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OPTIMIZING COLD IN PLACE RECYCLING (CIR)APPLICATIONS THROUGH FRACTURE ENERGY PERFORMANCE

National Road Research Alliance 2016

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Acknowledgments

- Minnesota Local Road Research Board
- Carver County
- American Engineering Testing
- Minnesota Department of Transportation

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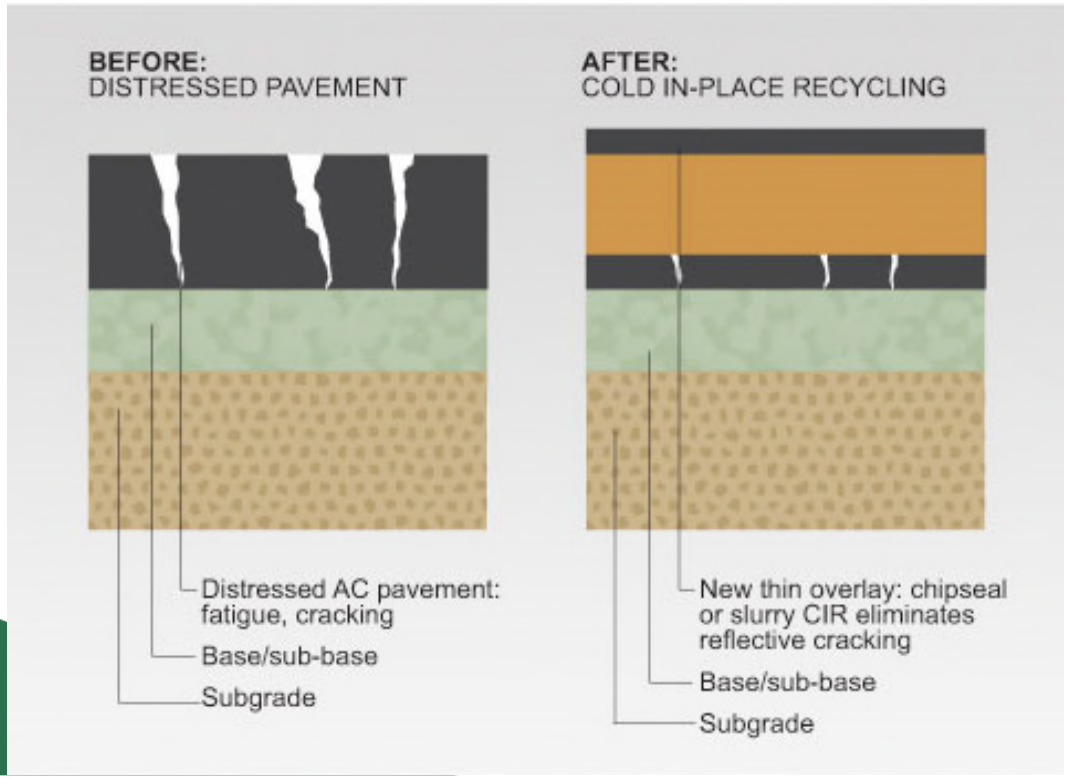
Cold In-Place Recycling (CIR)

- An eco-friendly in-place pavement rehabilitation process performed without the use of heat
- CIR retards or eliminates the occurrence of reflective cracking



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CIR Mix Design

- Medium and coarse gradations / 3 point design

Lab Testing	Requirements
Bulk Specific Gravity (G_{mb})	
Density	
Maximum Specific Gravity (G_{mm})	
Dry Stability (@40°C)	1250 lbs, MIN
Vacuum Saturation Level (%)	55-75
Retained Stability (soaked @40°C)	
Retained Stability (%)	70% MIN
Voids (%)	
Moisture Absorption (%)	
Raveling Test, %	2%, MAX
Indirect Tensile (IDT)	

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CIR Mix Designs

Stabilization Material	Lab	Three point design			Optimum Binder Content
Engineering Emulsion (EE)	BRAUN	2.5	2.8	3.0	2.8%
High Float Emulsion (HFMS-2s)	BRAUN	1	2	3	2.0%
Foamed Asphalt (PG XX-34)	AET	1.8	2.2	2.6	2.2%
Cement with Commodity Emulsion (CSS-1)	AET	2.3	2.7	3.0	2.3% Emulsion 1.5% Cement

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Fracture Mechanics Testing (Contd.)

- Has been successfully used to study crack initiation and propagation in all types of materials
- Fracture properties of asphalt pavement dictate its ability to resist cracking
- This type of analysis requires testing notched specimens

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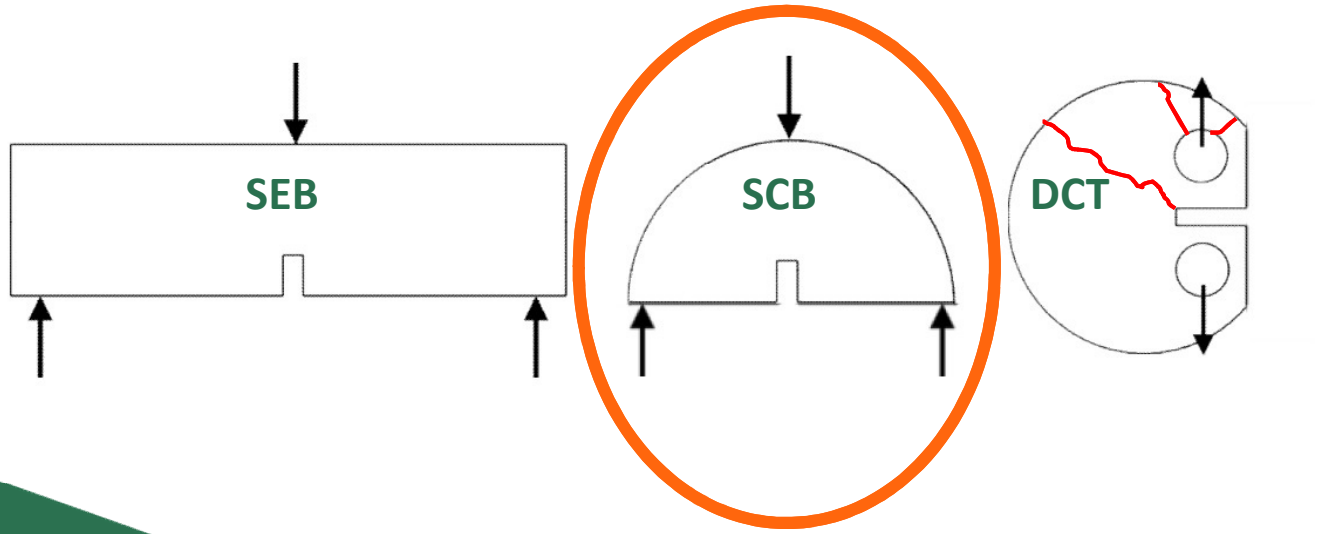
Fracture Mechanics Testing

- Methods:
  - Single-Edge Notched Beam (SEB)
  - Disc-Shaped Compact Tension Test (DCT)
  - Semi-Circular Bend (SCB)



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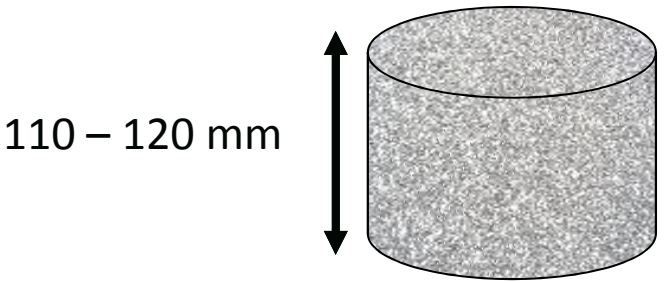
Sample Preparation

- Height of 115±5 mm
- At optimum content
- Compacted at room temperature for 30 gyrations in 150 mm diameter mold, at 600 kPa pressure and 1.16 degree internal angel
- Emulsion samples were cured at **60℃ for 48 ± 1 hr**.
- Foamed asphalt samples were cured at **40℃ for 72 ± 1 hr**.



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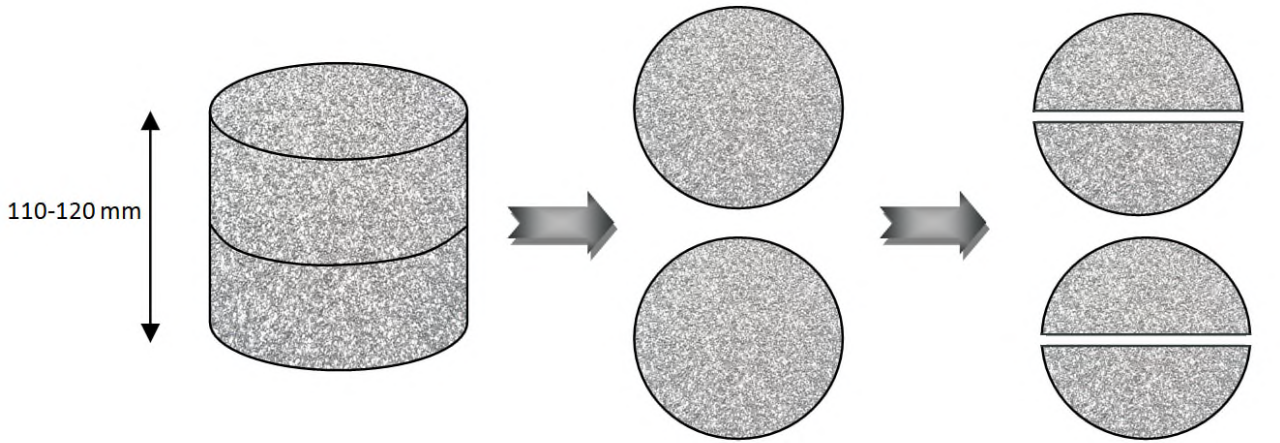
Sample Preparation (Contd.)



2 DCT's **4 SCB's**

- Same amount of material would result in twice as many SCB's as DCT's

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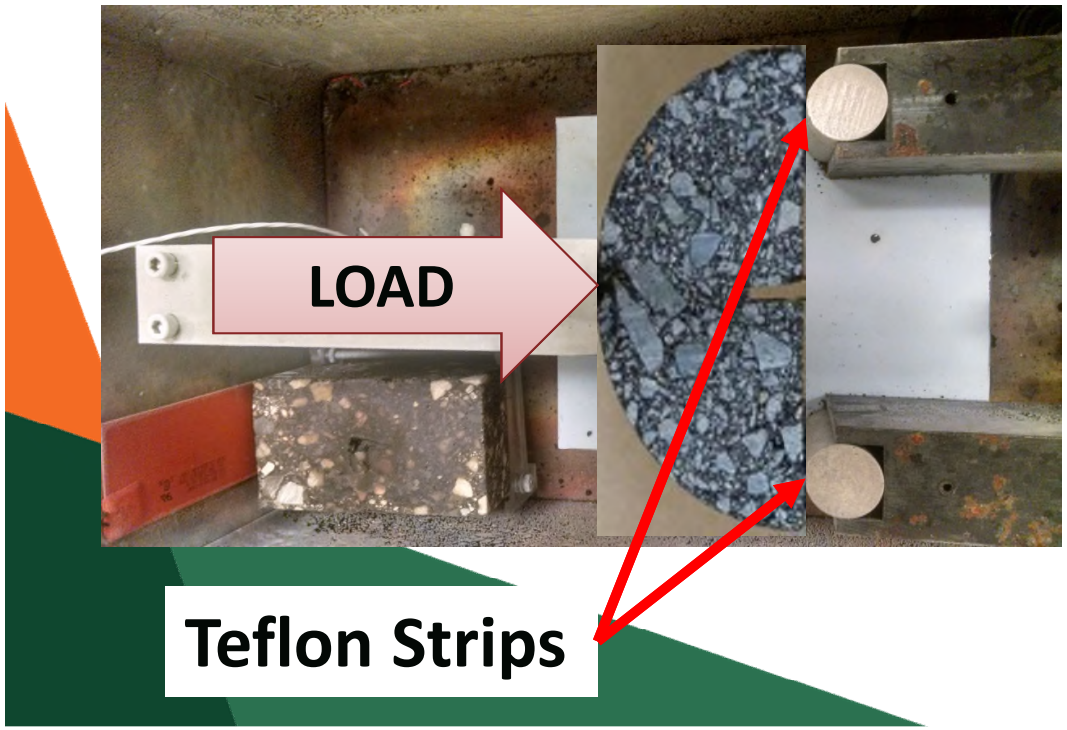
SCB Testing

- Modifications to the testing machine:
  - Aluminum Plate
  - Teflon strip (1/16 inch thickness/adhered with two part epoxy)



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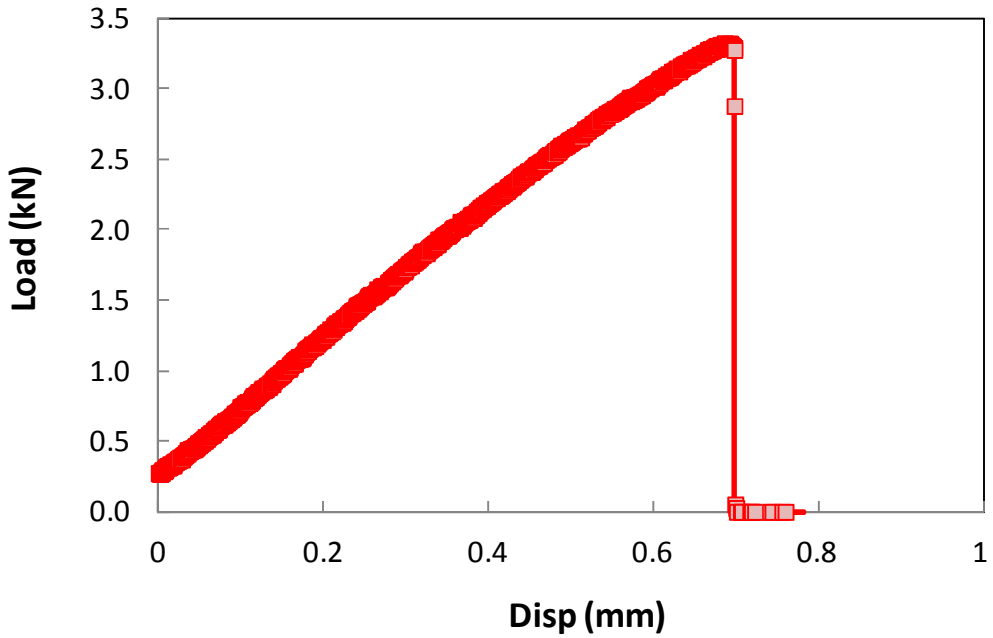
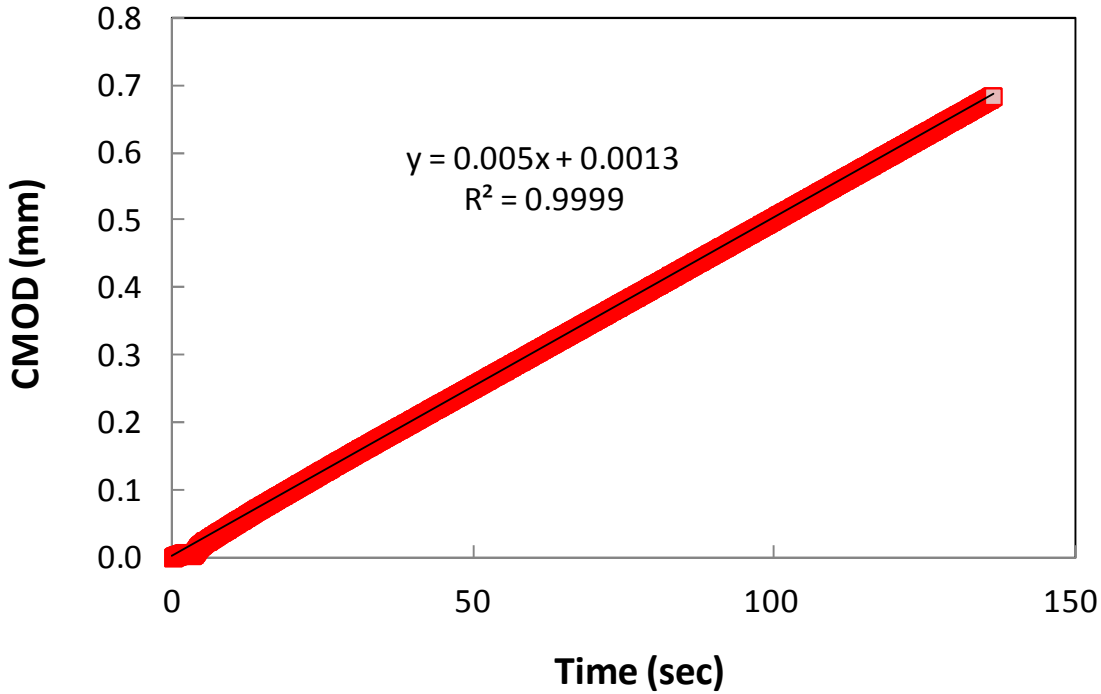
SCB Testing (Contd.)

- Actuator Displacement Control
  - Rates of 1, 0.5, and 0.1 mm/min
  - No post-peak behavior!



SCB Testing (Contd.)

- CMOD Control



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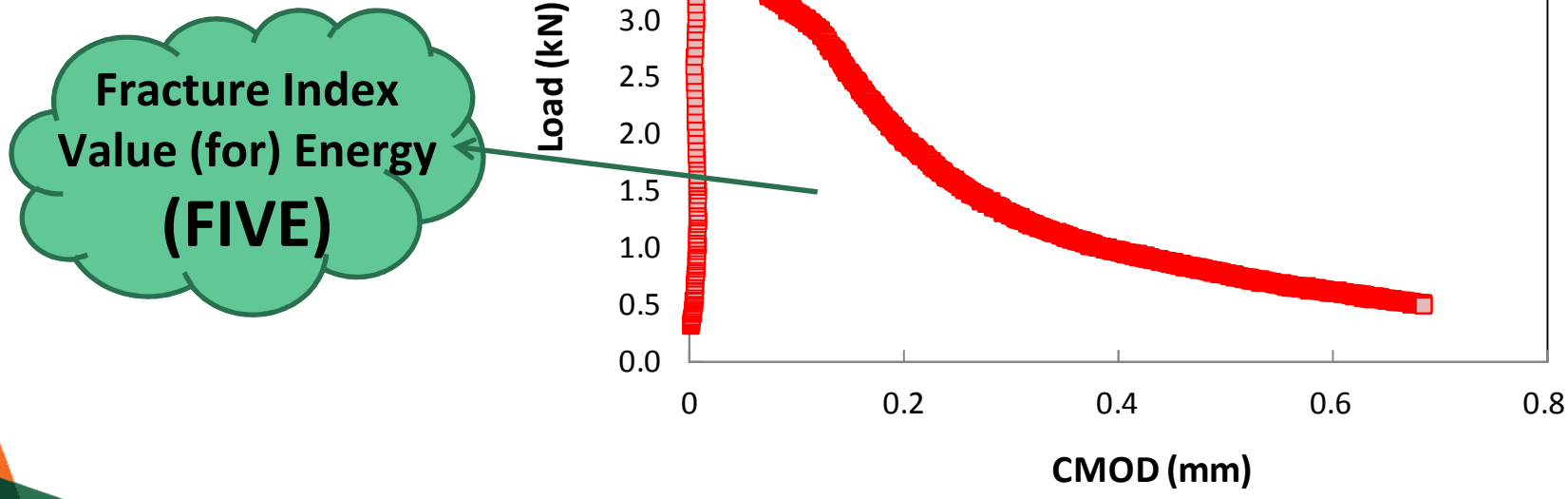
SCB Testing (Contd.)

- CMOD Control



$$FIVE = \frac{\text{Area under load vs. CMOD curve (J)}}{\text{ligament area } (\text{m}^2)} \left(J/m^2 \right)$$

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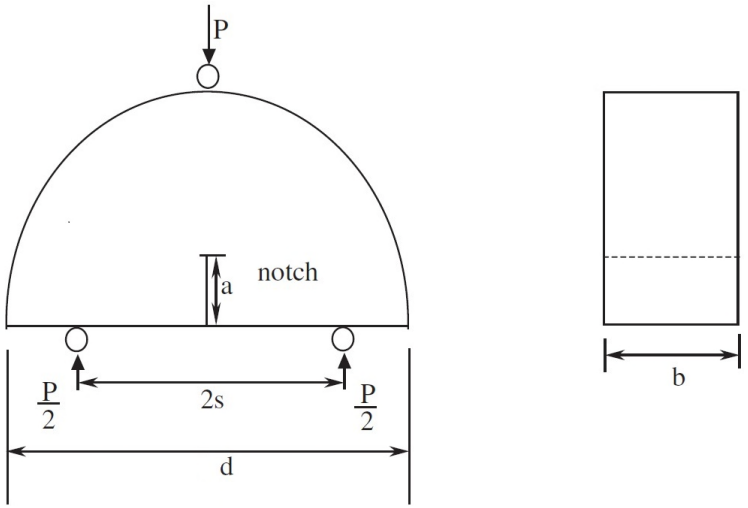
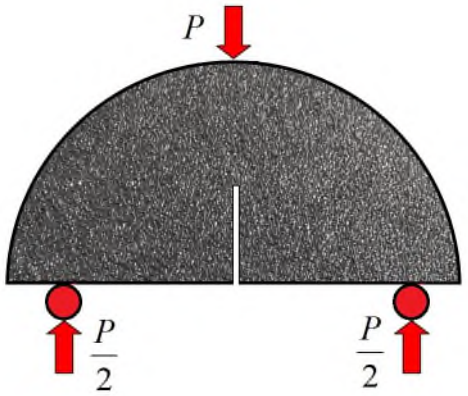
SCB Parameters

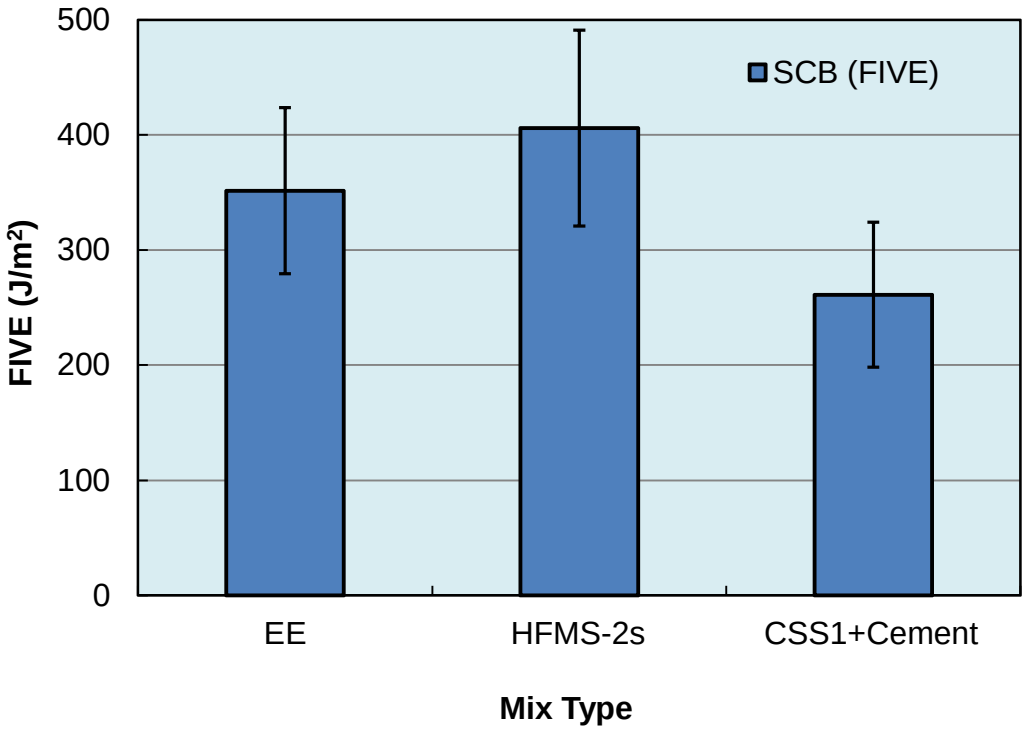
Parameters		Target
Sample Geometry	d, mm	150
	b, mm	50 to 60
	r, mm	75
	a, mm	15
	2s, mm	127
	Notch width, mm	< 1.5
Testing Condition	CMOD rate, mm/sec	0.005
	Temperature, °C	-18°C
	Sitting Load	0.3 kN
	Post-Peak Load	0.5 kN



FIVE Test Verification

- 6 EE, 7 HFMS-2s, and 8 CSS-1 samples were tested at Braun
- HFMS-2s and EE are statistically the same (t-test)





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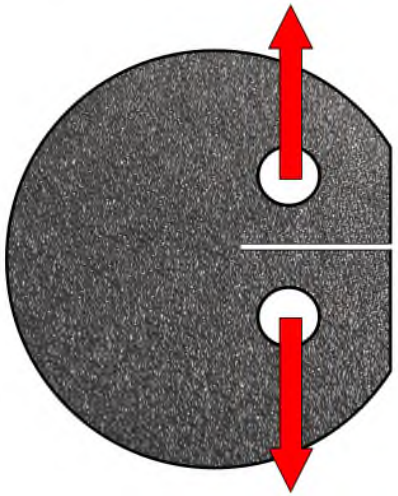
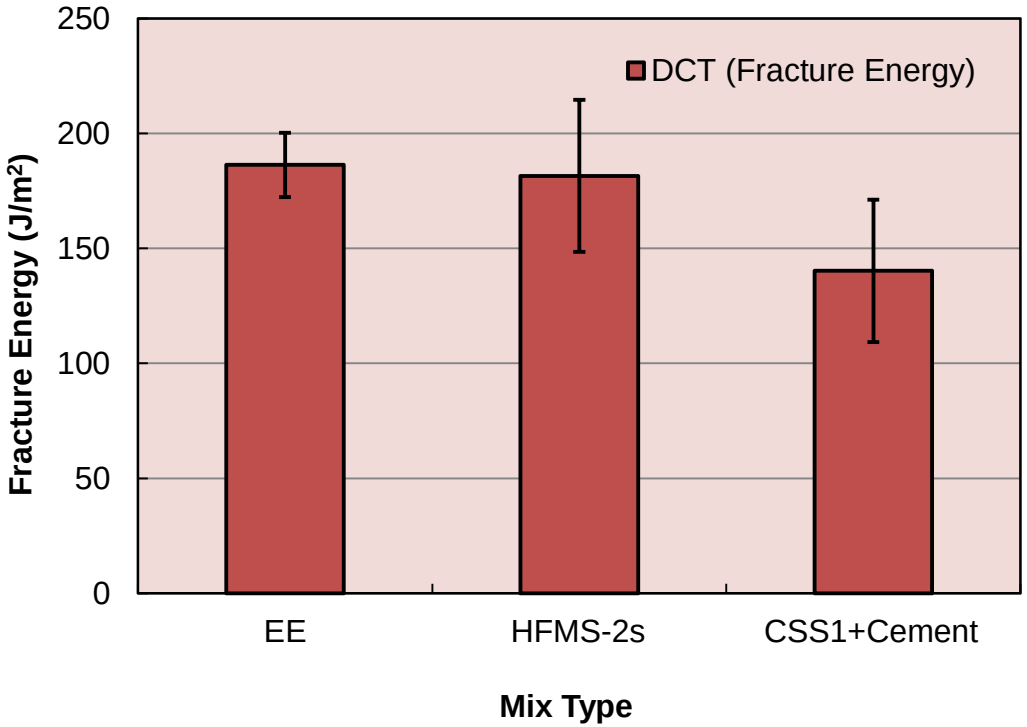
DCT Testing Results

- 6 EE, 6 CSS-1 , and 4 HFMS-2s samples were tested at MnDOT
- Two HFMS-2s samples got broken during the test





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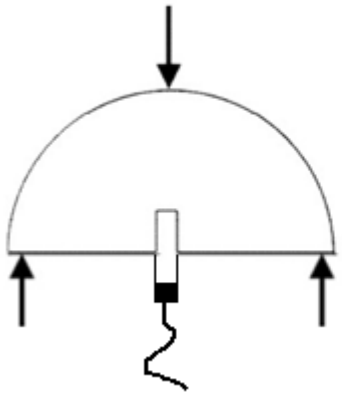
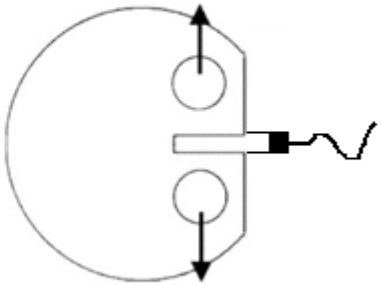
SCB vs. DCT

- Different modes of loading:
  - Tension
  - Compression (Indirect Tension)

- Fracture Energy (DCT) and FIVE (SCB) values are NOT comparable





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Round Robin Test

Mixture	BRAUN	AET	MnDOT	Total
Design EE	12	12	12	36
Design HF	12	12	12	36
Design FOAM	12	12	12	36
Design CSS	12	12	12	36
Total	48	48	48	144

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RESULTS

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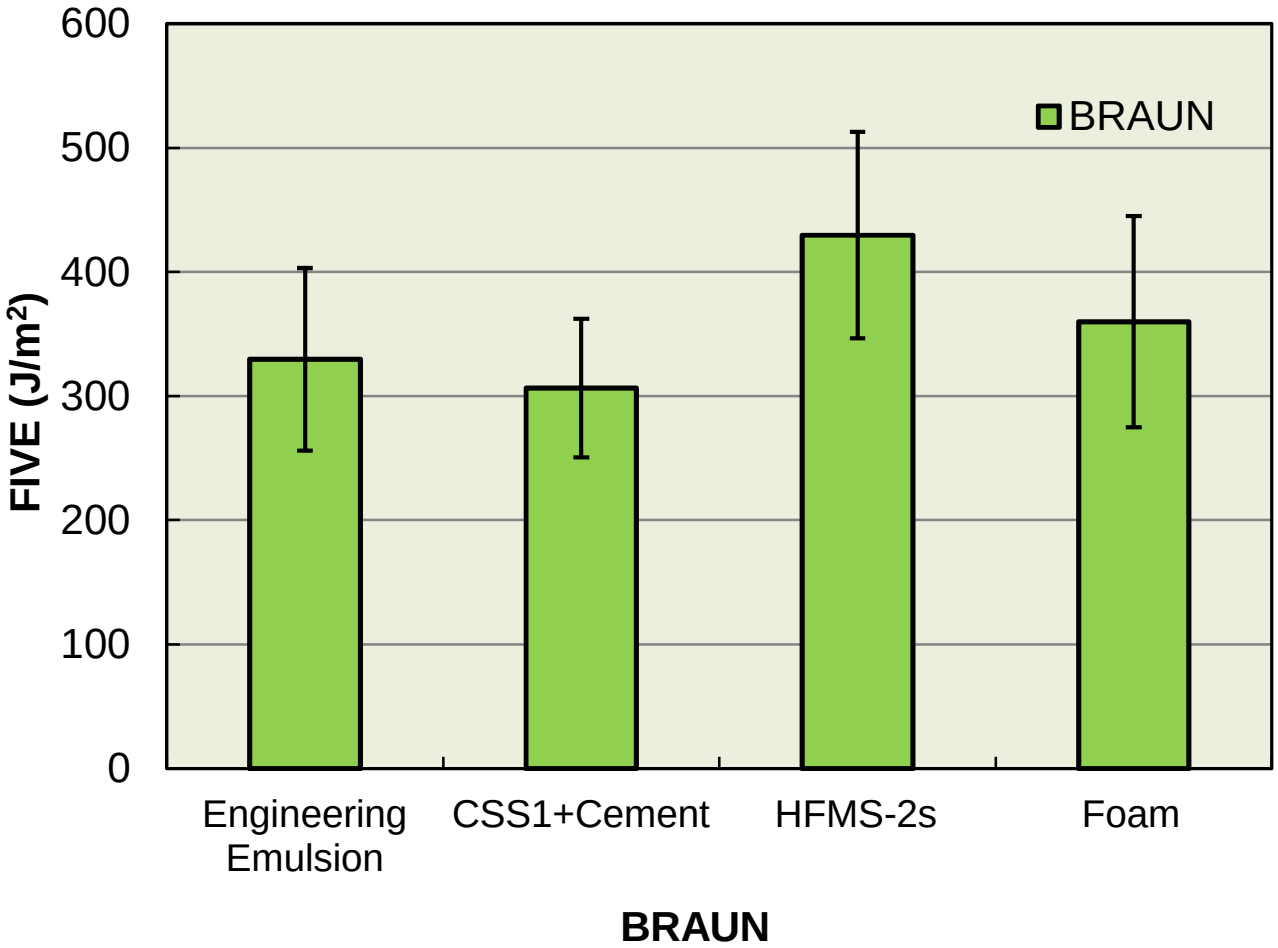

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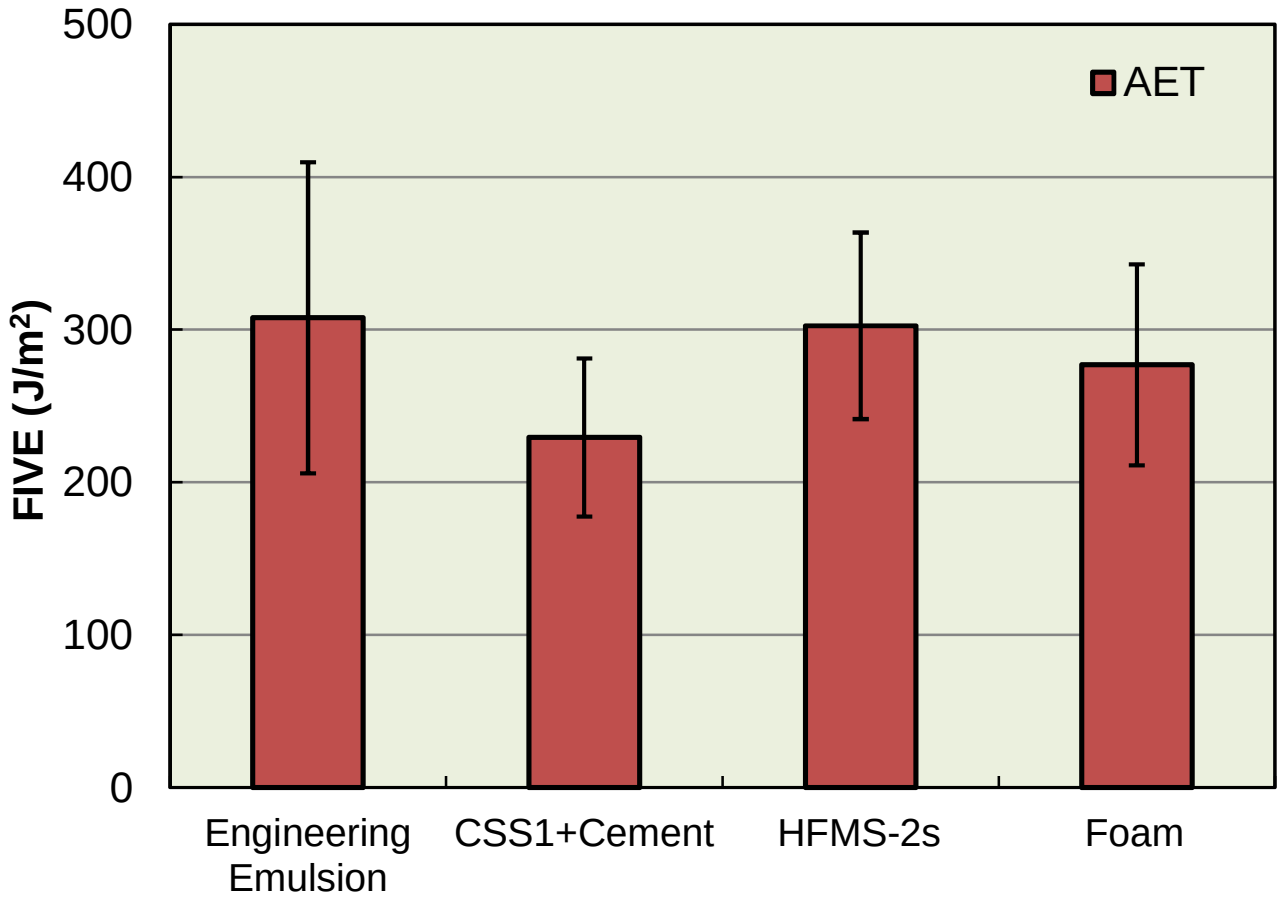
AET



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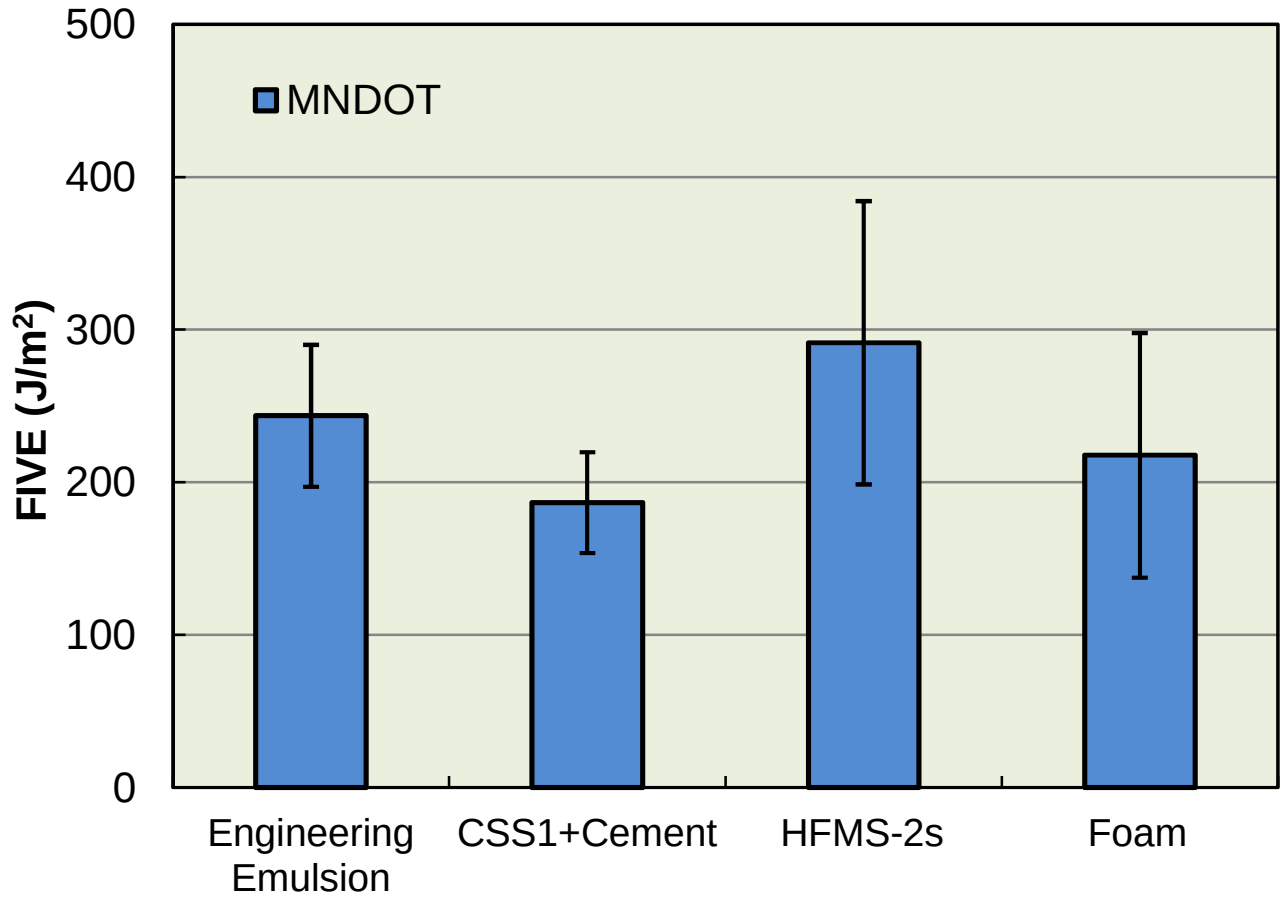
MnDOT



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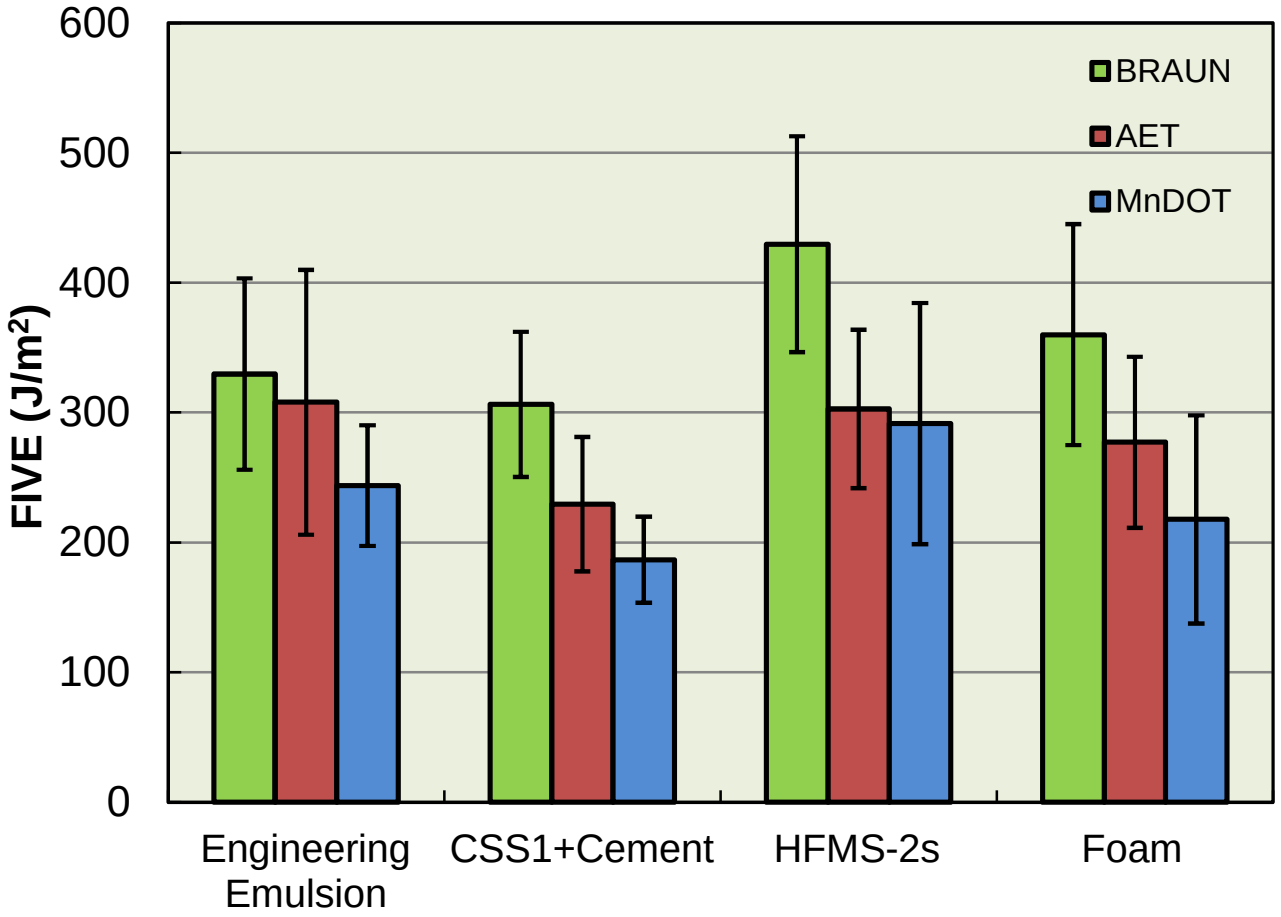
FIVE



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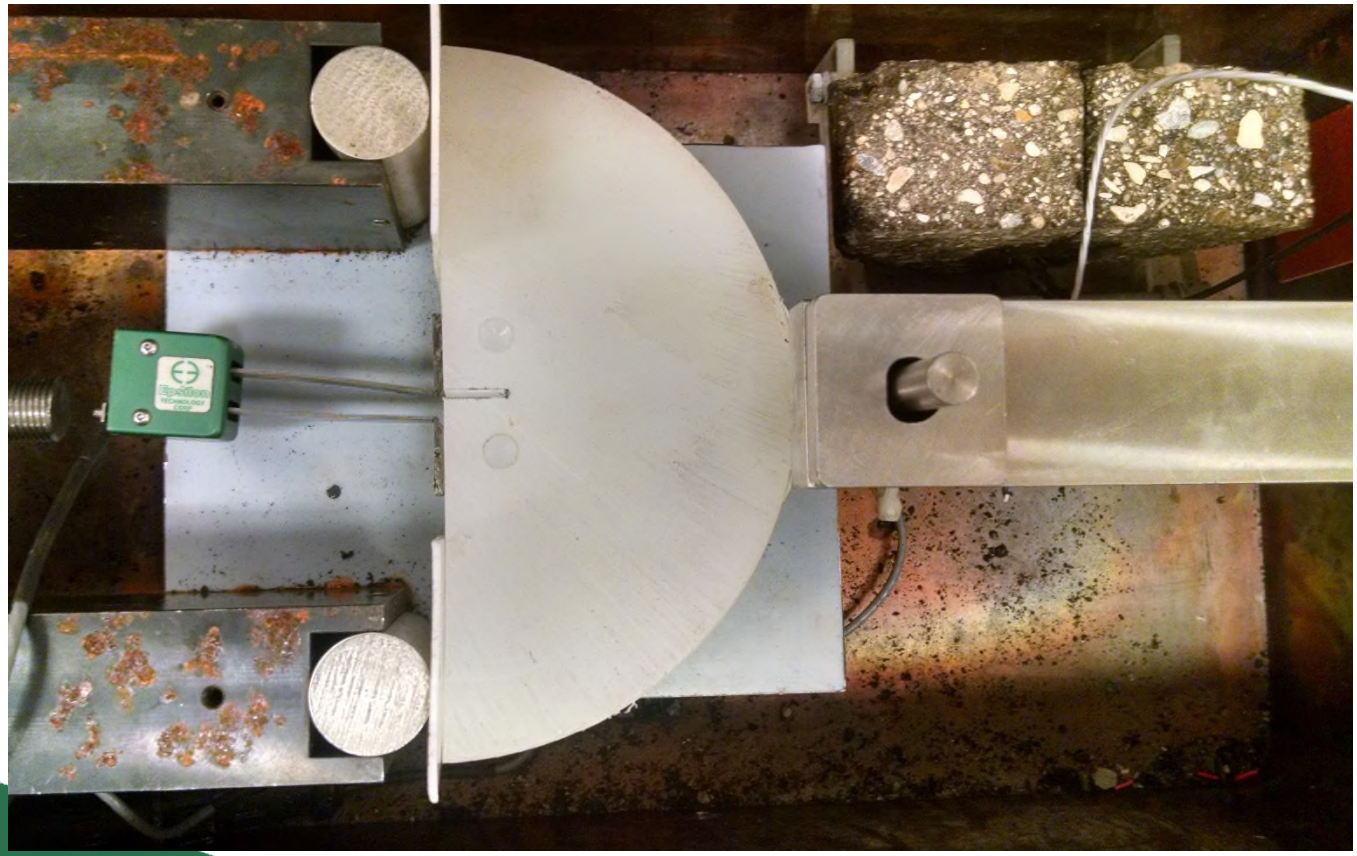
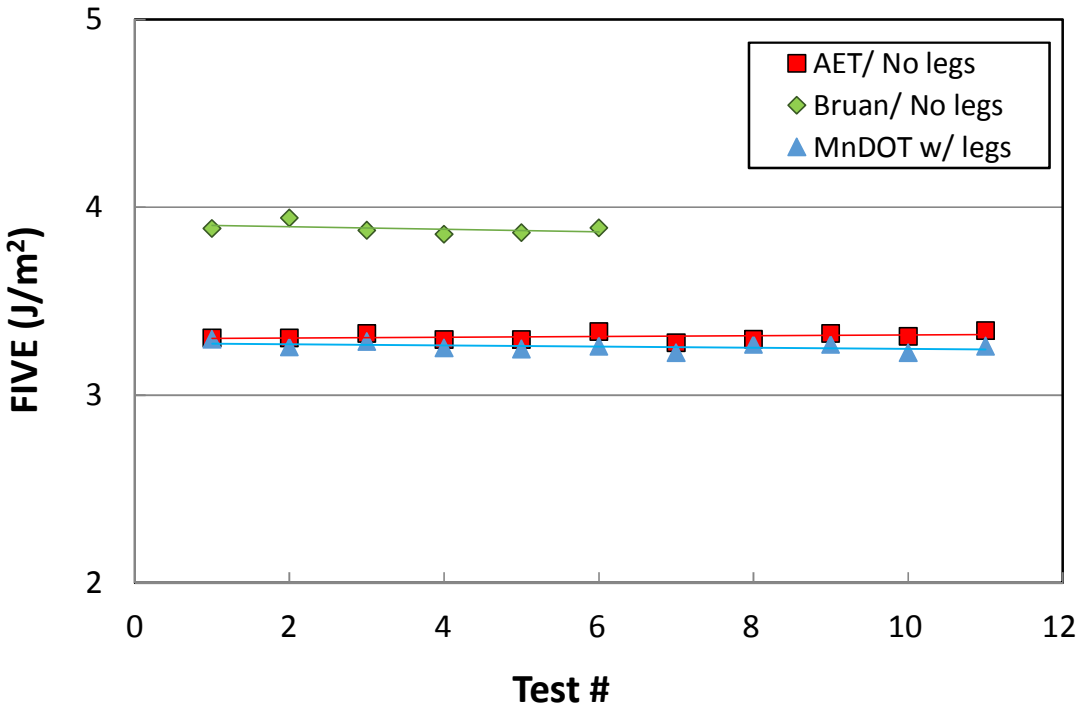
Plastic SCB



Plastic SCB – All Labs



- BRAUN is approximately 15% higher than AET and MnDOT
- AET and MnDOT are 2% different

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Statistical Analysis (AET & MnDOT)

Mixture	p-value	Status
Engineering Emulsion	0.031	Not Significant
CSS1+Cement	0.012	Not Significant
HFMS-2s	0.366	Not Significant
Foam	0.054	Not Significant

- α=0.01 (level of significance)
- P>0.01 → There is sufficient evidence to conclude that the populations are statistically the same.

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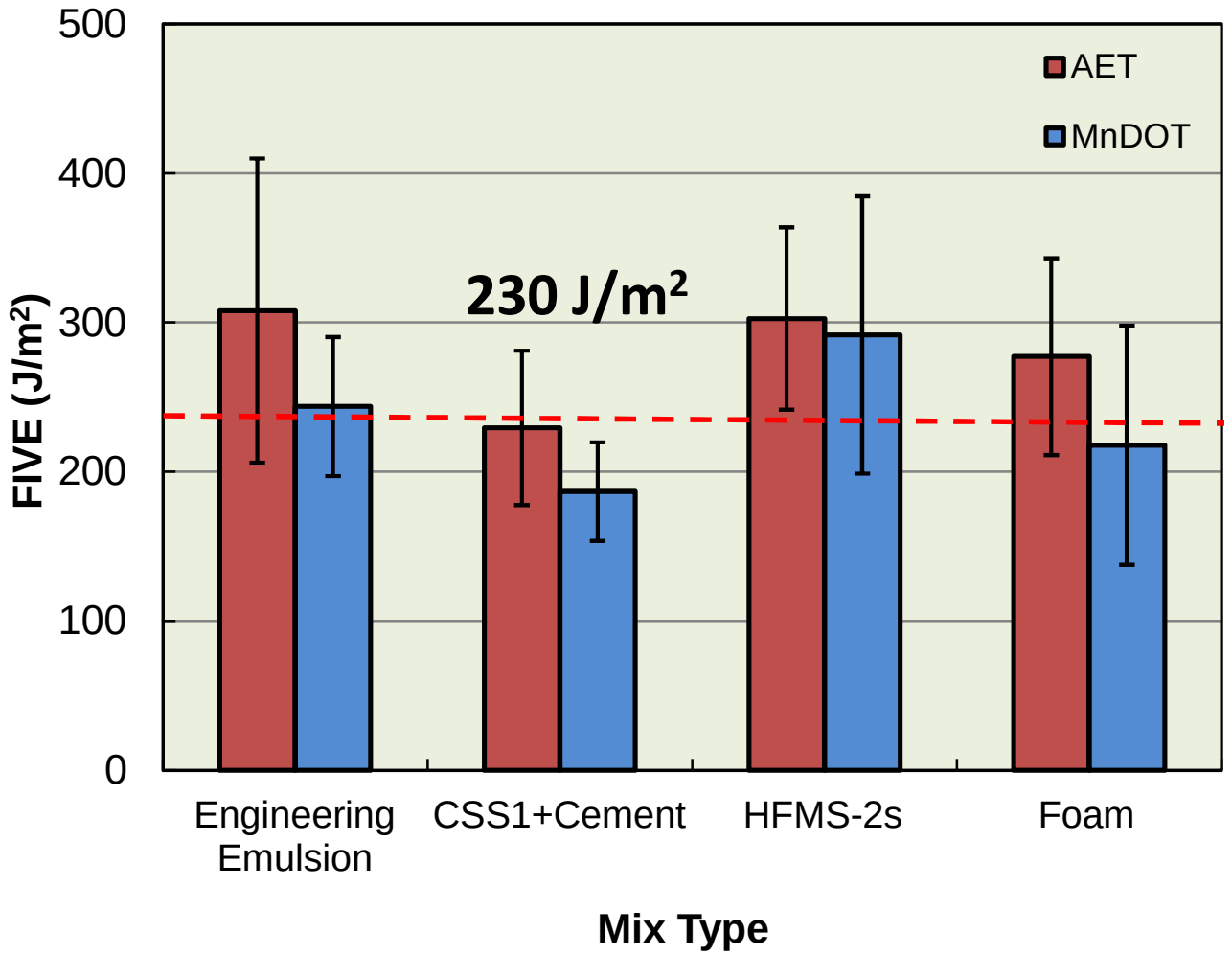
FIVE (AET & MnDOT)



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Conclusions

- Fracture Index Value for Energy (FIVE) concept is a viable option to characterize Cold In-Place Recycling (CIR) material behavior.
- SCB FIVE test showed a great potential to be used in CIR performance specification.
- Among the total 144 SCB testing performed in this study, only three samples failed during testing. This is a success rate of 98% which makes the FIVE test even more reliable.
- Statistical analysis suggested AET and MnDOT data sets are statistically the same for all the four study mixtures.

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Conclusions (Contd.)

- Field performance is required to validate the laboratory testing results.
- Even though the study samples were cured in the lab more curing may have happened.
- To avoid further curing, testing the CIR samples is recommended to be completed during a *specific time window* once the emulsion is introduced into the mixture.

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THANK YOU!

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