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

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UHPC Properties


UHPC Mix at UH Structural Lab
Understanding UHPC Shear Behavior with the Universal Element Tester (UET) at UH
Test Setup of Panels

*Shear Testing Procedure using UET*

- 5 Top
- 5 bottom
- 5 Right
- 5 Left
- 3 in-plane
- 3 out-of-plane

Compression Jacks
Tension Jacks
Rigid links
UHPC Panel Shear Test Program

Considering **Axial Effects**

Shear Tests on UHPC panels

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

Max. Thickness

Double in-plane jacks

Single in-plane jacks

4 in. thick
Pure Shear Test Mechanism using UET

Before Loading

After Loading

$\sigma_1$

$\sigma_2$

$\sigma_1$

$\sigma_2$
Unreinforced UHPC Panel Casting at UH Structural Lab
Reinforced UHPC Panel Casting at UH Structural Lab

Shear Reinforcement in one direction: 6 #4 bars (Ratio is 0.57%)
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

Shear stress vs strain

Shear + 5% Compression

Strength = 8.7 MPa [1.26 ksi]

Principal tensile stress vs strain

South Side
Panel#4 - Test Results

North Side

Shear stress vs strain

Shear + 35% Tension Load

Strength = 3.6 MPa [0.52 ksi]

Principal tensile stress vs strain
All Panel Test Results – No Rebars

Shear stress vs strain comparison

- 100% increase by 10% compression
- 37% decrease by 35% tension
Fiber Orientation - Sampling

Core taken from the panel

Cut into halves

Panel#4-CS10

Casting point

Close to the crack

Panel#2-TS

Casting point

Close to the crack

Fibers direction
Fiber Orientation - Distribution

DTT

ACI DTT - D1-A
Total fibers = 697

ACI DTT - D1-B
Total fibers = 1231

PCI DTT - D2-A
Total fibers = 563

PCI DTT - D2-B
Total fibers = 1168

Panel#2-TS

ACI Panel (LHS) - P1-L
Total fibers = 3711

ACI Panel (MIDDLE) - P1-M
Total fibers = 3795

ACI Panel (RIGHT) - P1-R
Total fibers = 3593

Tensile Strips

Panel#4-CS10

PCI Panel (LHS) - P2-L
Total fibers = 3683

PCI Panel (MIDDLE) - P2-M
Total fibers = 3655

PCI Panel (RIGHT) - P2-R
Total fibers = 3897

PCI Strip - S1-M
Total fibers = 2763

PCI Strip - S2-M
Total fibers = 4310
Fiber Orientation - Distribution

Probability Density functions of Angle Distributions for all specimens

- ACI DTT - D1-A
- ACI DTT - D1-B
- PCI DTT - D2-A
- PCI DTT - D2-B
- ACI Panel - P1-L
- ACI Panel - P1-M
- ACI Panel - P1-R
- ACI Strip - S1-M
- PCI Panel - P2-L
- PCI Panel - P2-M
- PCI Panel - P2-R
- PCI Strip - S2-M
Softened Membrane Model for UHPC (SMM-UHPC)

Comparison with Test Data

(a) YS1

(b) YS5

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°.
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