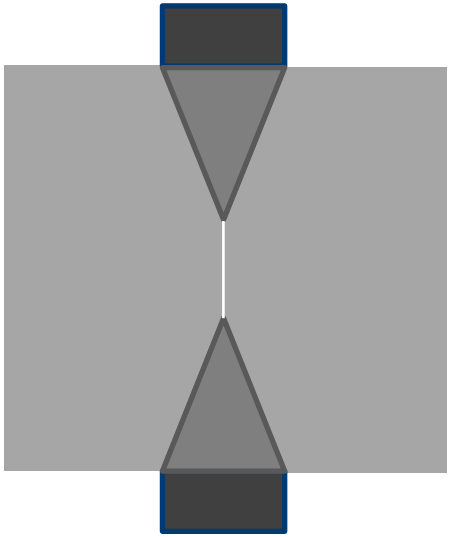
The Double-Punch Test for UHPC Quality Control

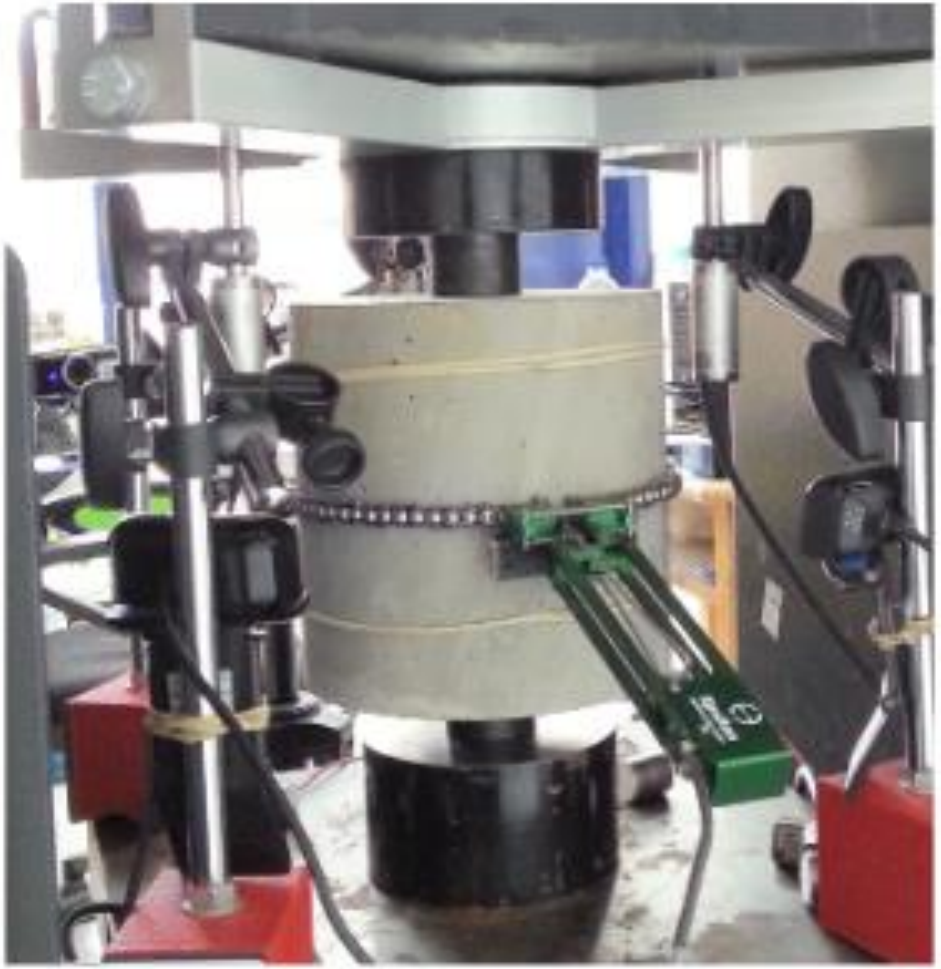
Megan Voss, Kyle Riding, Raid Alrashidi, Christopher Ferraro, Trey Hamilton, Daniel Alabi, Joel Harley

Research Purpose

- Develop a QC test for UHPC tensile strength
- Improve upon split cylinder test
  - Give a measure of toughness instead of one tensile value.
  - Avoid inflated results associated with compressive stress increasing fiber bond
  - Maintain low cost to allow all labs to perform QC checks on their concrete

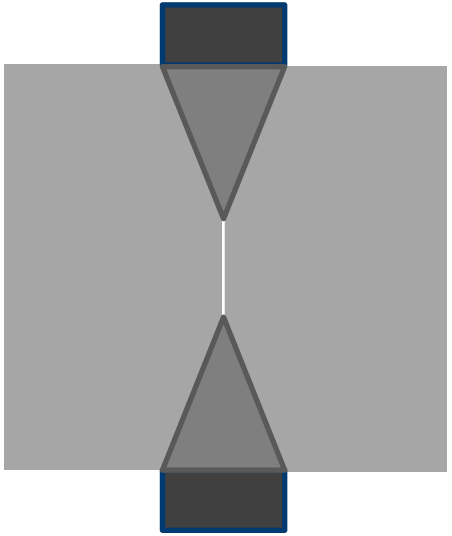
Double Punch Test

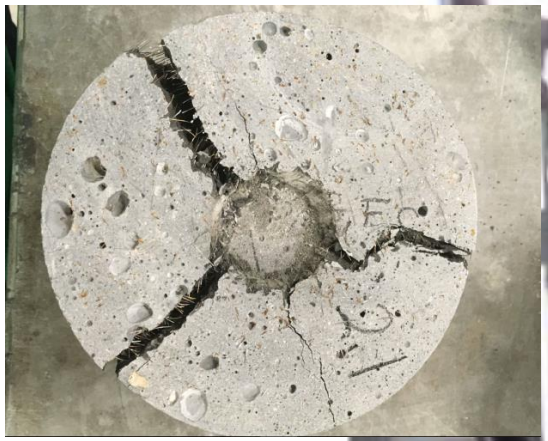




Choumanidis, D., E. Badogiannis, P. Nomikos, and A. Sofianos. (2017). Barcelona test for the evaluation of the mechanical properties of single sand hybrid FRC, exposed to elevated temperature. *Construction and Building Materials*, *138*. 296-305

Double Punch Test



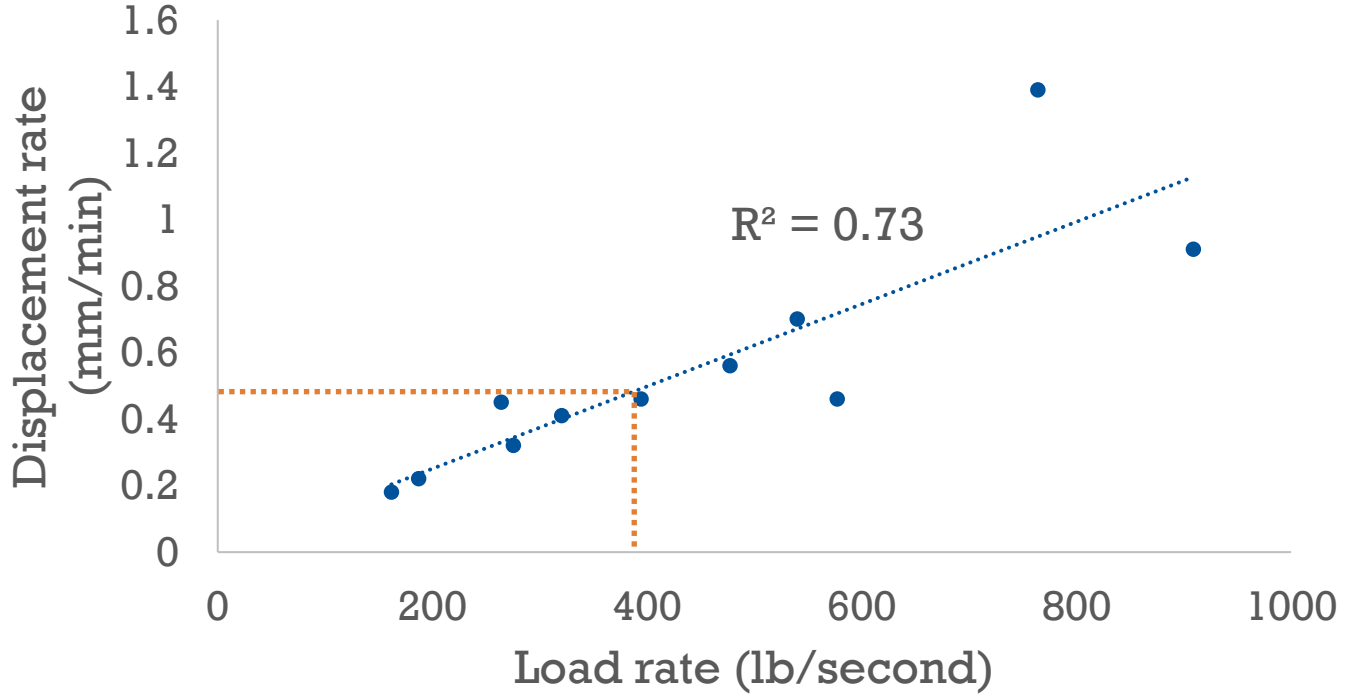


Choumanidis, D., E. Badogiannis, P. Nomikos, and A. Sofianos. (2017). Barcelona test for the evaluation of the mechanical properties of single sand hybrid FRC, exposed to elevated temperature. *Construction and Building Materials*, *138*. 296-305.

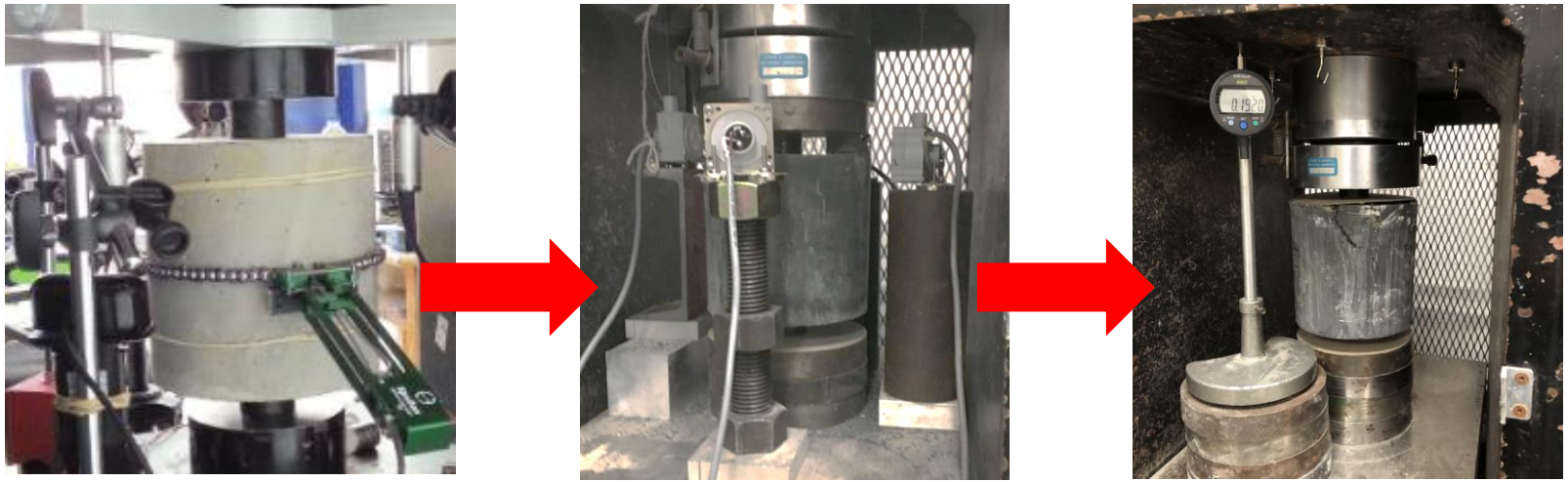
Questions

- How do we modify this test so it can be done in any lab?
  - Part 1: Use a standard compression machine
  - Part 2: Use a low cost data collection method
- What parameters of the test method must be controlled in the specification?
- Do the simplified double punch results correlate with those of the direct tension test and ASTM C1609?

Modification 1: Use low-cost manual compression machine



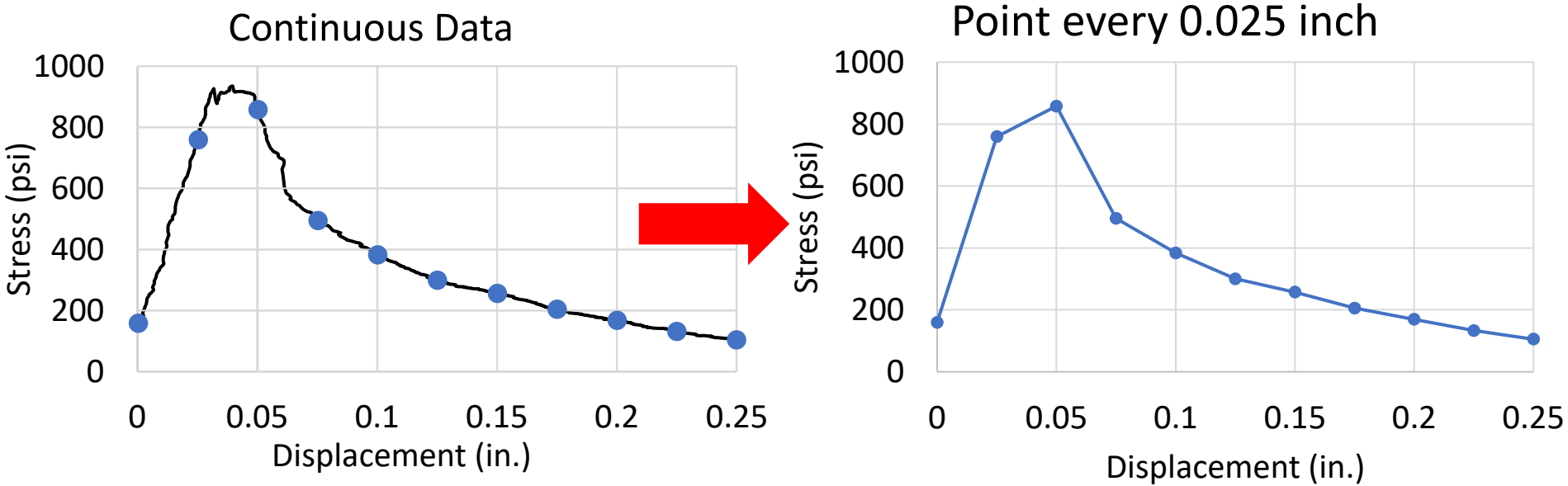
Modification 2: measure displacement with dial gauge



Choumanidis, D., E. Badogiannis, P. Nomikos, and A. Sofianos. (2017). Barcelona test for the evaluation of the mechanical properties of single sand hybrid FRC, exposed to elevated temperature. *Construction and Building Materials, 138*. 296-305.

Data from dial gauge

- Data collected manually at discreet points instead of continuously plotted

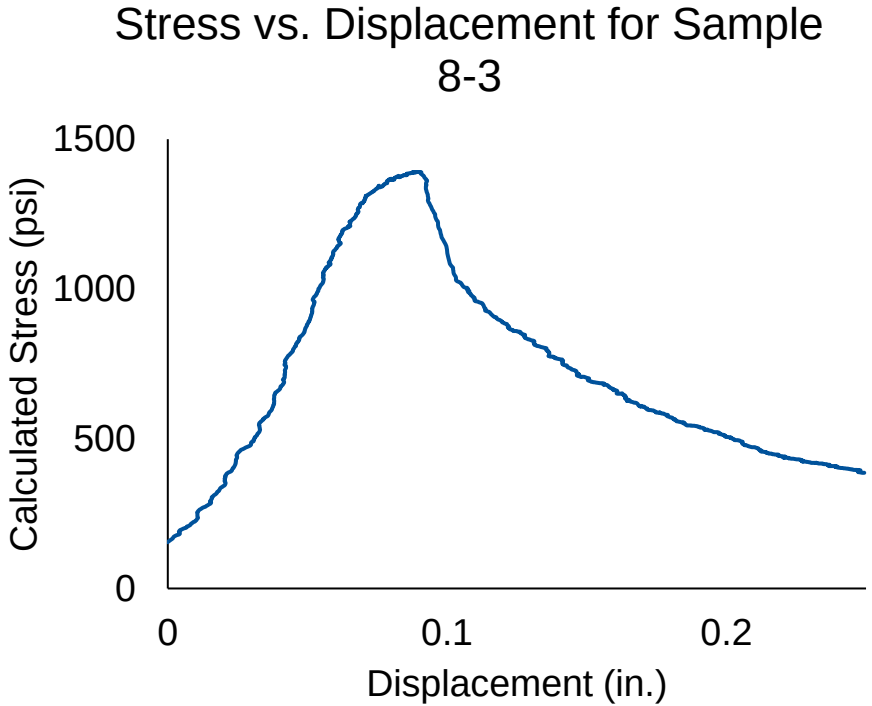


Toughness results

Data point displacement interval	Average toughness deviation from continuous data	Maximum toughness deviation from continuous data
0.050 in.	2.1%	4%
0.025 in.	0.55%	1.5%
0.010 in.	0.38%	2%

Parameters Measured

- Max stress
- Toughness
- Post-cracking strength (0.13 in.)



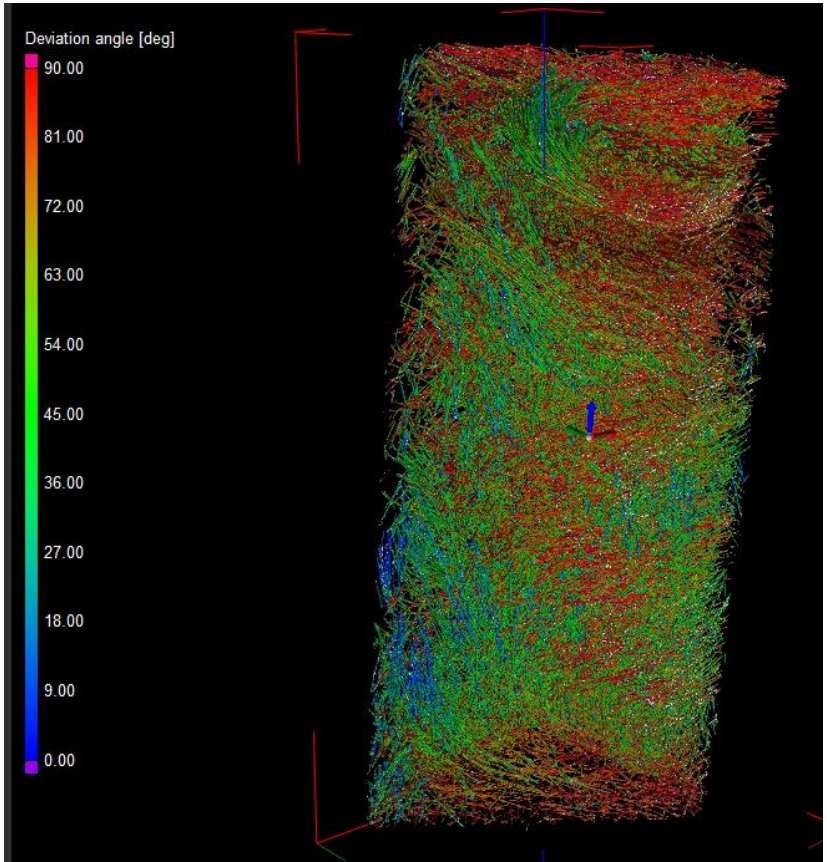
Double-Punch Ruggedness

- Casting method
  - Filled with a scoop (slow filling)
  - Filled with a bucket (fast filling)
- Surface roughness
  - Ground with cylinder grinder
  - Not ground
- Loading Rates
  - Fast: 700-800 lb/second
  - Slow: 200-300 lb/second
- Punch centering
  - Centered
  - Top punch 5mm off-center

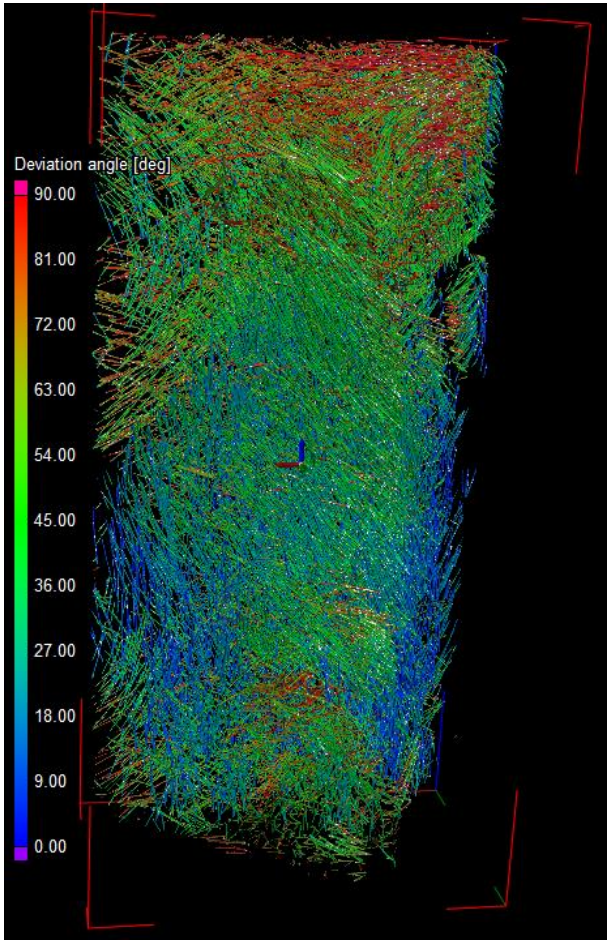
Double-Punch Ruggedness

- Casting method – Significant above 99% confidence interval
  - Filled with a scoop (slow filling)
  - Filled with a bucket (fast filling)
- Surface roughness – Not significant
  - Ground with cylinder grinder
  - Not ground
- Loading Rates – Not significant
  - Fast: 700-800 lb/second
  - Slow: 200-300 lb/second
- Punch centering – Not significant
  - Centered
  - Top punch 5mm off-center

Scoop

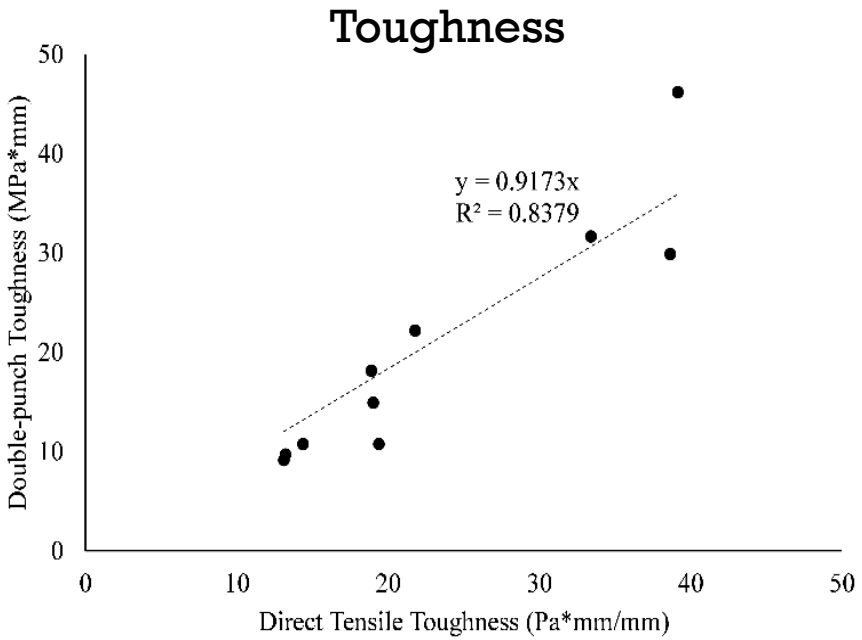


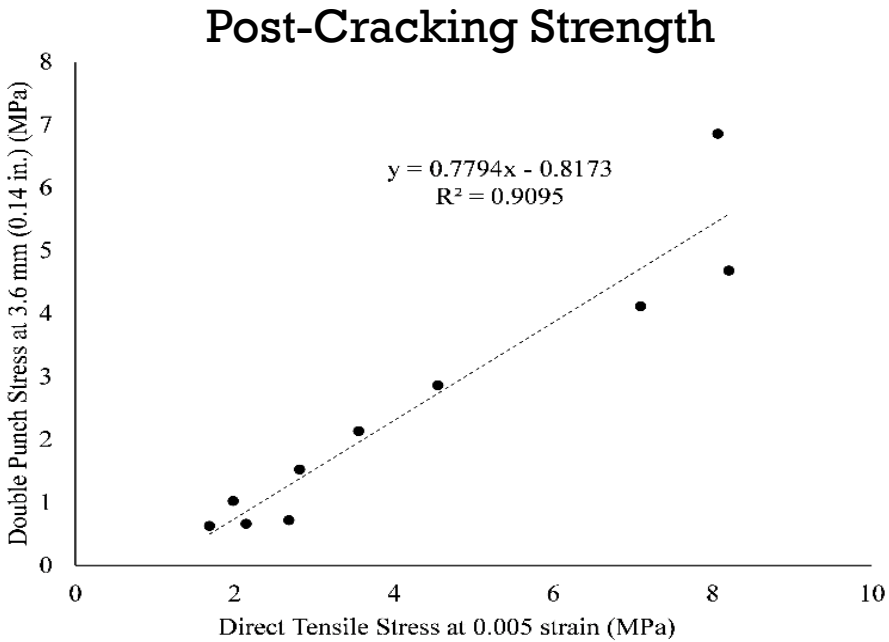
Bucket



Simplified Double Punch Test Compared to FHWA Direct Tension Test

Relation to Direct Tension Ductility Parameters

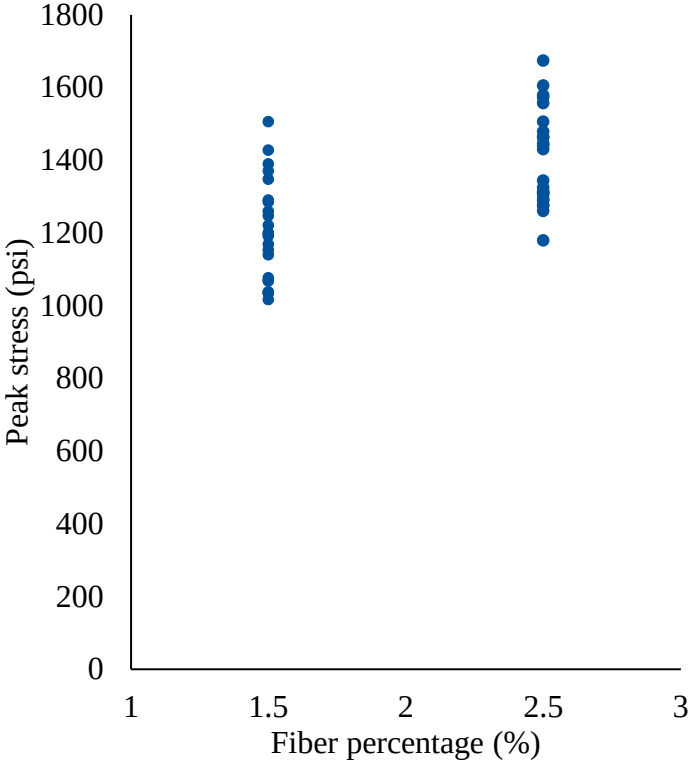


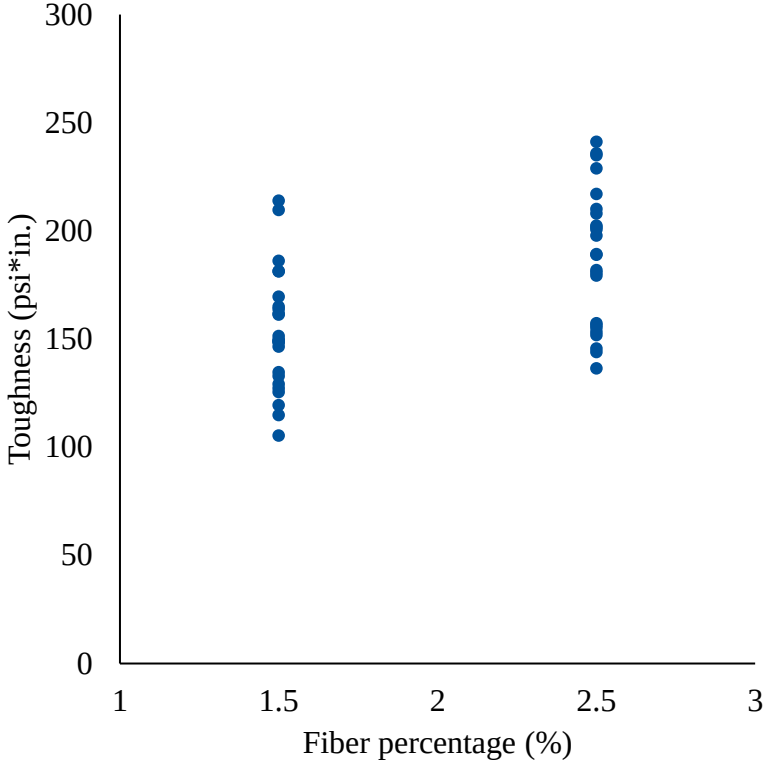


Round Robin Study

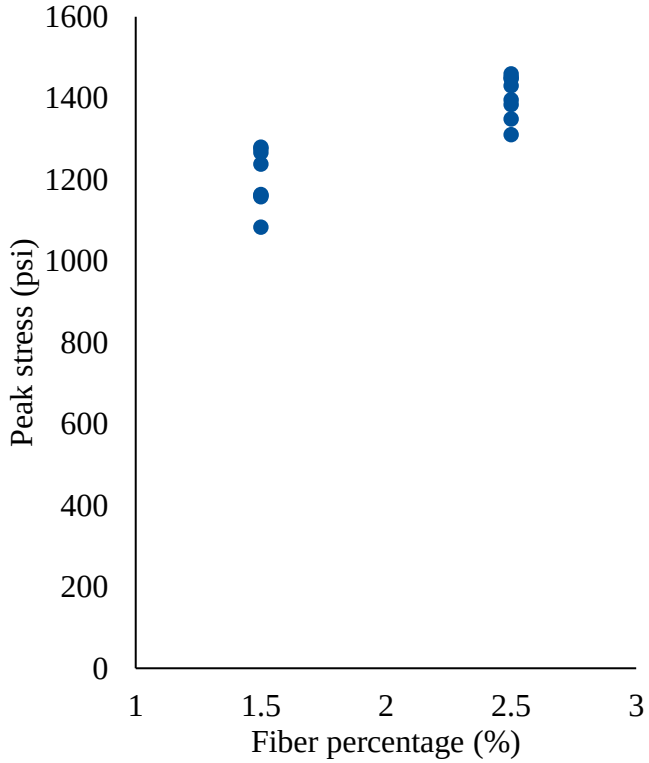
- 8 labs across Florida
- 2 mixes: 1.5% fiber and 2.5% fiber by volume
- 3 specimens for each mix for each lab

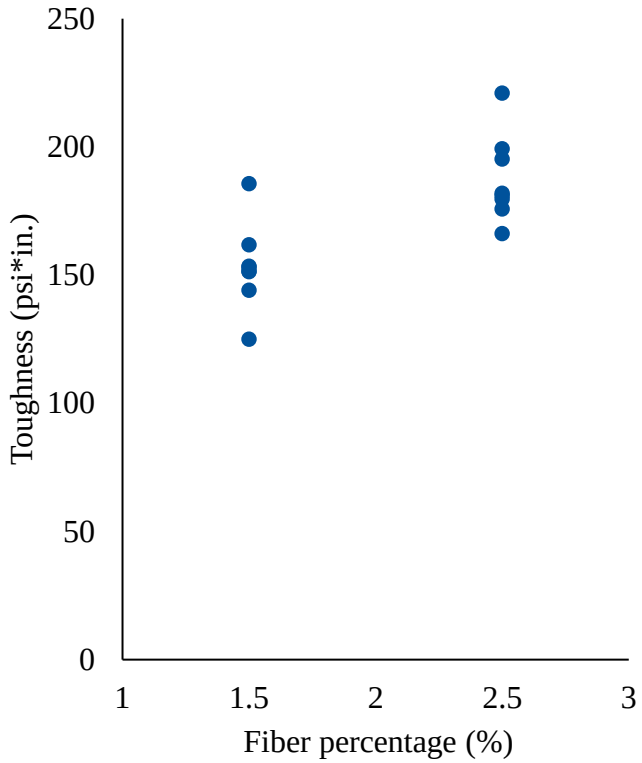
Round Robin Results – All Data





Round Robin Results – Averages





Round Robin Study Results

Standard deviations and CoVs for
All tests (24)/Lab averages (8)

	1.5% fibers		2.5% fibers	
	Peak Stress (psi)	Toughness (psi*in.)	Peak Stress (psi)	Toughness (psi*in.)
average	1205.5	153.2	1403.8	187.4
st.dev	139/72	28.0/16.9	131/54	32.0/17.1
CoV (%)	11.5/6.0	18.3/11.1	9.4/3.8	17.1/9.1

For comparison, ASTM C1609 gives single operator COV of:

- 9.2% for peak strength
- T^{100}_{600} is 17.3%

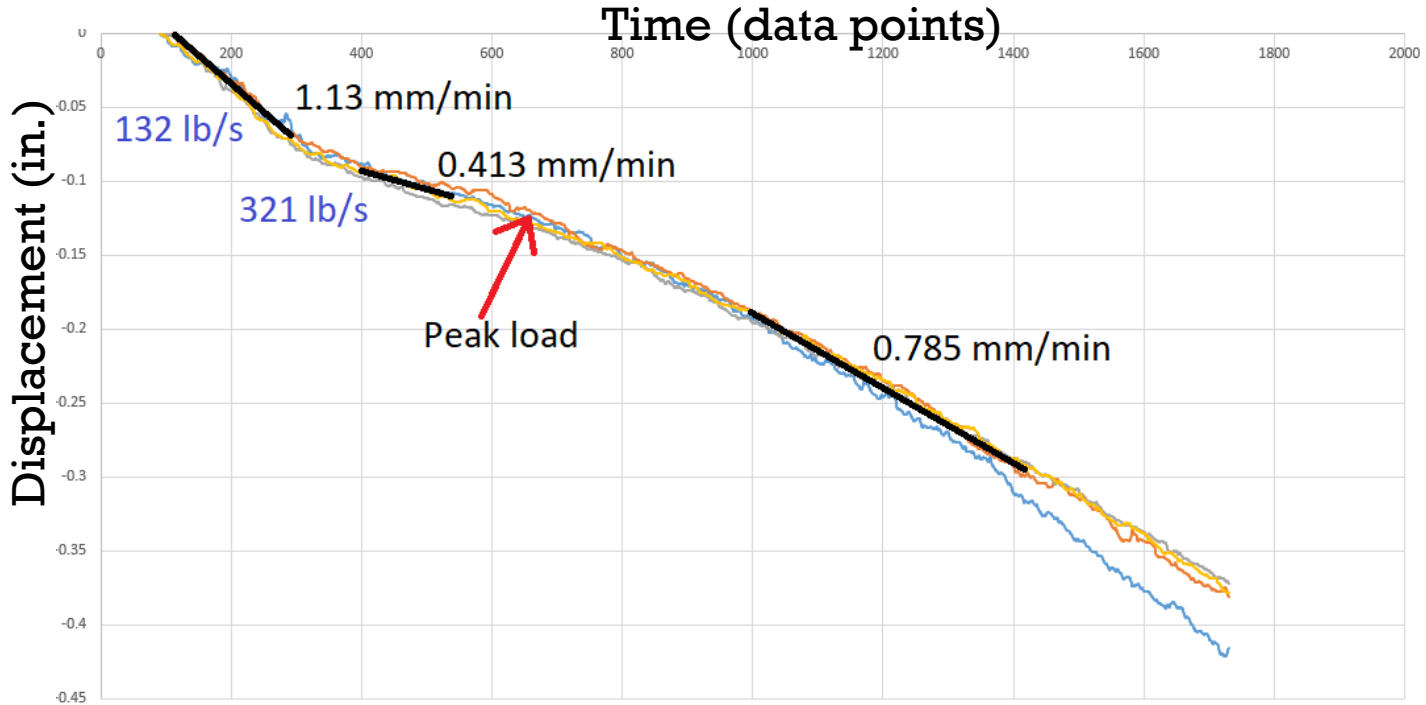
Tensile Testing Summary

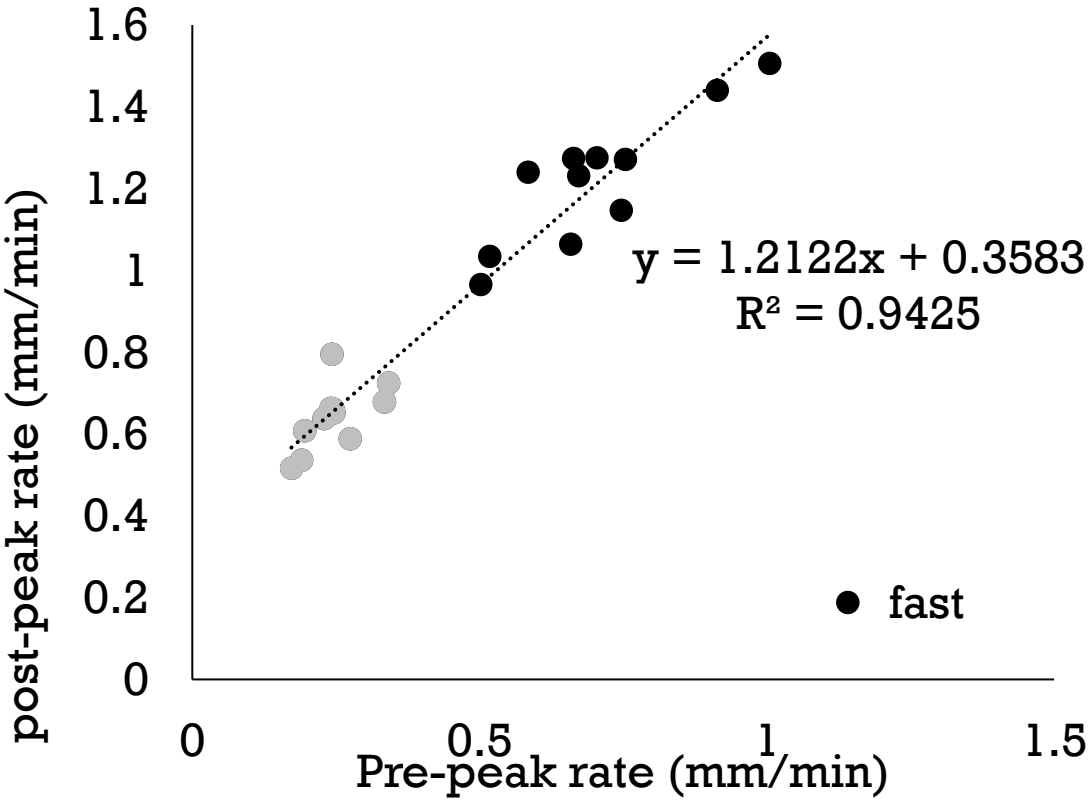
- QC Tensile test method MUST have a measure of toughness/ ductility
- Modified double punch test:
  - Test is easy to perform and train others (we have trained undergraduate students to perform it)
  - Would require only a few hundred dollars of new equipment for plants to run (many may already have the equipment at the plant)
  - Differentiates performance between mixtures, including as a measure of toughness
  - Good correlation with other more expensive tests
  - Reasonable COV found in round robin study
- Recommendation: Qualify mixtures with direct tension test or ASTM C1609, use new modified double punch test as QC test at the plant

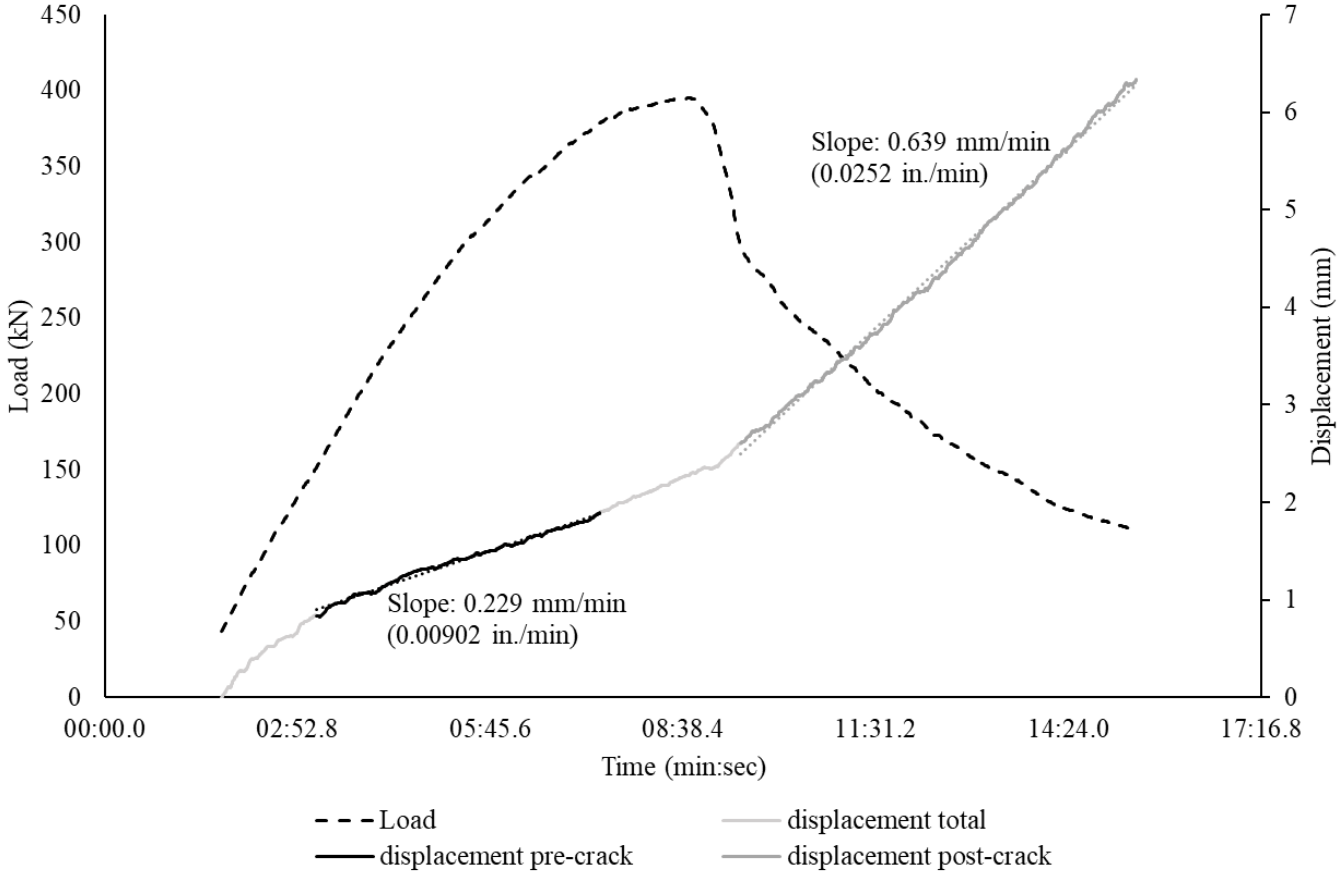
Thank You

- Florida Department of Transportation
- Material donors: Edgar Minerals, Argos USA, Sika Corporation
- Dr. Taylor Rawlinson, Josh Halford, Robbie Posada, Max Armstrong, Leonard Iacopelli
- Participating Labs

Displacement with standard compression machine




1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
post-peak rate (mm/min)
y = 1.2122x + 0.3583
R² = 0.9425
fast
0
0.5
1
1.5
Pre-peak rate (mm/min)


Load (kN)
Displacement (mm)
Time (min:sec)
00:00.0
02:52.8
05:45.6
08:38.4
11:31.2
14:24.0
17:16.8
Slope: 0.639 mm/min
(0.0252 in./min)
Slope: 0.229 mm/min
(0.00902 in./min)
Load
displacement pre-crack
displacement total
displacement post-crack

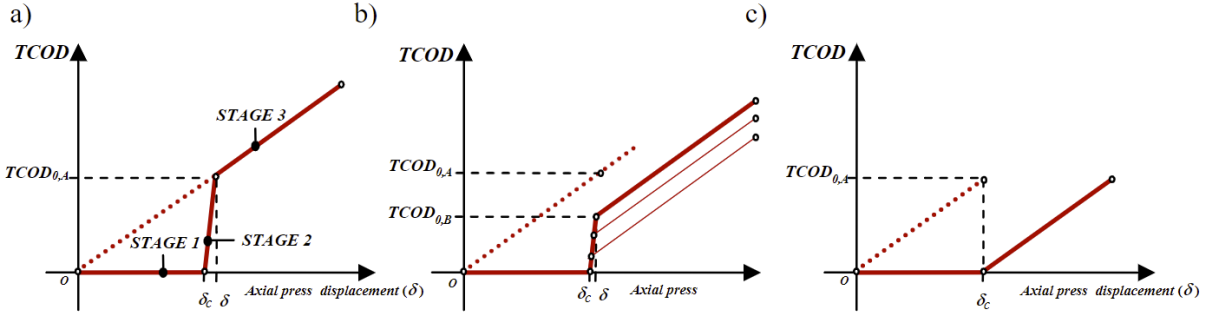


Fig. 6. Curves that relate *TCOD* and δ for FRC with: a) almost no residual strength; b) softening; and c) hardening

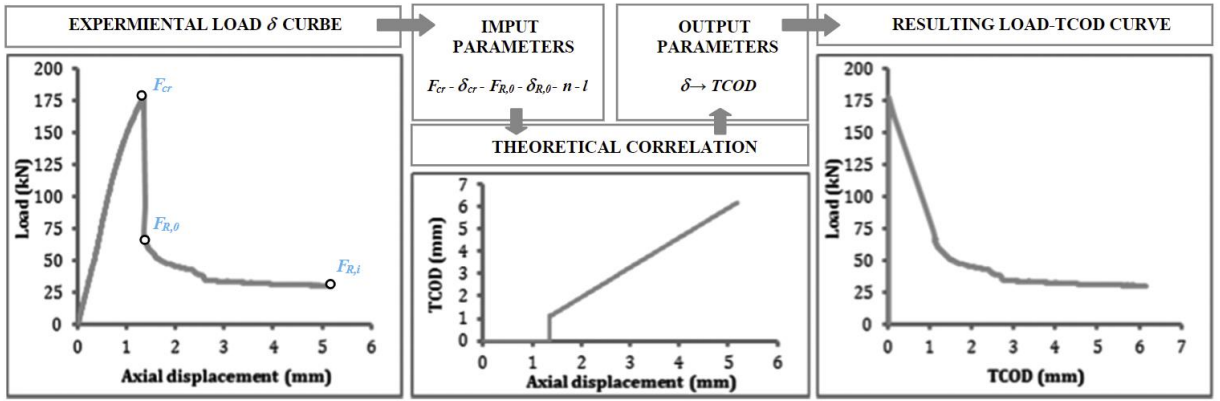


Fig. 7. Overview of the work philosophy to correlate *TCOD* and axial displacement (δ)