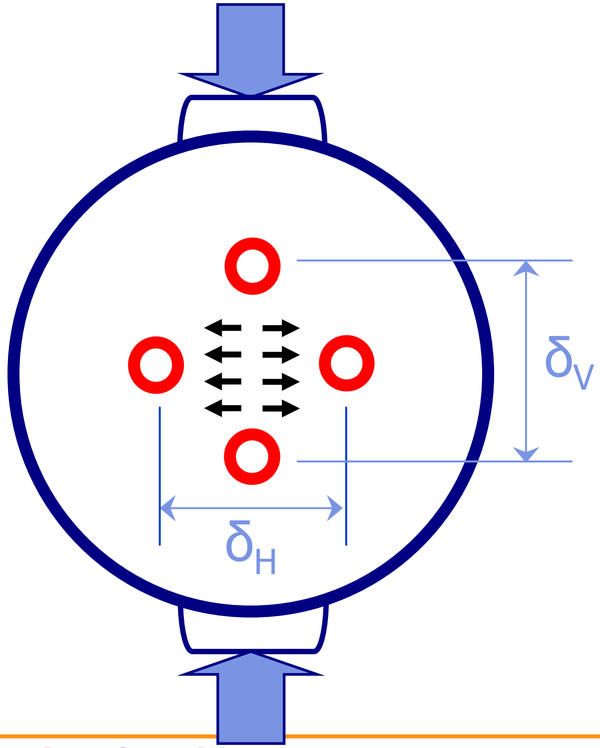
- Age hardening



Mixture Properties

Superpave indirect tensile test:

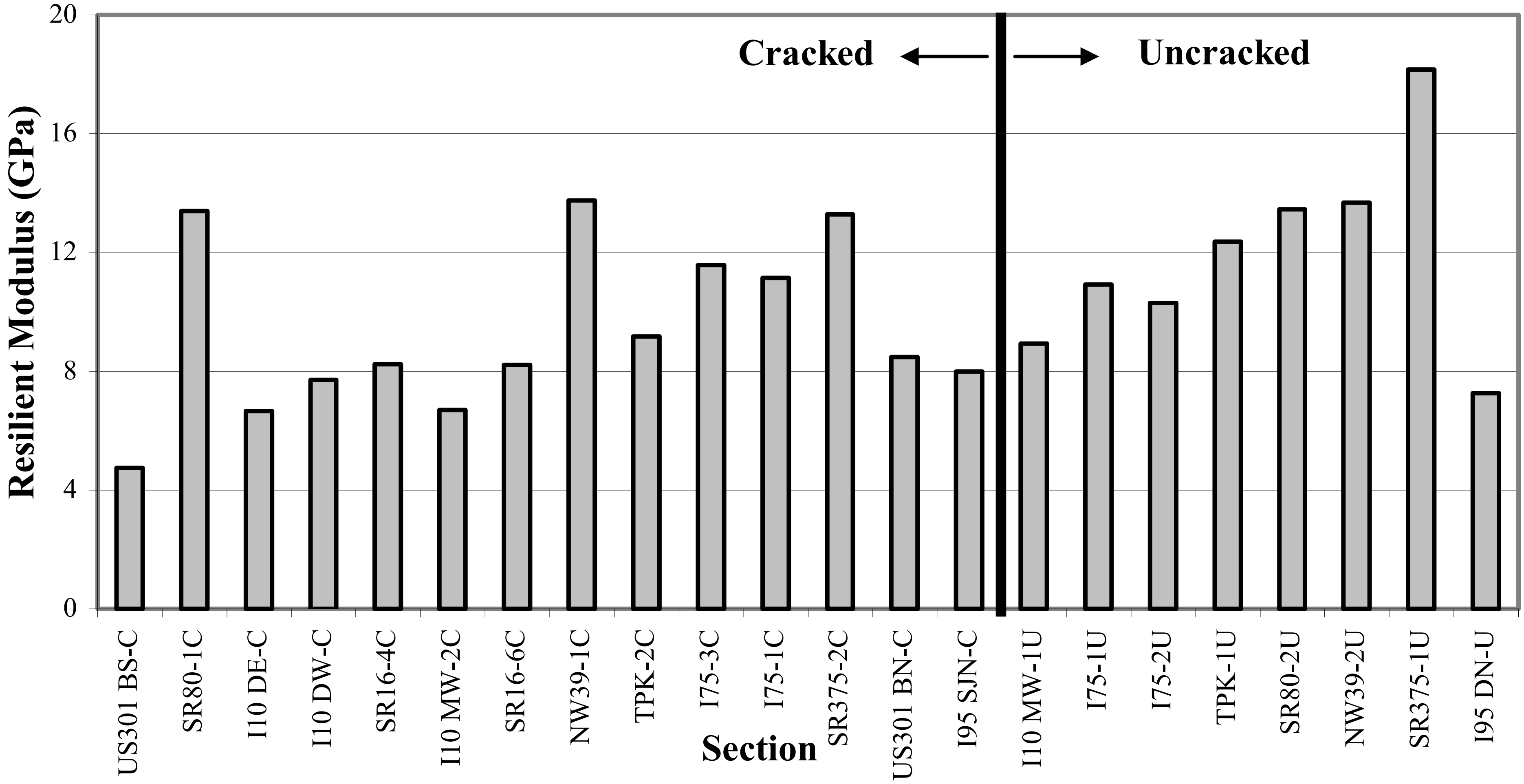
1. Resilient modulus (Cyclic loading)
2. Creep (Constant load with time)
3. Strength (Increase load until fracture)



- Apply vertical load
- Measure vertical & horizontal deformations

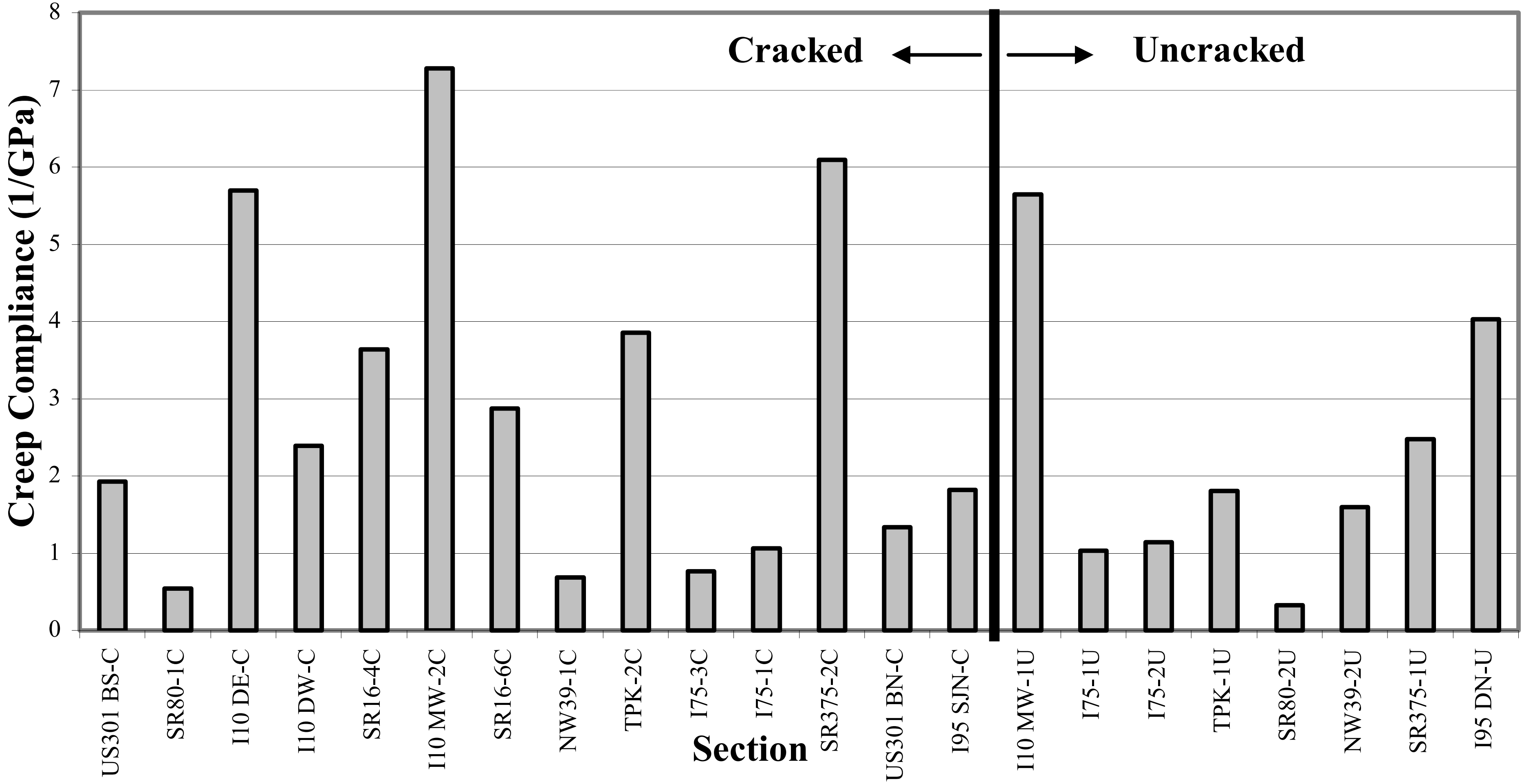
Resilient Modulus

- Measure of elastic stiffness



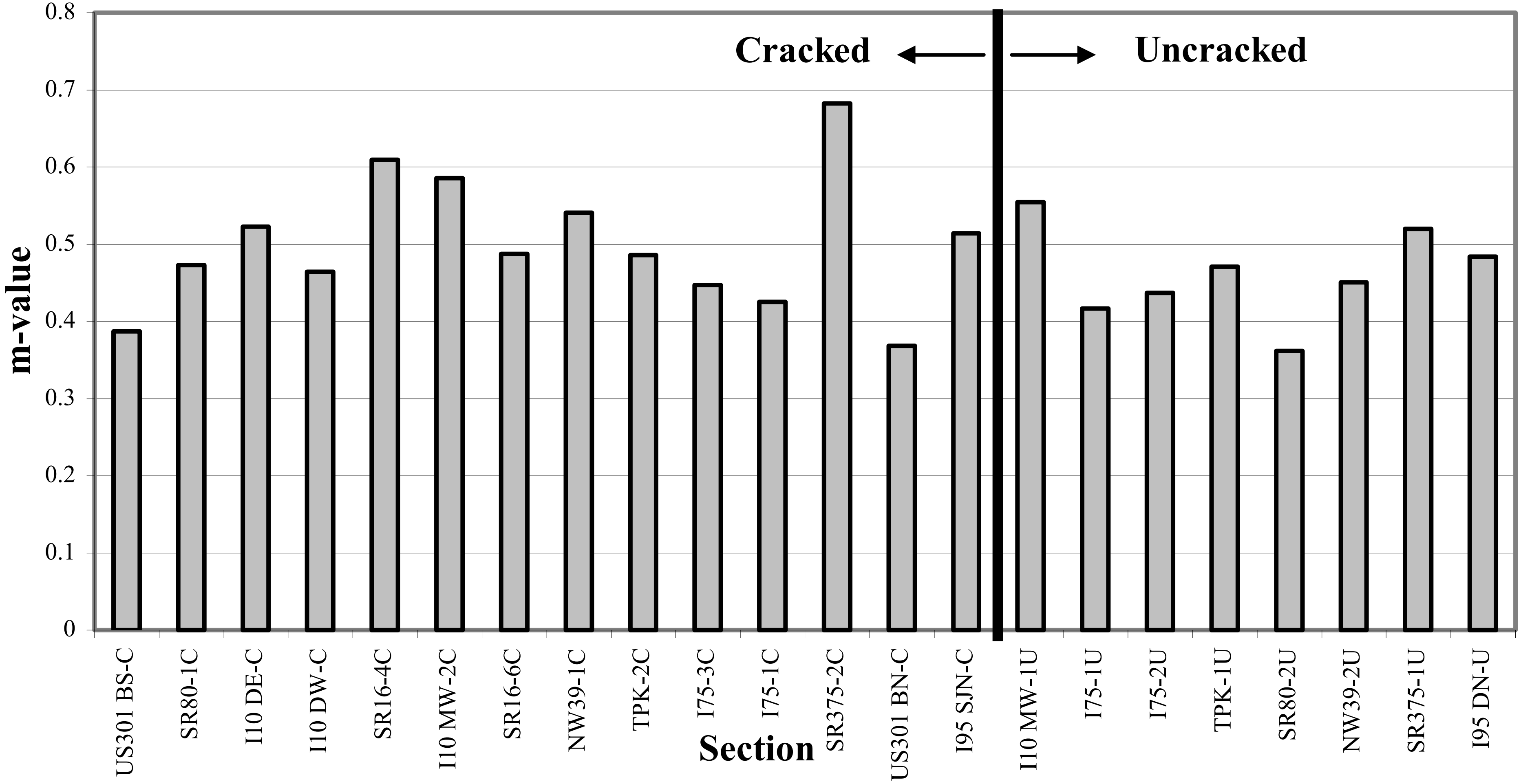
Creep Compliance

- Ability of the mixture to relax stresses



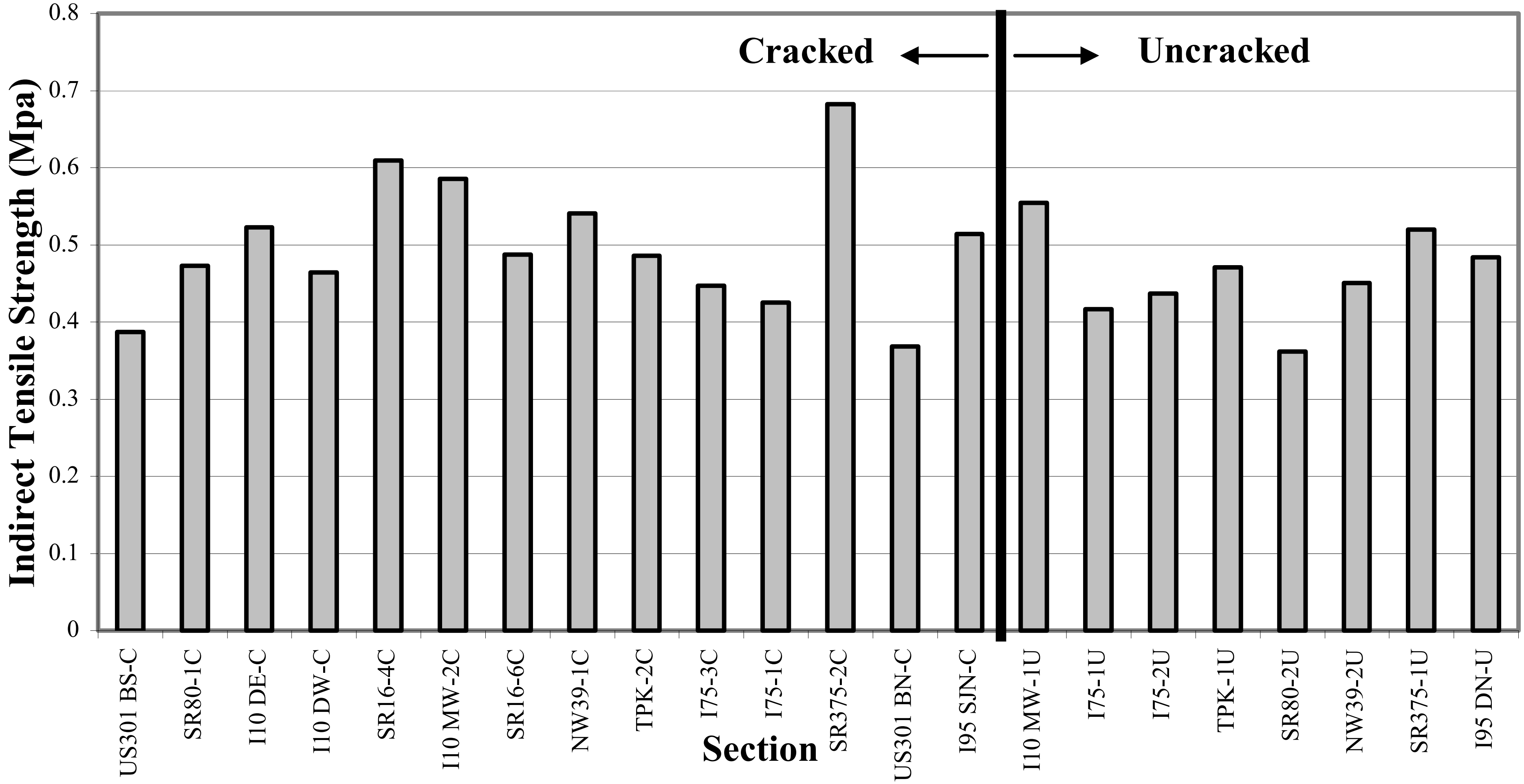
m-Value

- Measurement of creep rate (rate of damage)



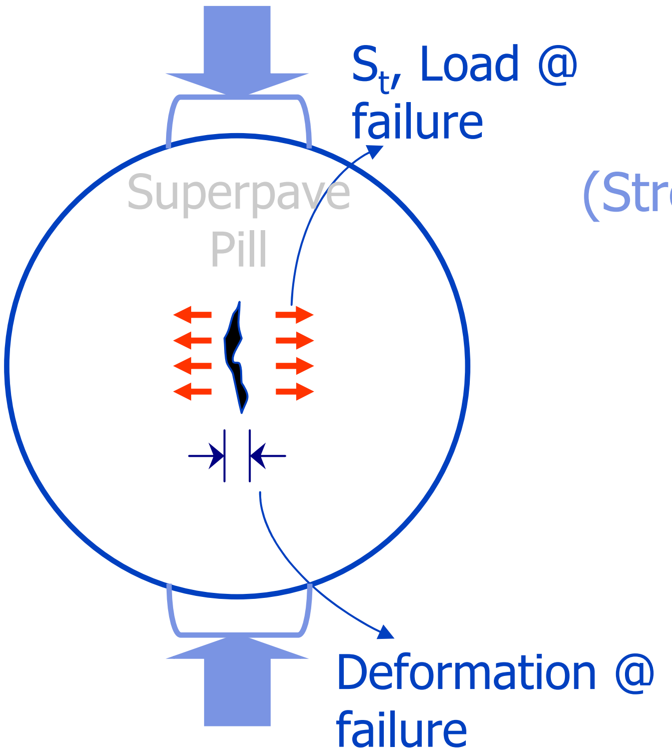
Tensile Strength

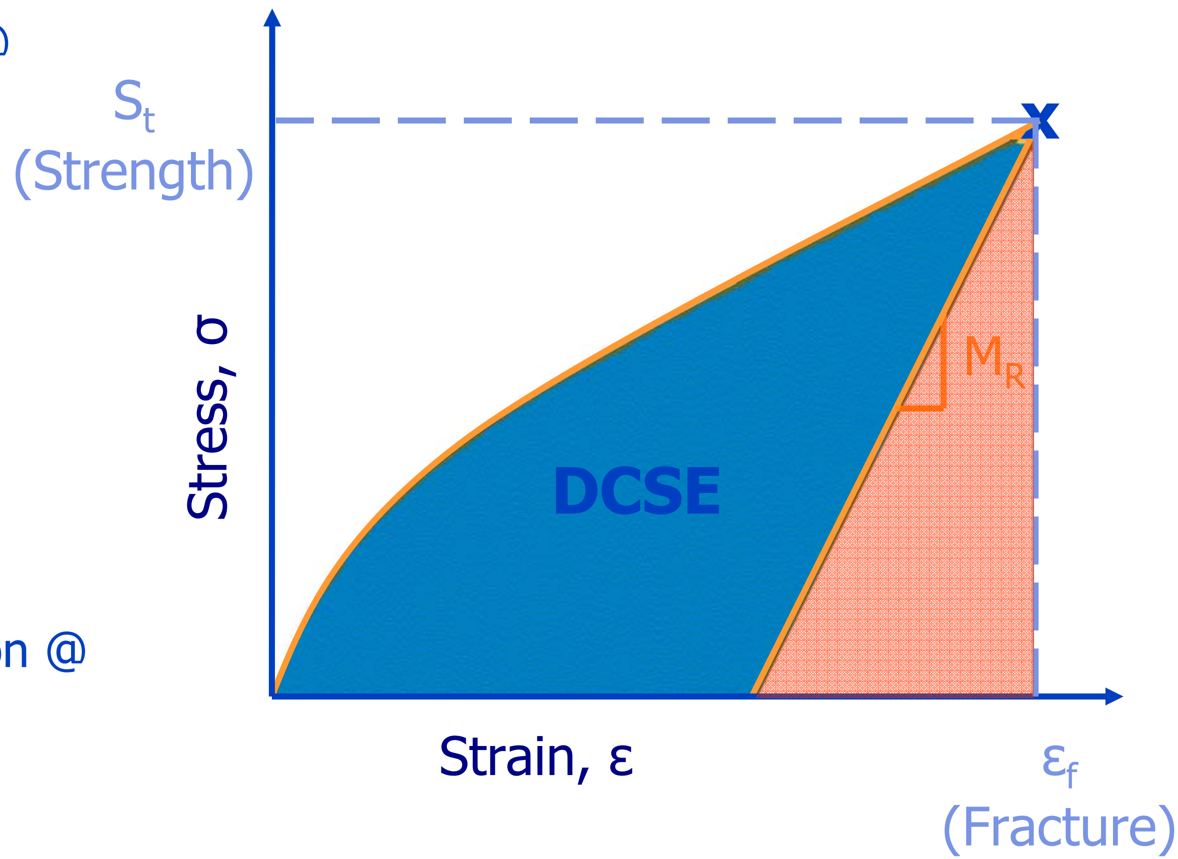
- Maximum tensile stress before failure



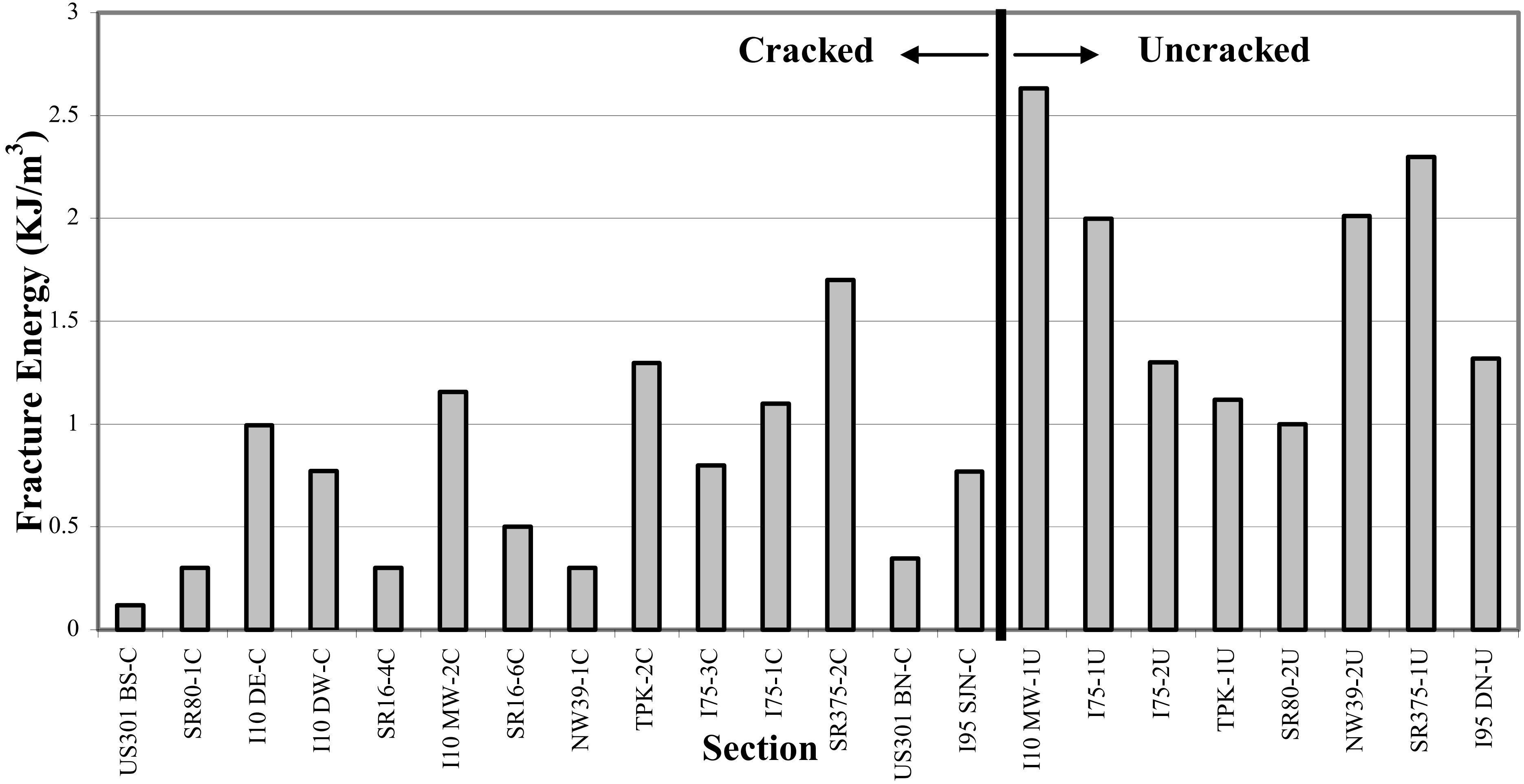
Dissipated Creep Strain Energy

Based on the M_R and Strength tests

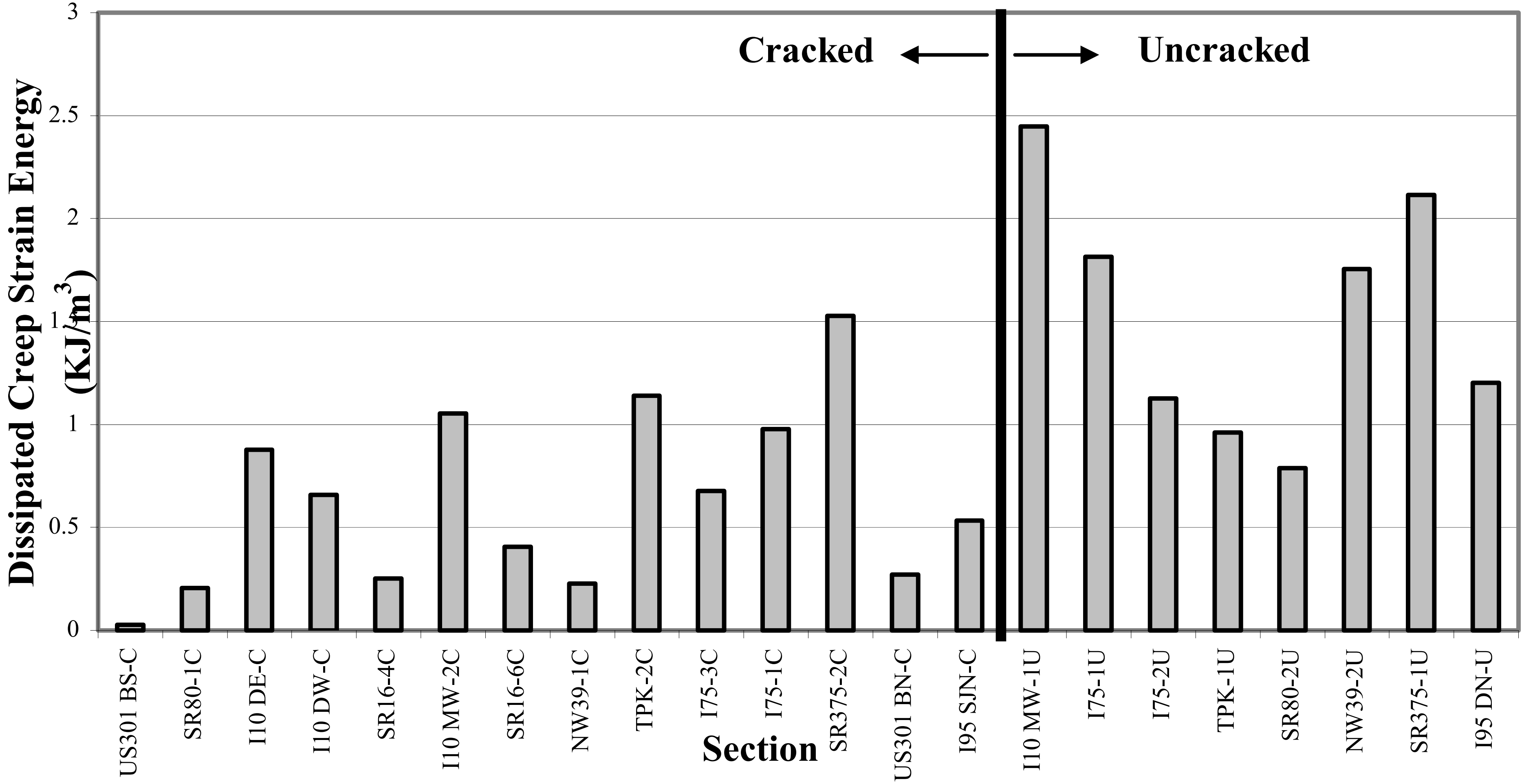




Fracture Energy (FE)



DCSE



Cracked
Uncracked
Dissipated Creep Strain Energy (KJ/m^3)
3
2.5
2
1.5
1
0.5
0
Section
US301 BS-C
SR80-1C
I10 DE-C
I10 DW-C
SR16-4C
I10 MW-2C
SR16-6C
NW39-1C
TPK-2C
I75-3C
I75-1C
SR375-2C
US301 BN-C
I95 SJN-C
I10 MW-1U
I75-1U
I75-2U
TPK-1U
SR80-2U
NW39-2U
SR375-1U
I95 DN-U

What is missing?

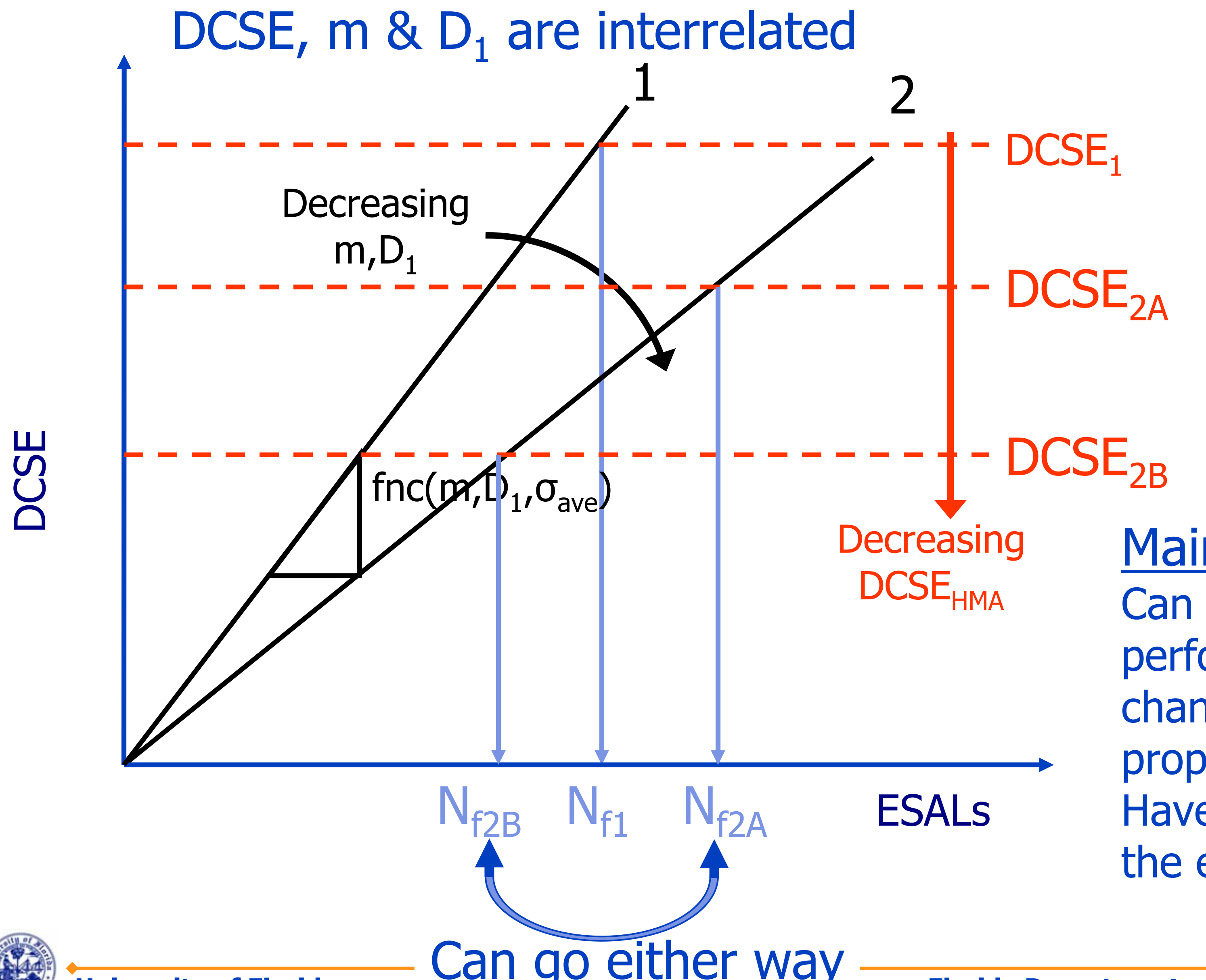
- Energy by itself did not accurately predict the performance of all sections
- Need to introduce a model that predicts cracking performance based on material properties (from IDT creep test) and pavement structure characteristics (predicted tensile stress)

HMA Fracture Model

- Calculates the crack growth for a given level of applied stress

- Using:
  - Material properties – m, D_1 & $DCSE_f$
  - Structural properties – σ_{AVE}

HMA Fracture Model

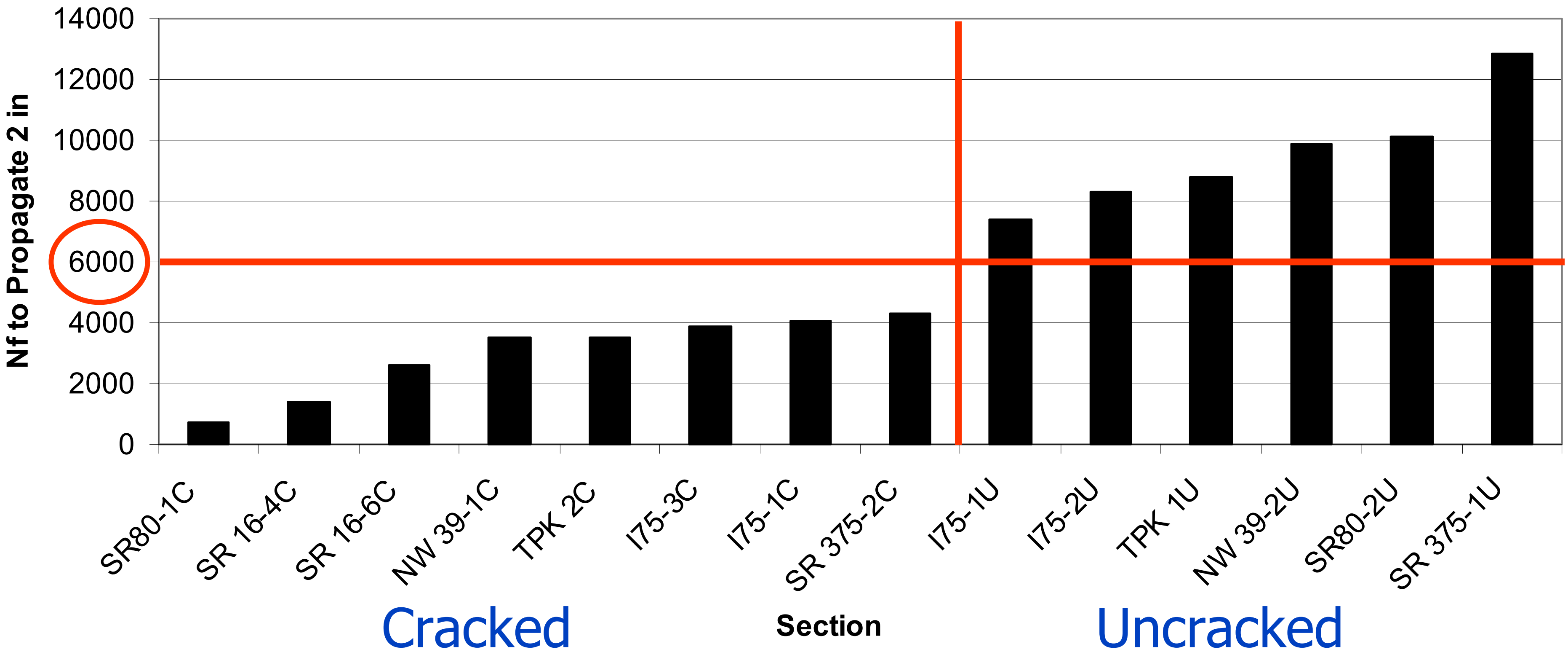


Main Idea:

Can not improve performance by changing a single property.
Have to consider the entire system.

Cycles to Failure

- Used the HMA Fracture Model to calculate N_f for crack to propagate 2 in



- Mixtures with N_f<6000 performed poorly

Minimum Energy

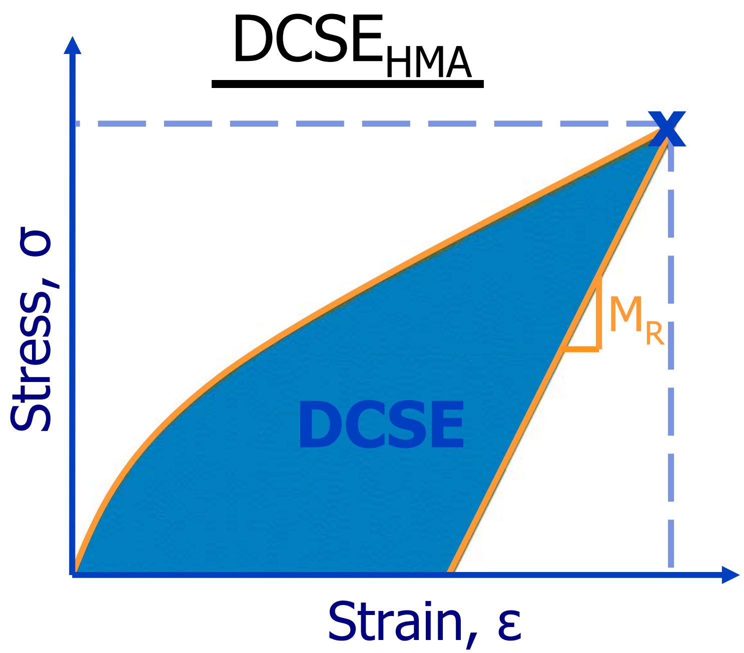
- $DCSE_{min}$ is the minimum energy required to produce N_f=6000
- Express the $DCSE_{min}$, D_1 & m-value relation in a single function:

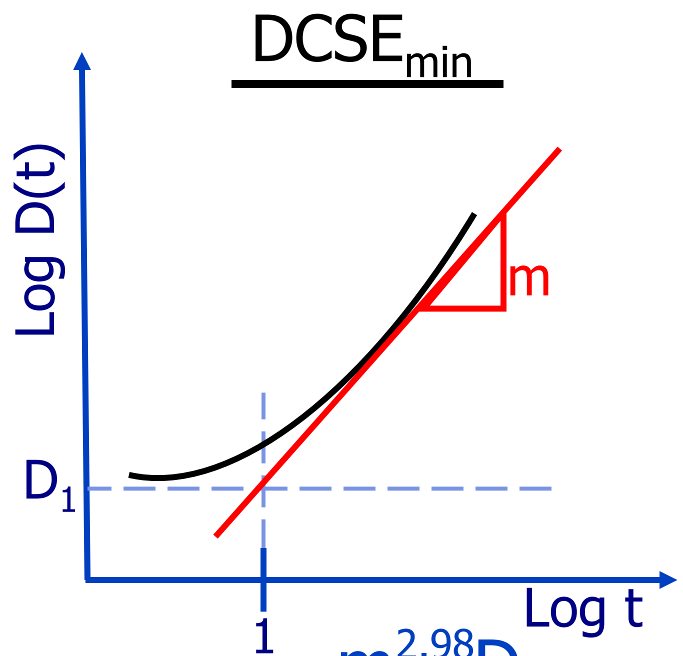
  - $$DCSE_{min} = \frac{m^{2.98} D_1}{A}$$
  - $$A = \frac{(6.36 - S_t)}{33.44 \times \sigma_t^{3.1}} + 2.46 \times 10^{-8}$$

S_t = Tensile Strength
σ_t = Tensile Stress

Energy Ratio Concept

- The $DCSE_{HMA}$ has to be greater than the $DCSE_{min}$ for good cracking performance:





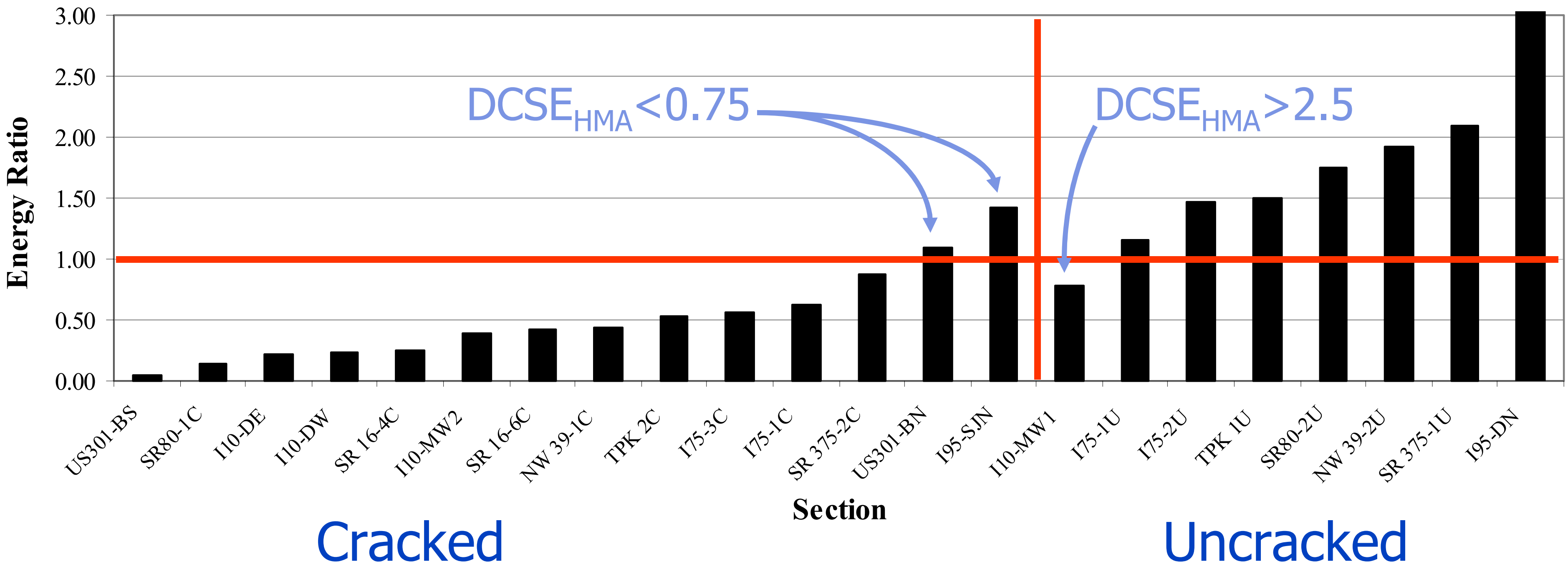
– $DCSE_{HMA} = AREA$

– $DCSE_{min} = \dfrac{m^{2.98} D_1}{A}$

$$\text{ENERGY RATIO} = \frac{DCSE_{HMA}}{DCSE_{min}} > 1$$

Energy Ratio Results

- Examined all sections
- Performance criteria: ER>1 ; $DCSE_{HMA}$>0.75



Summary & Conclusions

- Volumetric properties are not a good predictor for cracking performance
- Verified the importance of mixture properties and pavement structure in predicting cracking performance
- HMA fracture mechanics properly accounts for effects of mixture properties. The relative cracking performance predicted agrees with field observations

Summary & Conclusions

- Identified and defined a set of criteria that can predict mixture cracking performance:
  - $ER>1$
  - $DCSE_{HMA}>0.75$
- Verified the requirements with previous test sections
- No single property can be an accurate performance predictor; properties are interrelated and we need to consider them as a system