Experimental and Analytical Study on the Shear Behavior of Ultra-High-Performance Concrete (UHPC) Considering Axial Load Effects

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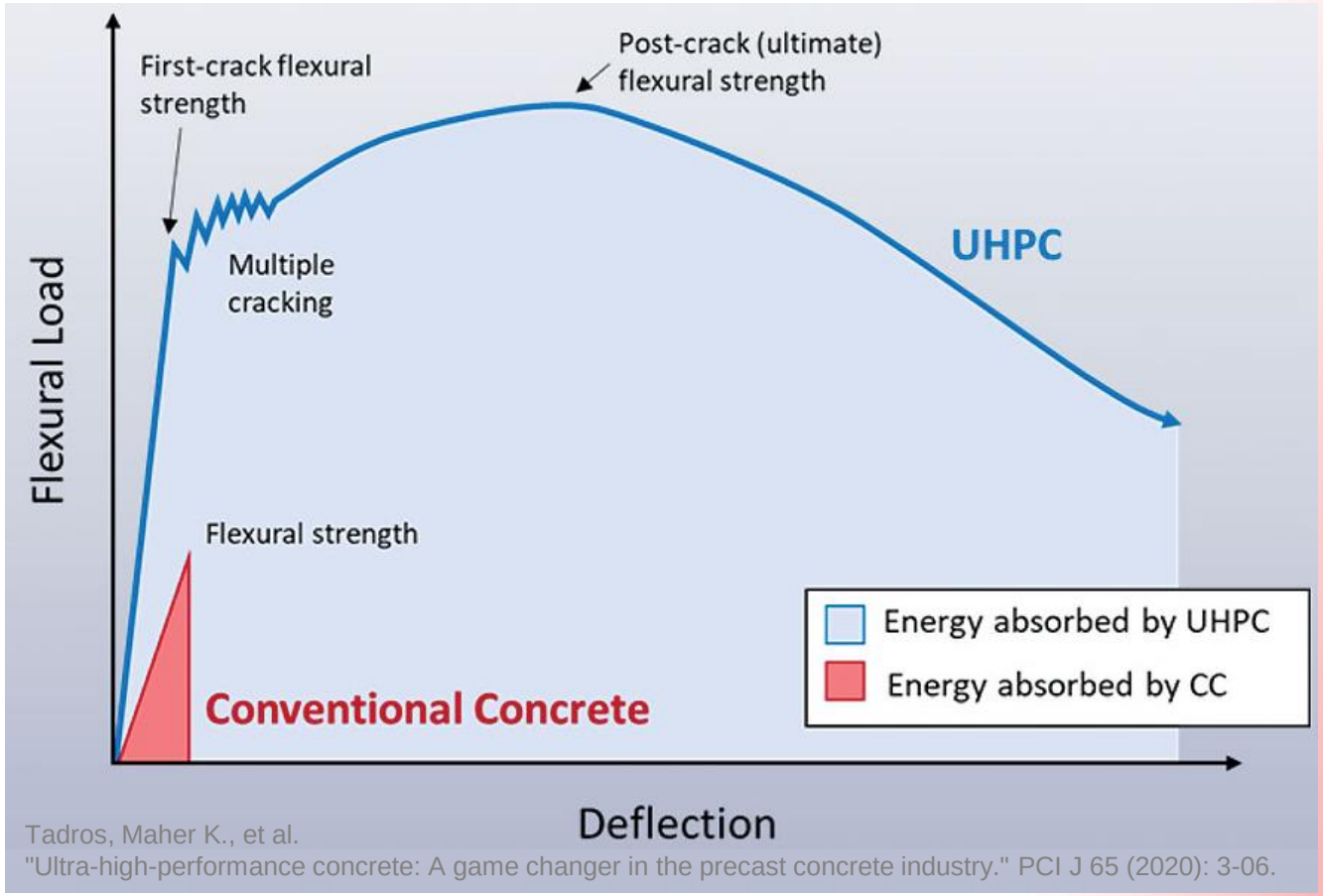
ACI Fall 2023 – Research in Progress Session

STRUCTURAL PERFORMANCE AND FLUID-STRUCTURE INTERACTION LAB

UNIVERSITY of HOUSTON
CULLEN COLLEGE of ENGINEERING

UHPC Properties

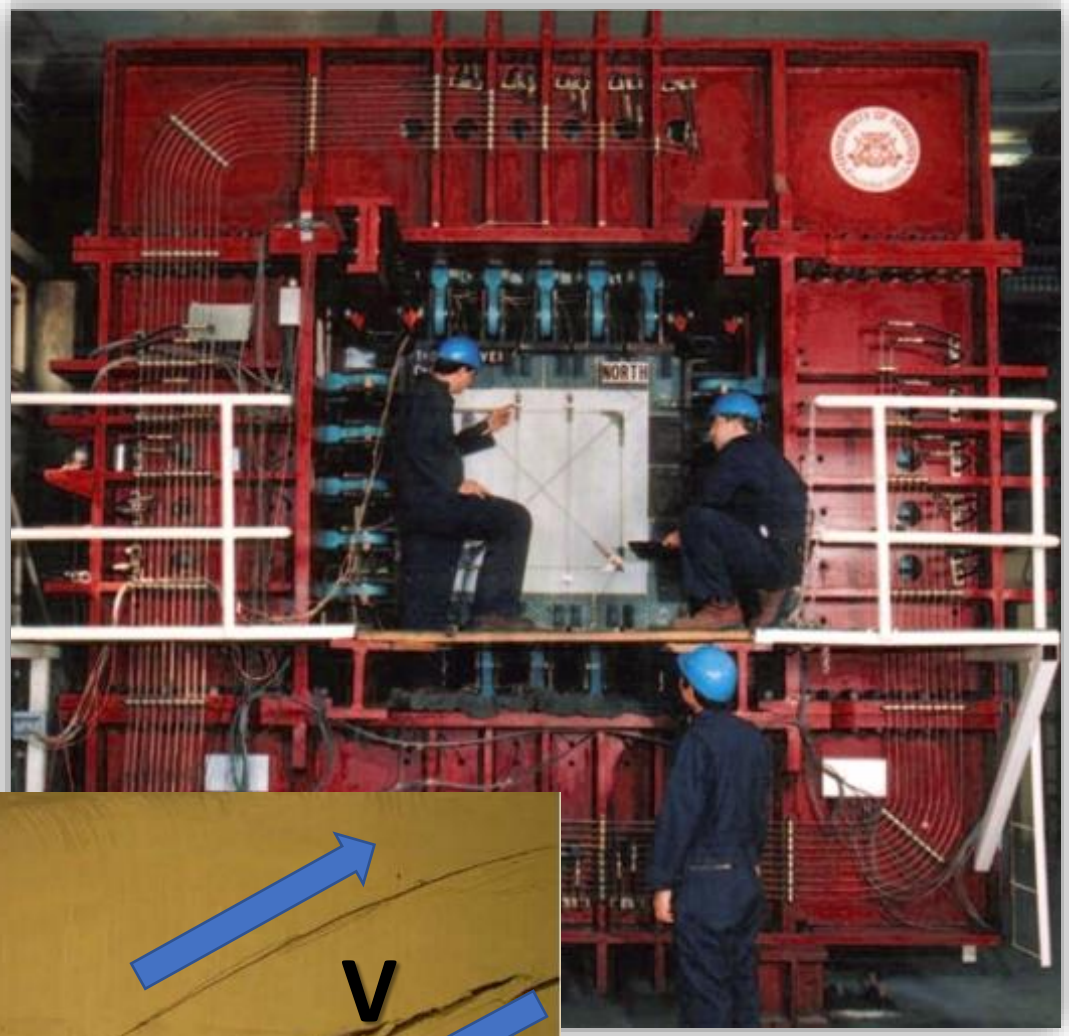
UHPC Mix at UH Structural Lab



Tadros, Maher K., et al.
"Ultra-high-performance concrete: A game changer in the precast concrete industry." PCI J 65 (2020): 3-06.

Understanding UHPC Shear Behavior
with the Universal Element Tester (UET) at UH

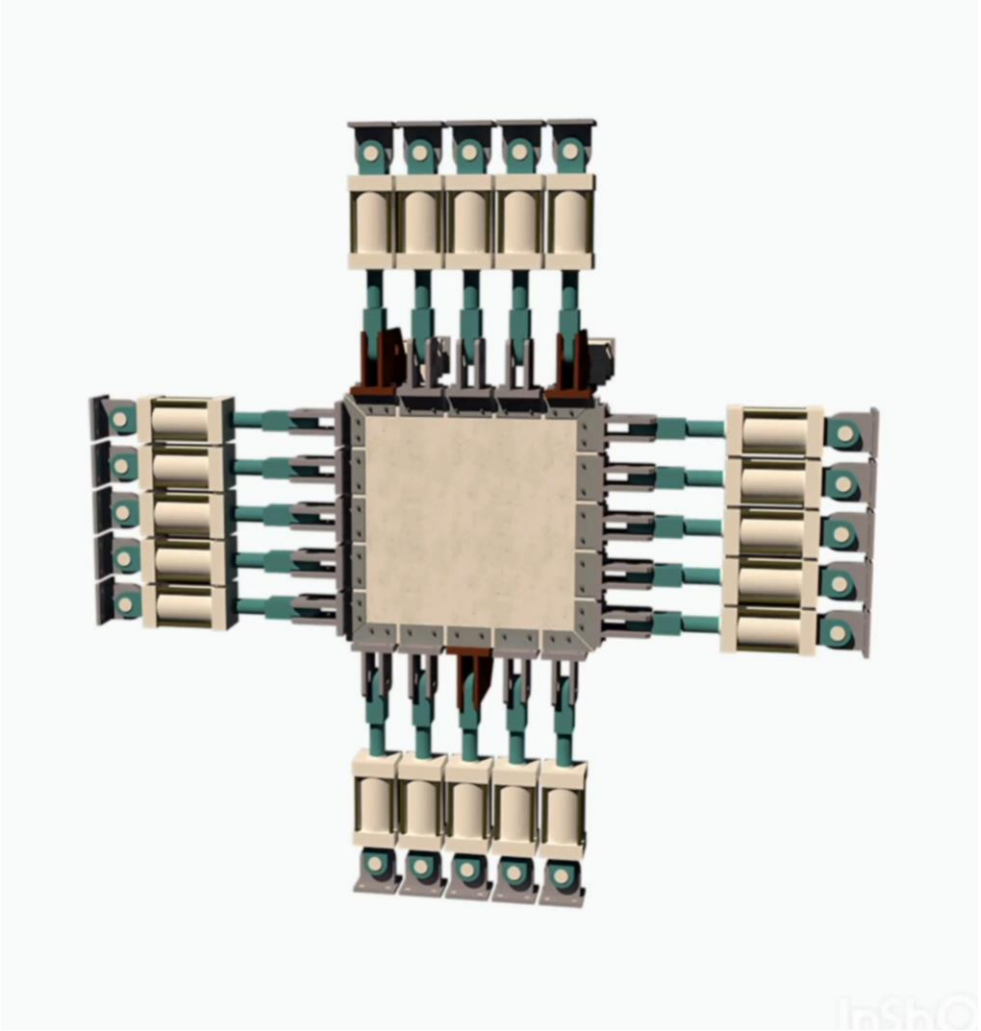
UET North Side



UET South Side

Test Setup of Panels

Shear Testing Procedure using UET



5 Top
5 bottom → **Compression** Jacks

5 Right
5 Left → **Tension** Jacks

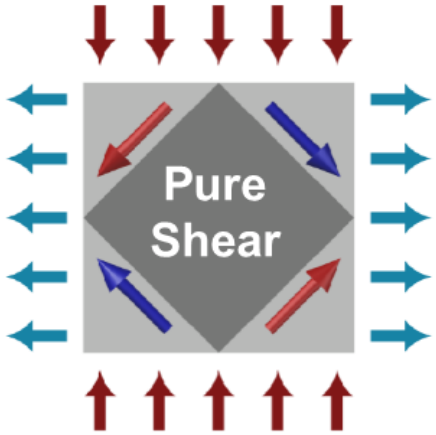
3 in-plane
3 out-of-plane → **Rigid** links

UHPC Panel Shear Test Program

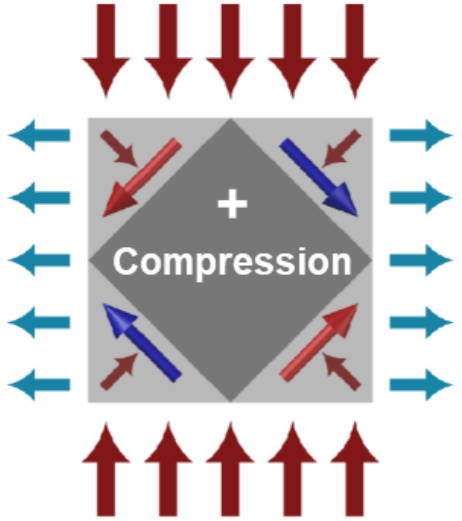
Considering

Axial Effects

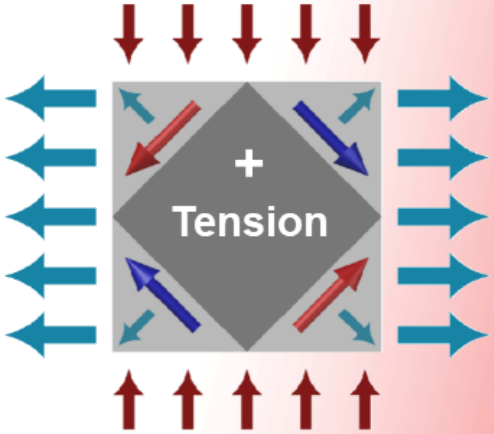
Shear Tests on **UHPC** panels



Pure Shear



Shear Compression



Shear Tension

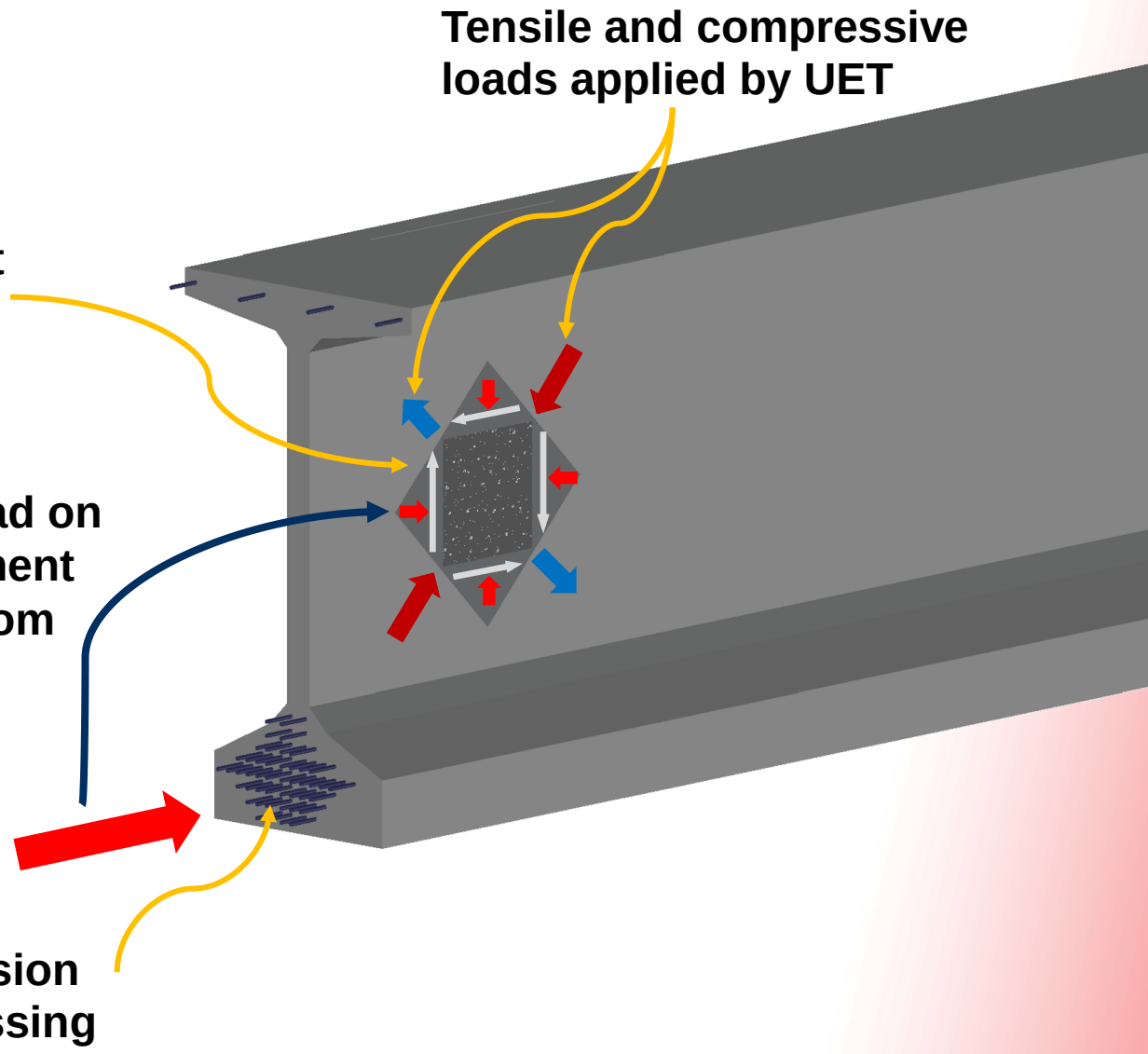
1. **Panel 1: Pure Shear**
2. **Panel 2: Shear + Compression at 5% of f'_c**
3. **Panel 3: Shear + Compression at 10% of f'_c**
4. **Panel 4: Shear + Tension at 35% of f'_t**

- **Unreinforced (without rebars)**
- **Reinforced (with rebars)**

Axial Effects in Structural Elements

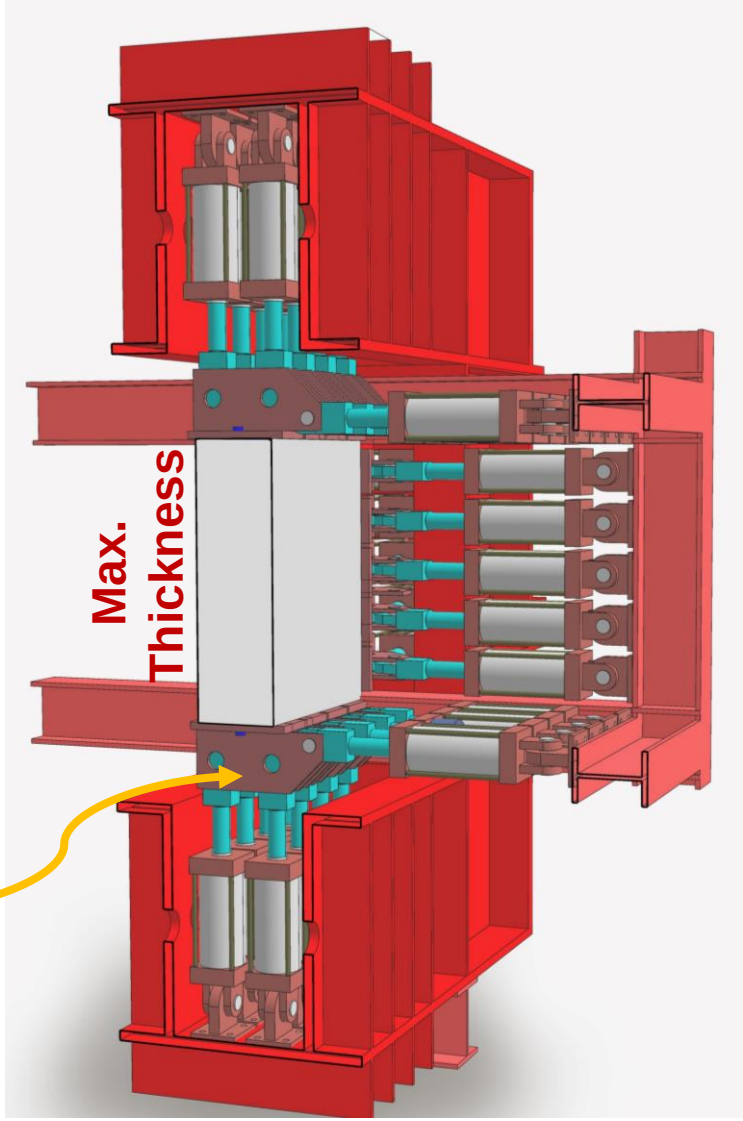
Application of axial effects using the UET

The axial effects are represented on the tested element in UET as transformed loads from the actual structural elements

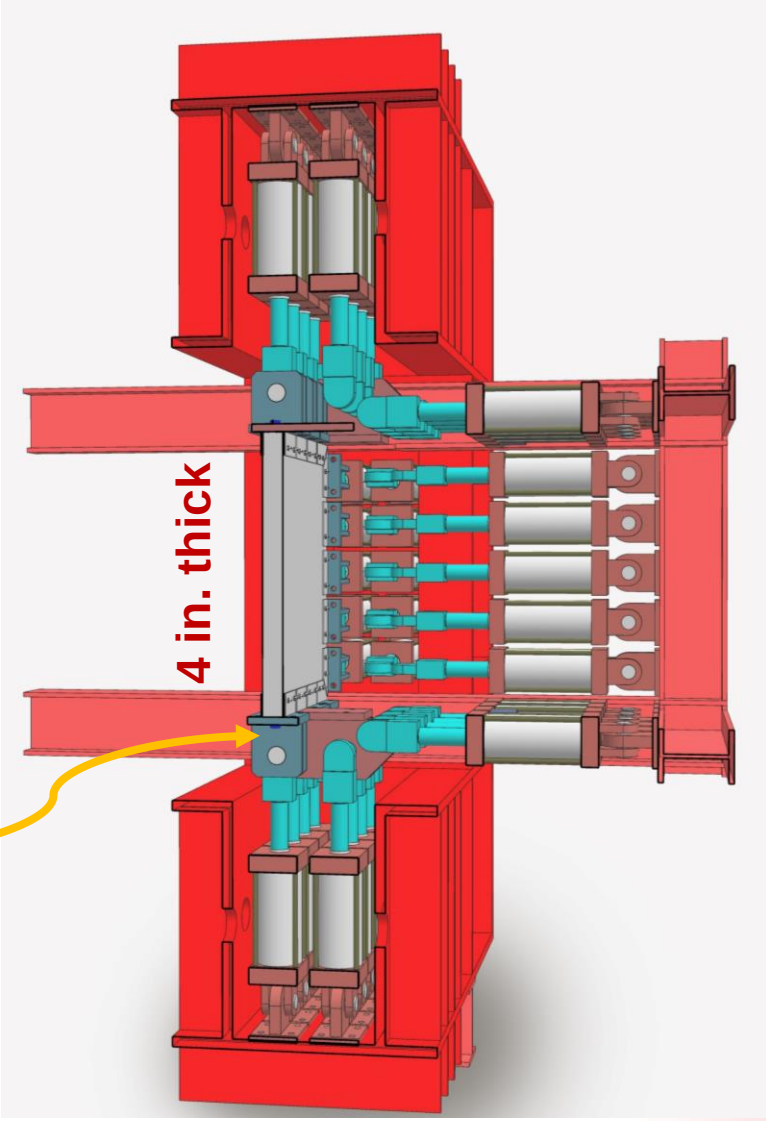


UET Modification for UHPC Shear Tests

Original UET setup

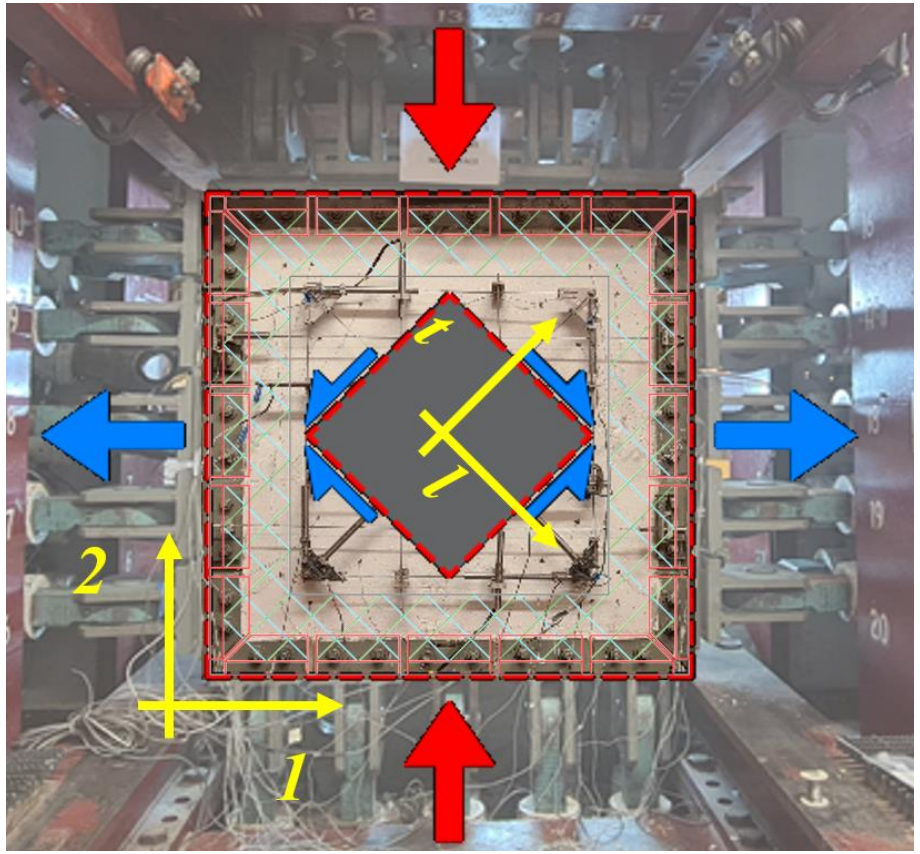


Thin panel Setup

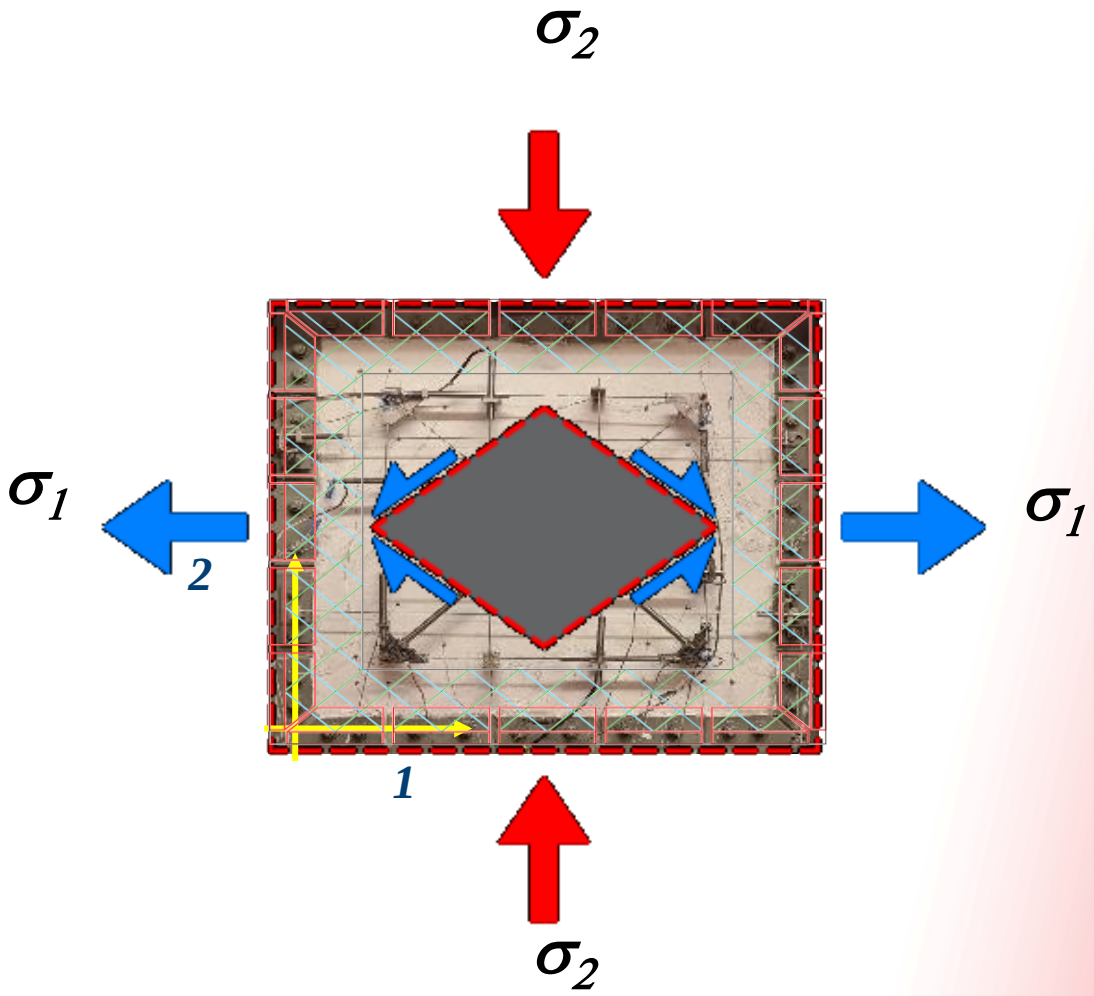


Pure Shear Test Mechanism using UET

Before Loading



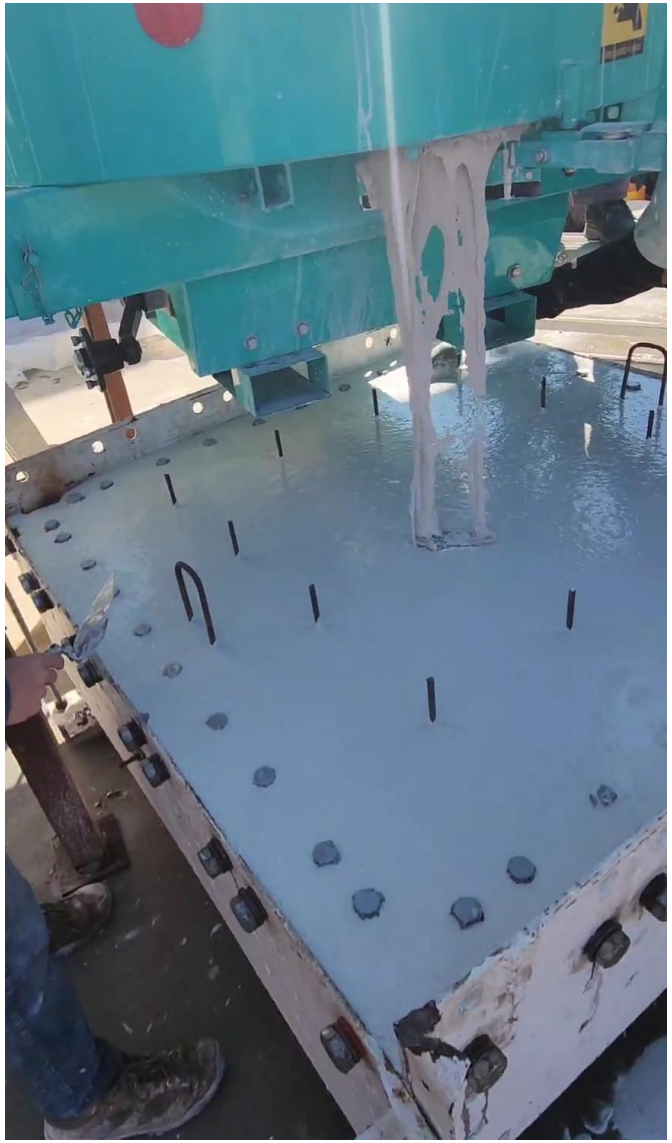
After Loading



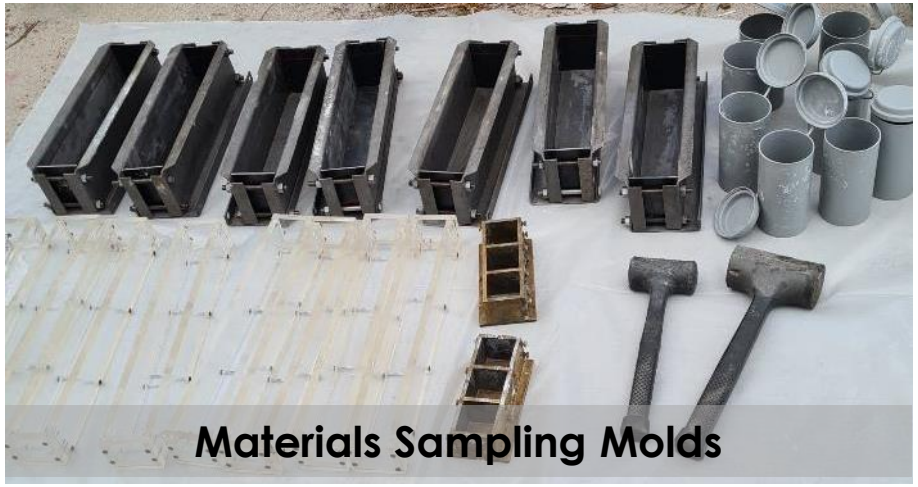
Unreinforced UHPC Panel Casting at UH Structural Lab

Reinforced UHPC Panel Casting at UH Structural Lab

UHPC Panel Casting at UH Structural Lab

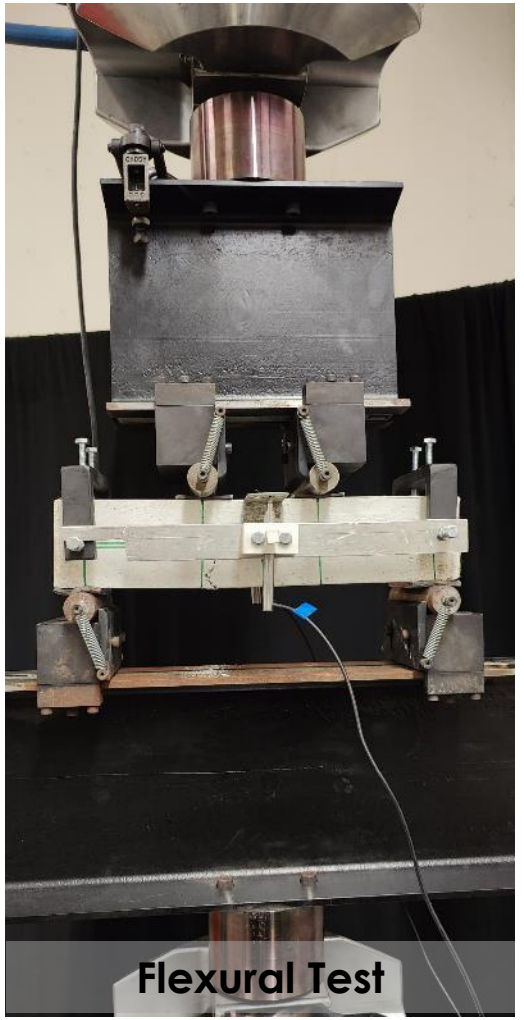


UHPC Material Tests


Materials Sampling Molds

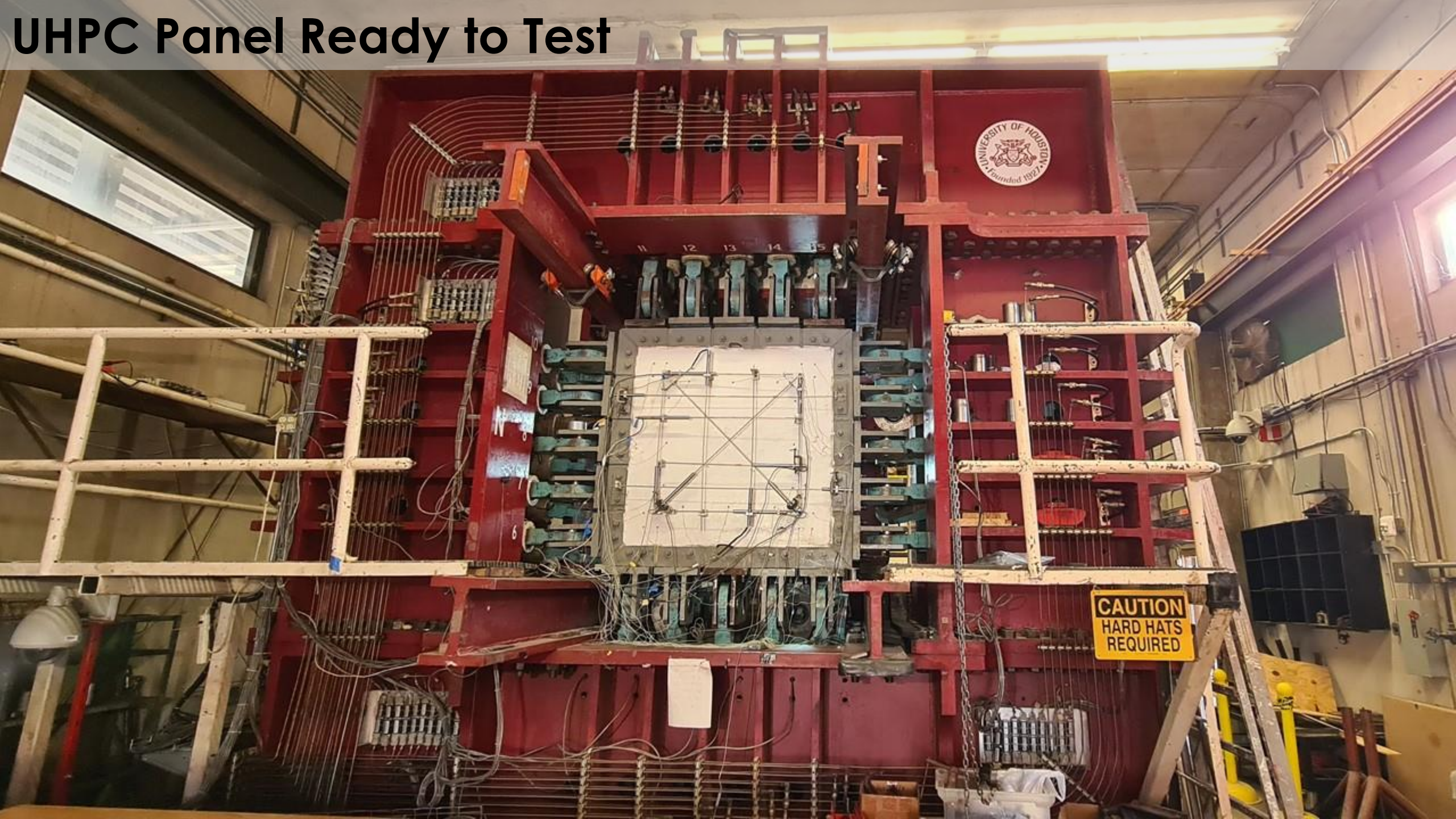

Material Testing Specimens


Compression Test


Flexural Test

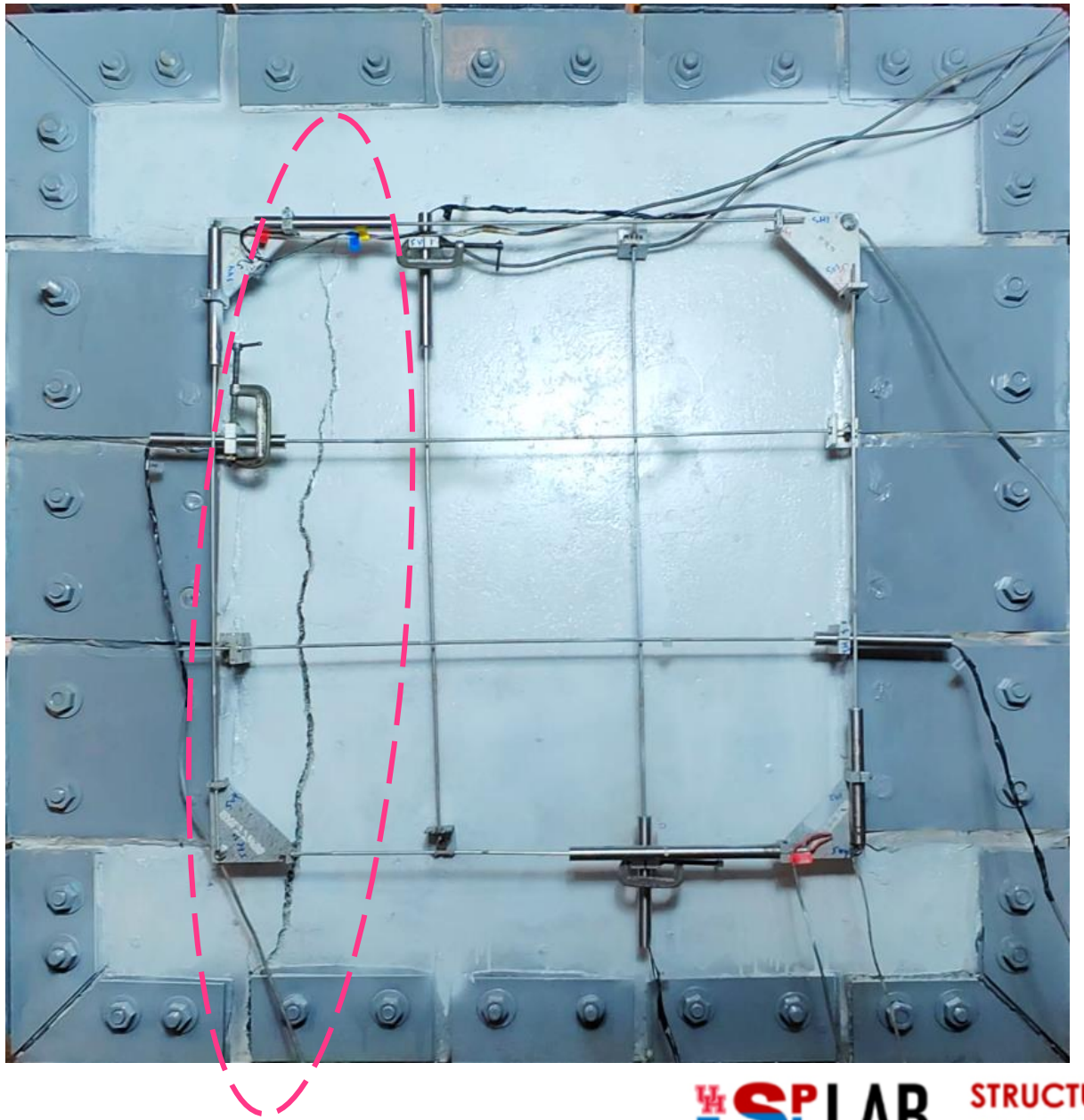
Direct Tension Test

UHPC Panel Ready to Test

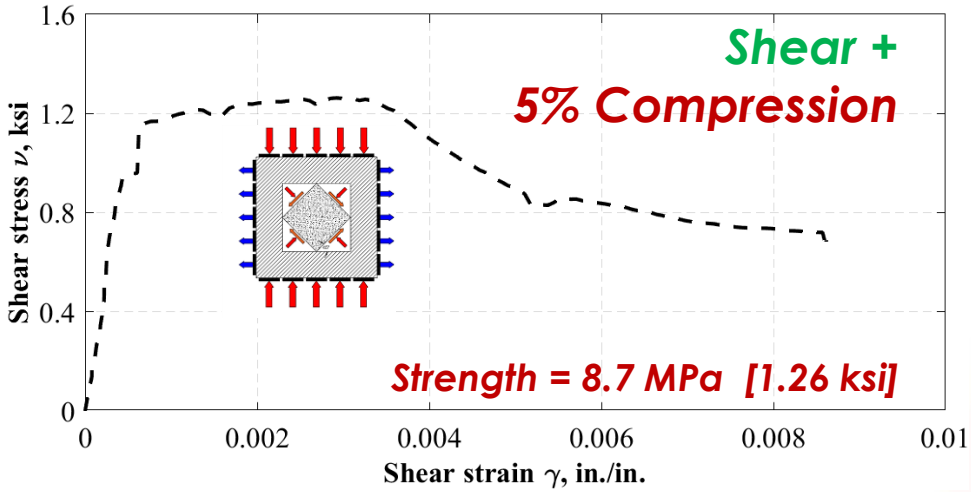


Panel#2 - Test Results

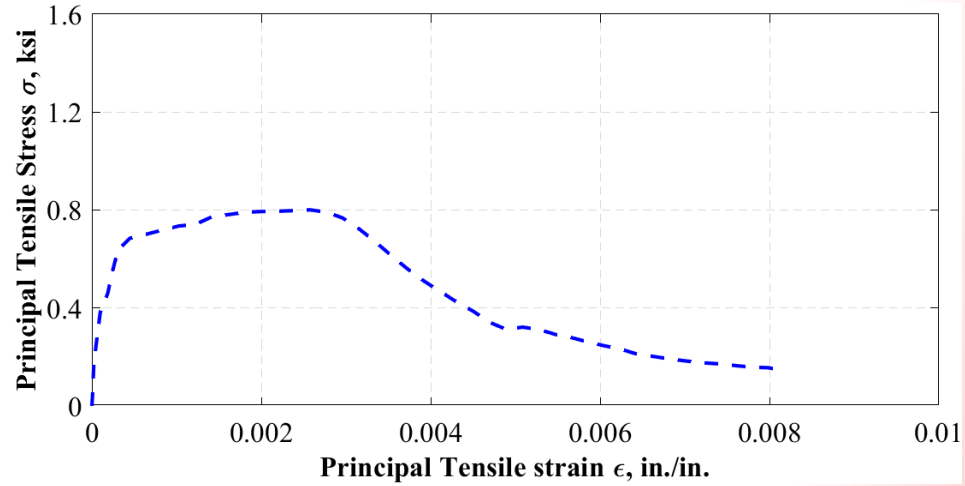
South Side



Shear stress vs strain

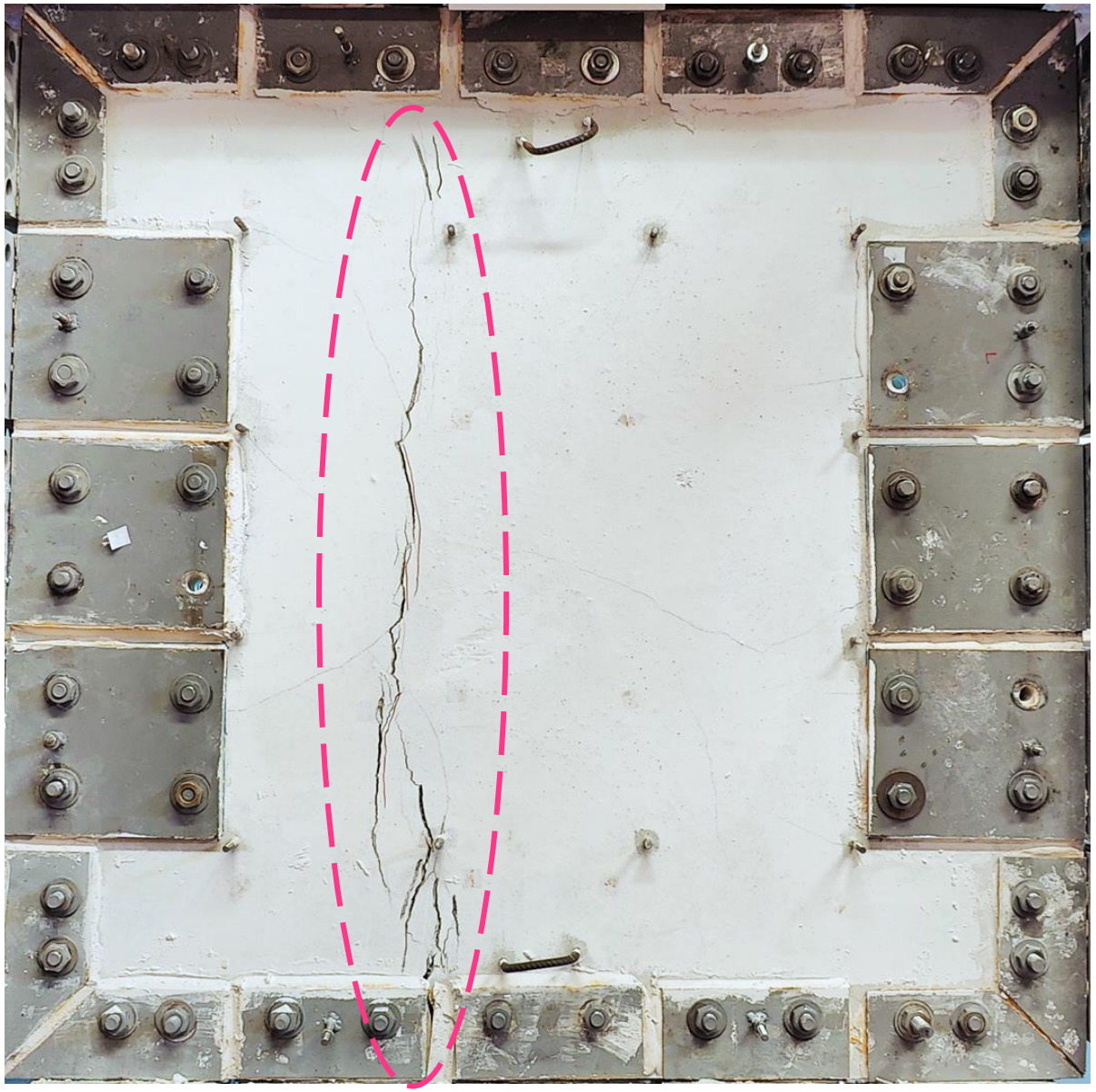


Principal tensile stress vs strain

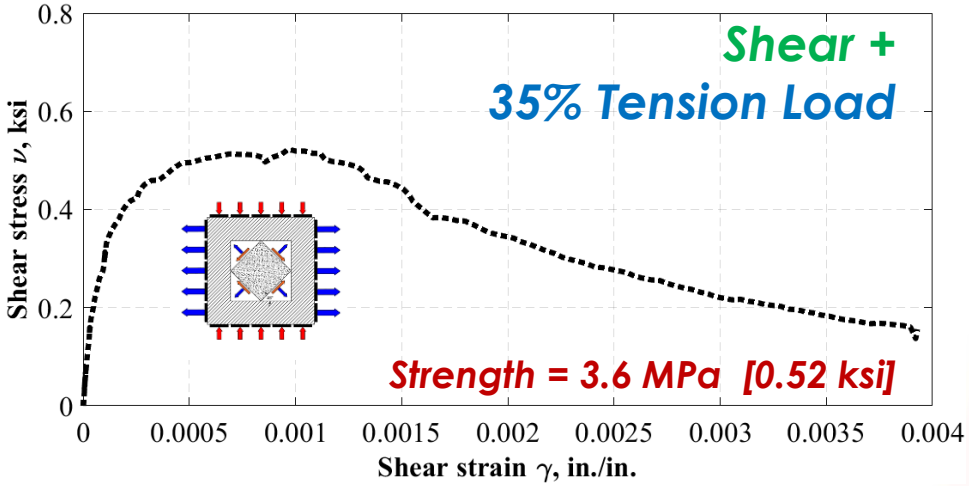


Panel#4 - Test Results

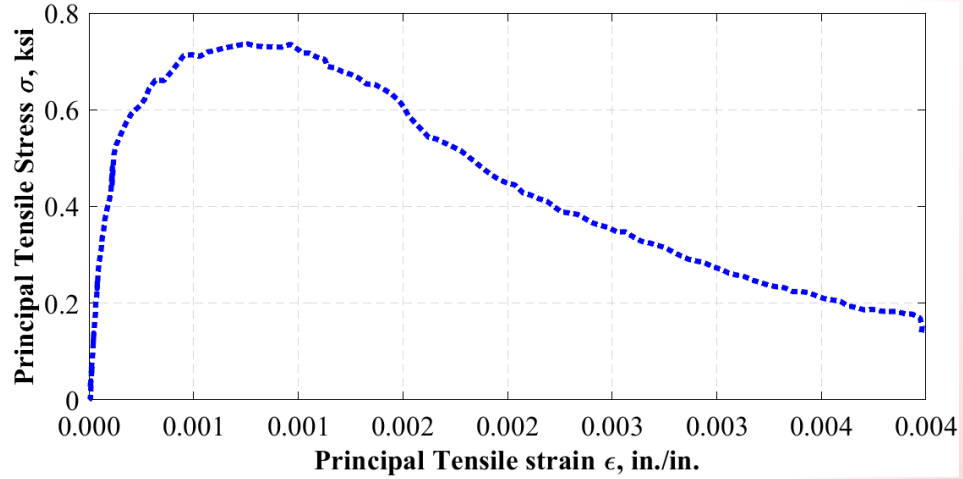
North Side



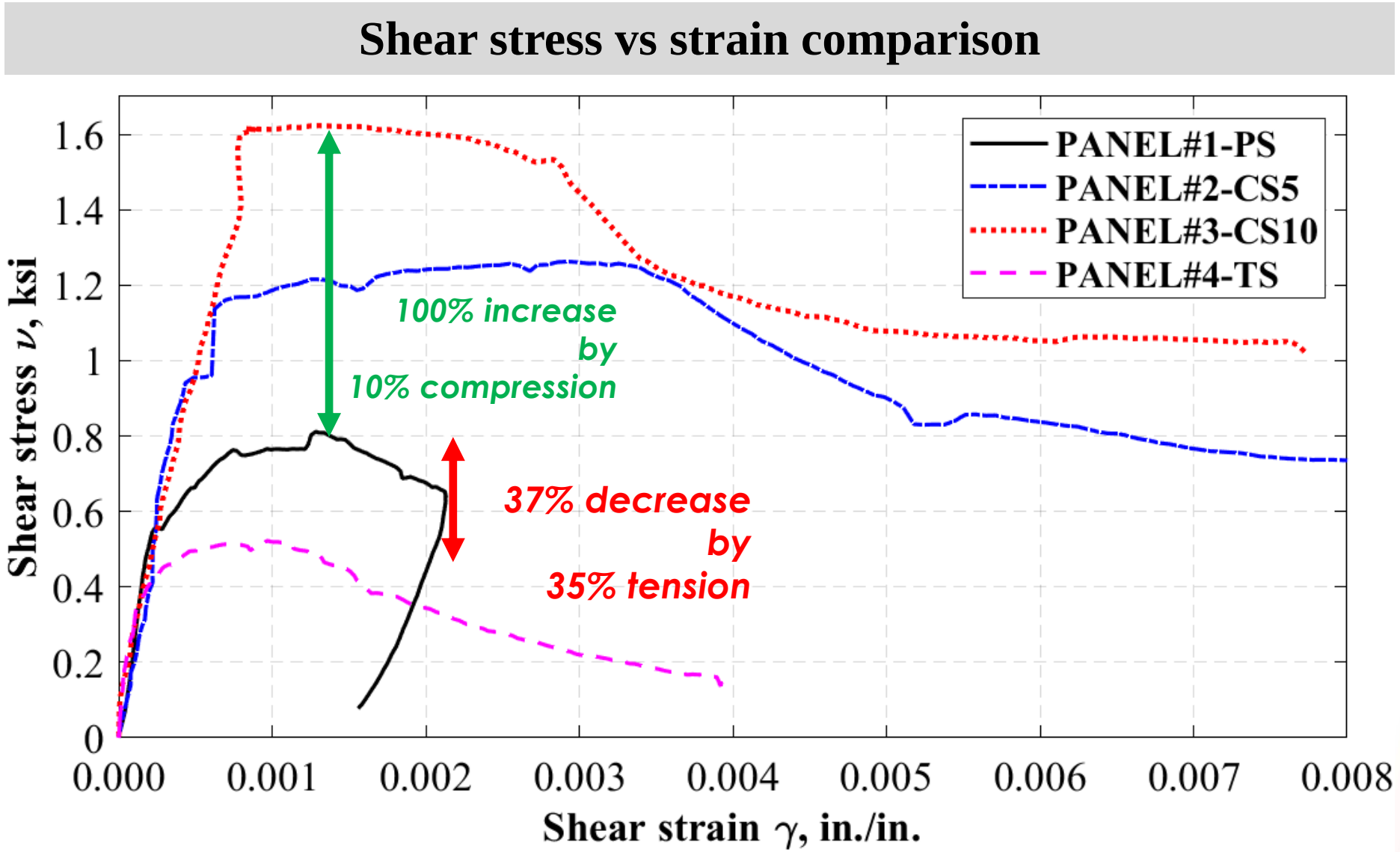
Shear stress vs strain



Principal tensile stress vs strain

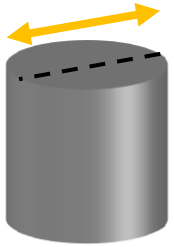


All Panel Test Results – No Rebars

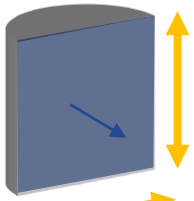


Fiber Orientation - Sampling

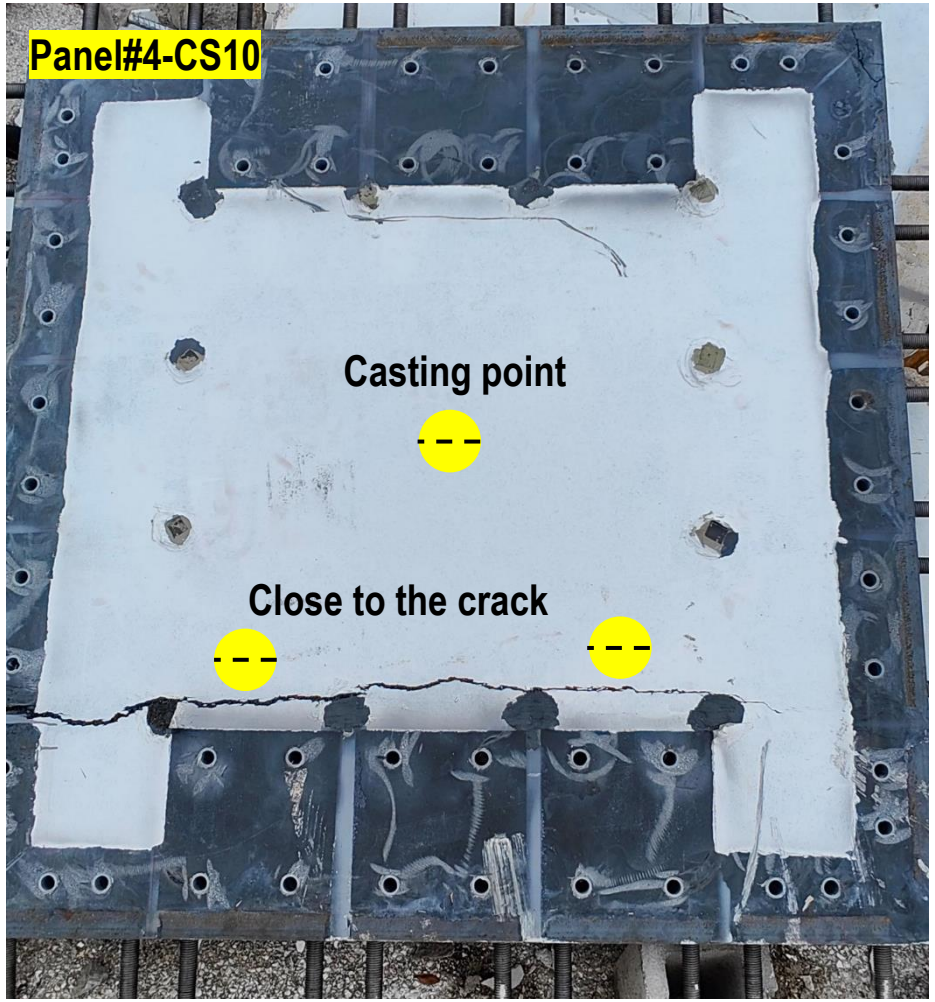
Core taken from the panel

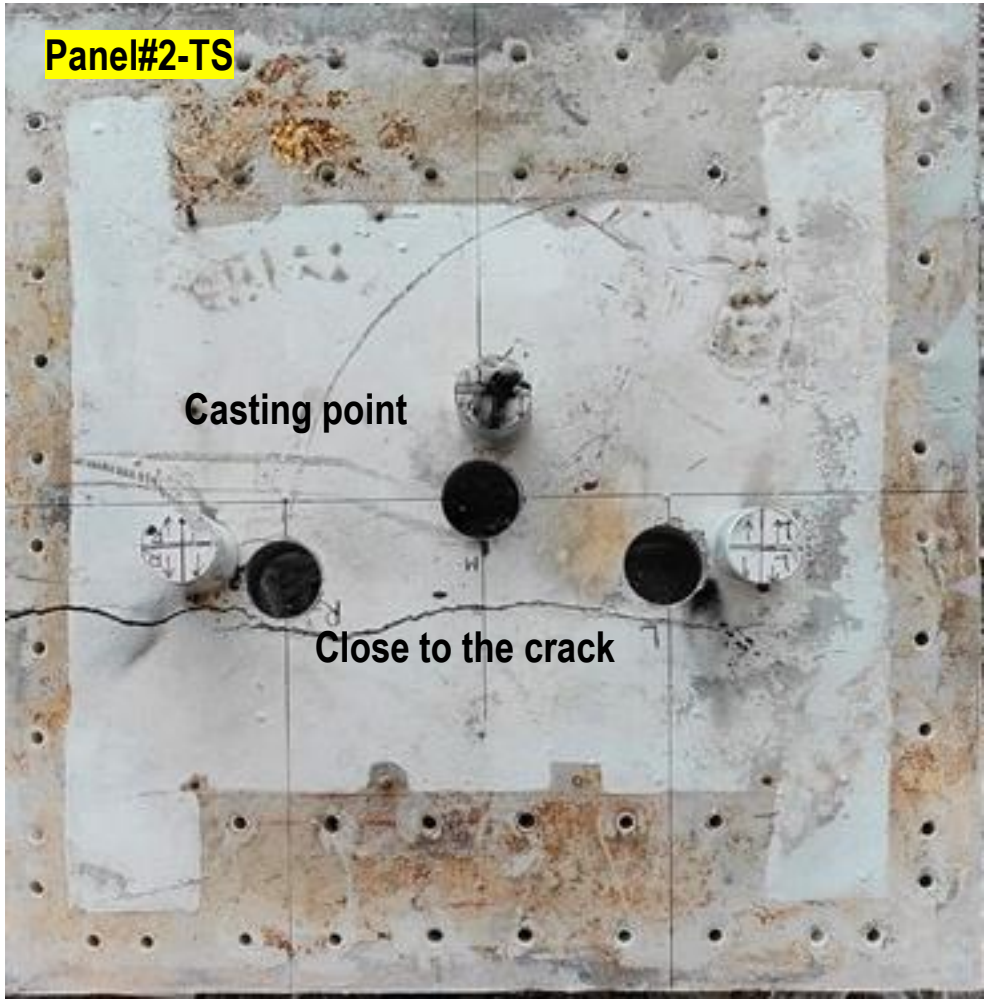


Cut into halves



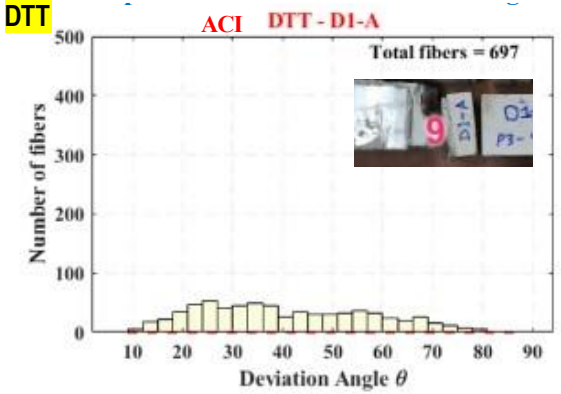
Fibers direction

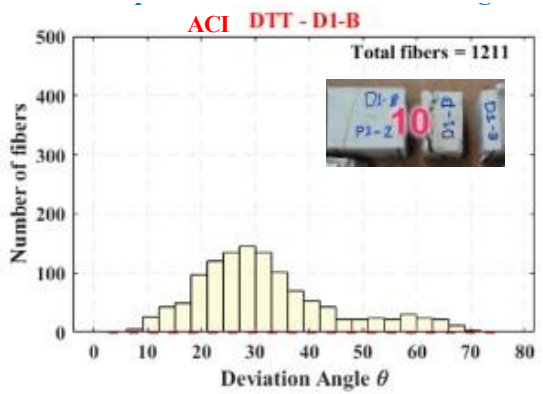


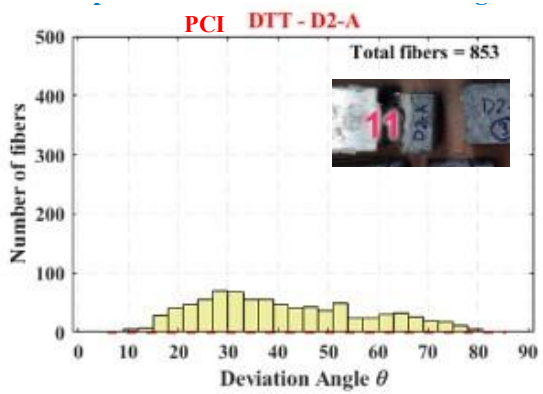


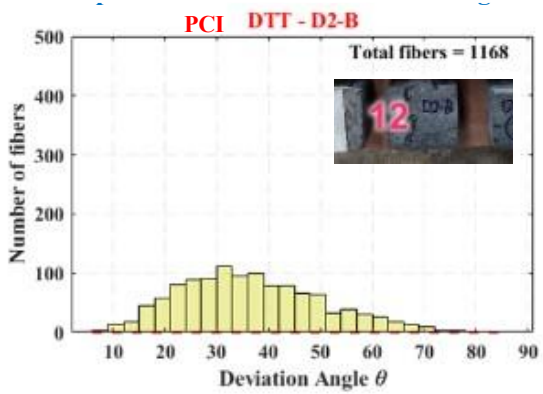
Fiber Orientation - Distribution

DTT

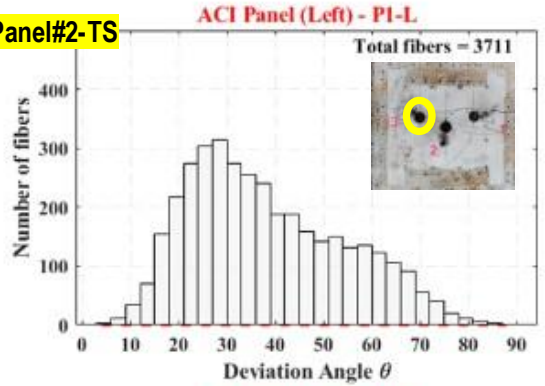


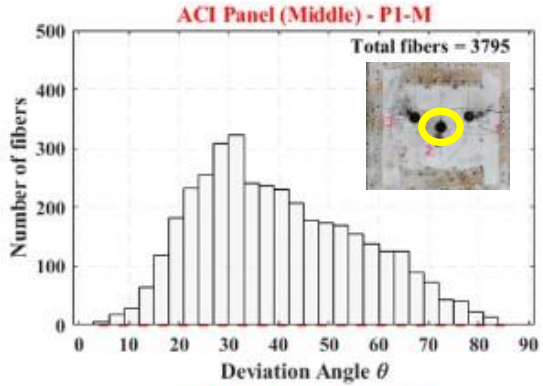


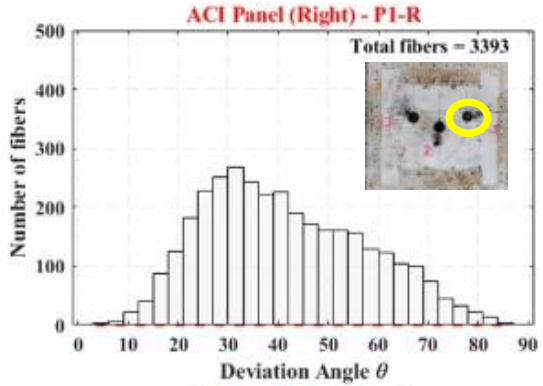




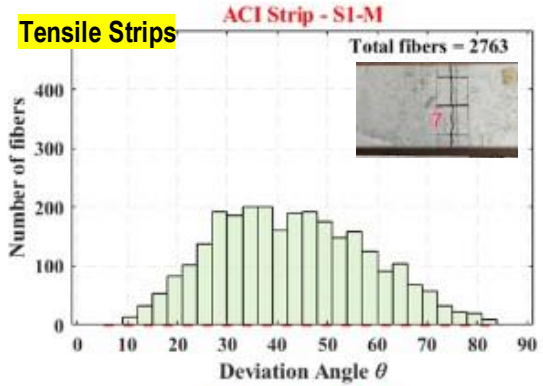
Panel#2-TS



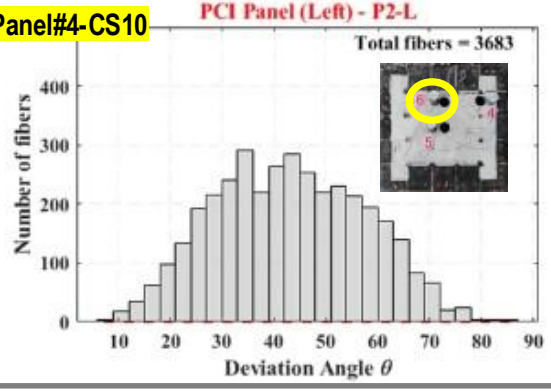


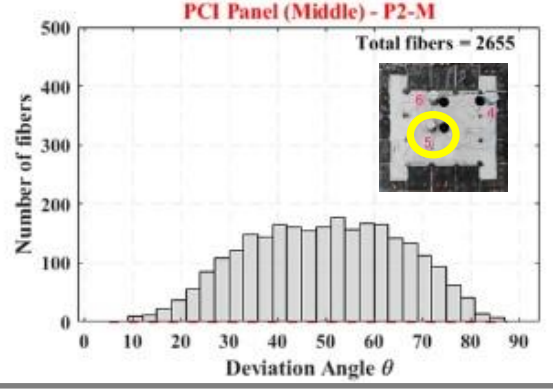


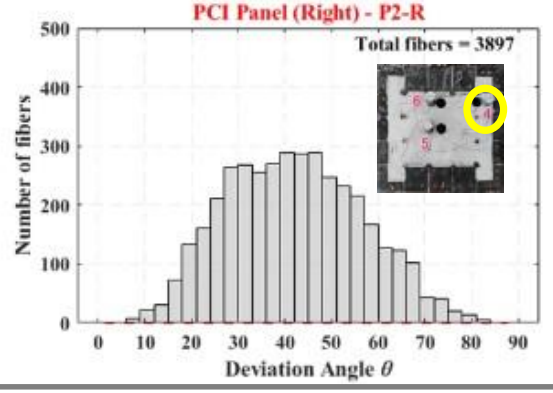
Tensile Strips

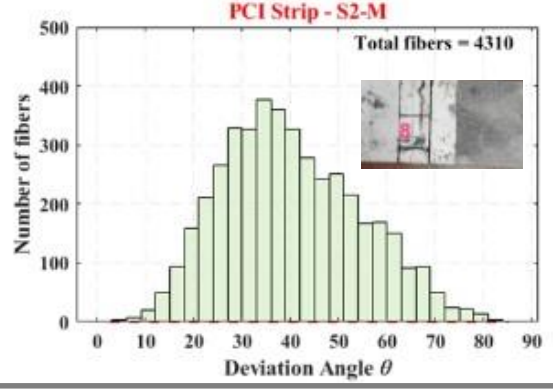


Panel#4-CS10

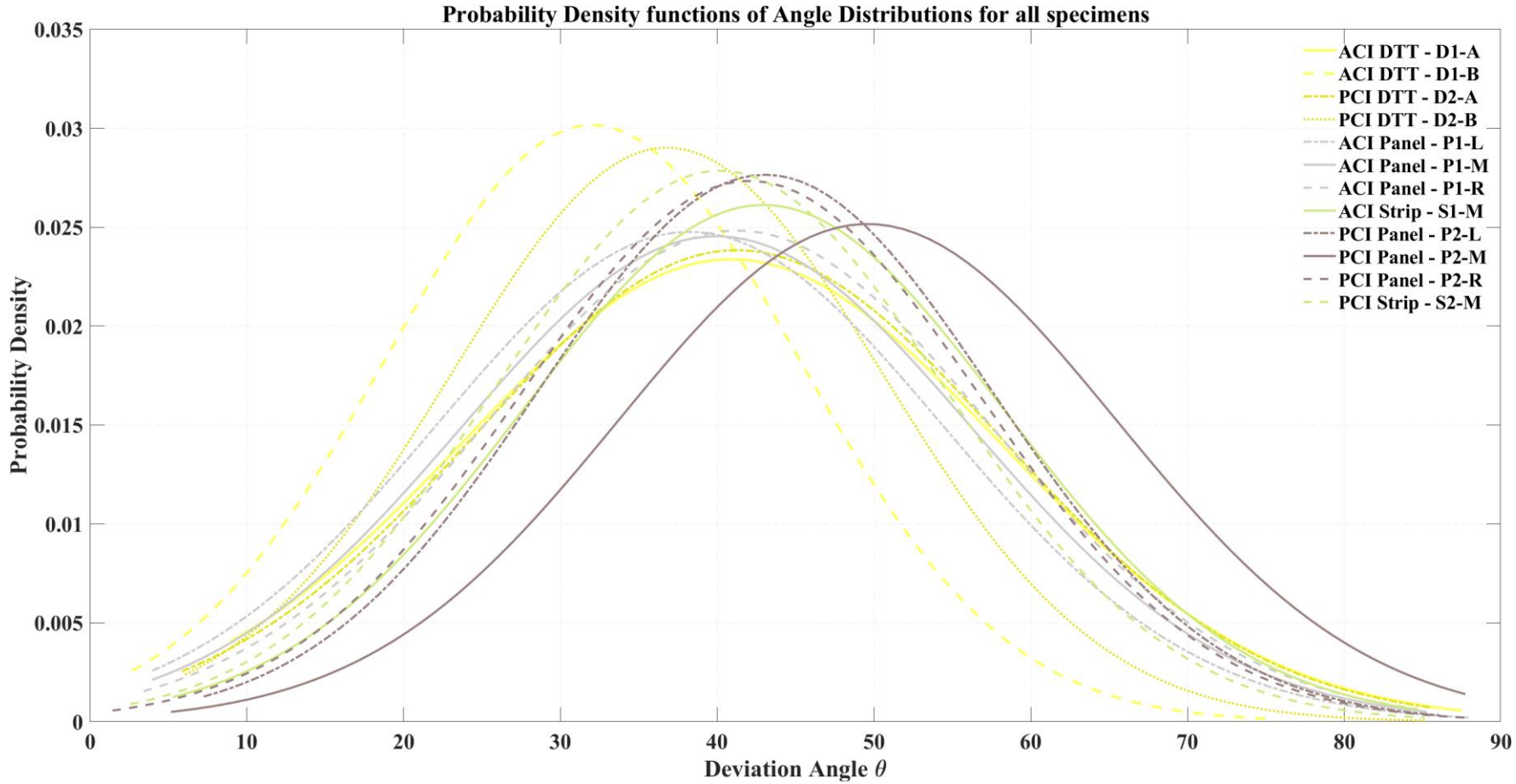




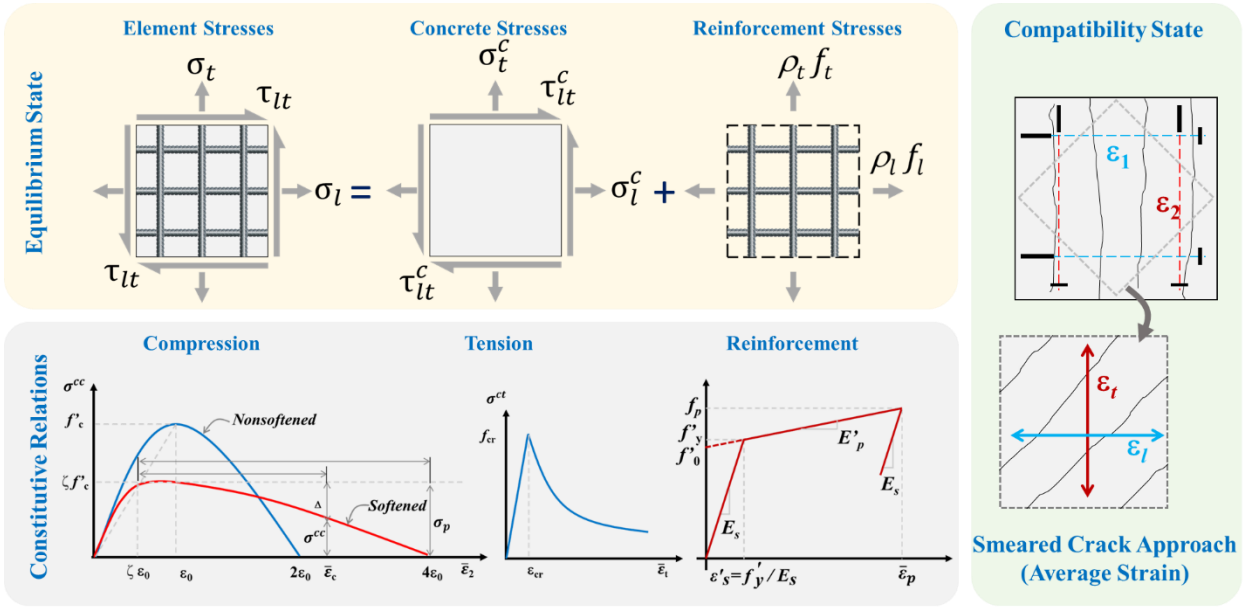




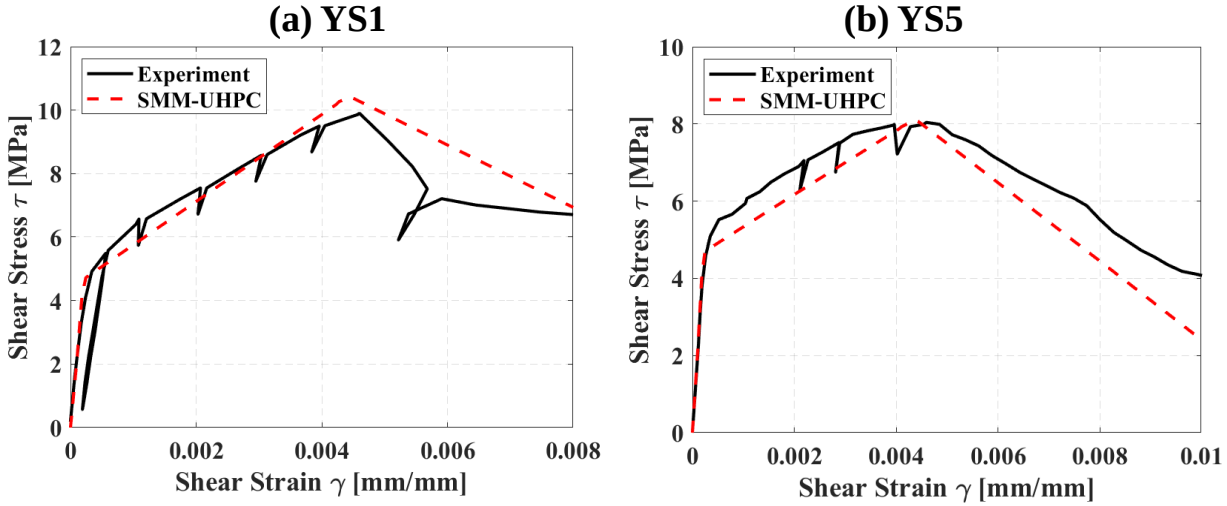
Fiber Orientation - Distribution



Softened Membrane Model for UHPC (SMM-UHPC)

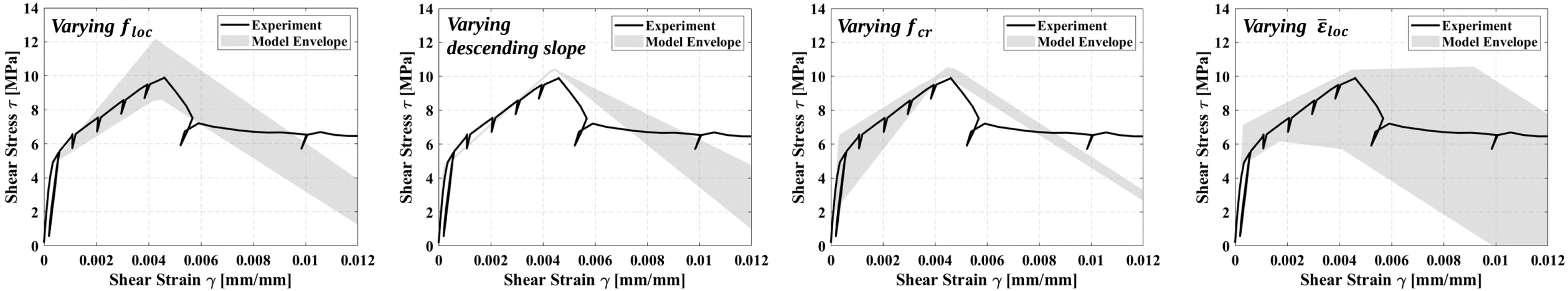


Comparison with Test Data



Experimental data from Yap (2020)

Uncertainty in UHPC Tensile Parameters



Summary

- Effective use of UET for combining shear with axial load effects
- The use of pre-compression appears to have a significant effect on the shear behavior of UHPC (50% and nearly 100% increase with only 5% and 10% Axial Load Ratio in the Principal Compression Direction.
- Applying higher tensile forces (35% of f_t) reduced the shear strength significantly (37% reduction)
- Evaluation of fiber alignment from various specimens showed a relatively random distribution with a tendency for angles <45°.

Acknowledgments

Steelike® Concrete | aci® American Concrete Institute | PCI® Precast/Prestressed Concrete Institute | Tindall

The authors would like to thank John Lawler and Elizabeth Wagner from WJE for their support on characterizing the fiber alignment in the test specimens.