Lessons Learned from Fabrication and Experimental Testing of Prestressed UHPC H-Piles

Gabrielle Willis

PhD Student, Univ. of Alabama, Tuscaloosa

Sriram Aaleti

Associate Professor, Univ. of Alabama, Tuscaloosa

Outline

- Motivation and Objective
- Section Development
- Pile Fabrication
- Material Testing
- Experimental Testing
- Conclusions
- Next Steps

Motivation

Pile Problems:

- Steel piles:
  - High capacity
  - Damage during driving
  - Low environmental resistance
- Prestressed concrete piles
  - Good environmental resistance compared to steel piles
  - Large cross-section and weight
  - Damage due to tensile driving stresses

Photo: ehsani et al. (2012)

Photo: Moser et al. (2011)

Photo: DiMillio (1998)

Solution

Durable and **Drivable** pile using High performance material such as **U**ltra **H**igh **P**erformance **C**oncrete (**UHPC**)

UHPC

- Compressive strength: Up to 26 ksi
- Tensile Strength Range: 1.1 ksi to 1.7 ksi
- Extremely durable!

Portland Cement | Supplementary Materials | Superplasticizers | Fiber Reinforcement

Objective

- **Develop a UHPC H-Pile Comparable to a Steel H-pile**

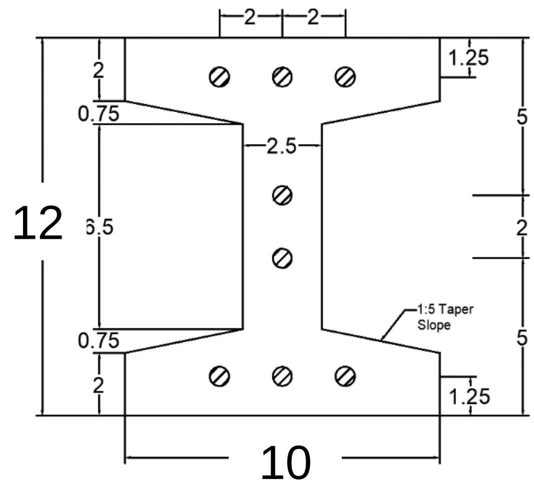
Section Development

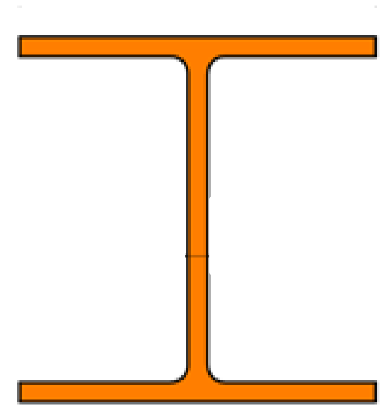
- Goals:
  - Create a 12-inch pile comparable to **HP12x53**
  - Create a 14-inch pile comparable to **HP14x89**
  - **Similar overall dimensions** to use the same pile driving cap
  - Maintain UHPC pile **weight within 20 lb/ft**
  - Precast plant **constructability**
  - Adequate **shear capacity**

- Tools:
  - Guidance from previous UHPC H-Piles (Iowa State, 2008)
  - First principles analysis
  - Prior UHPC experience

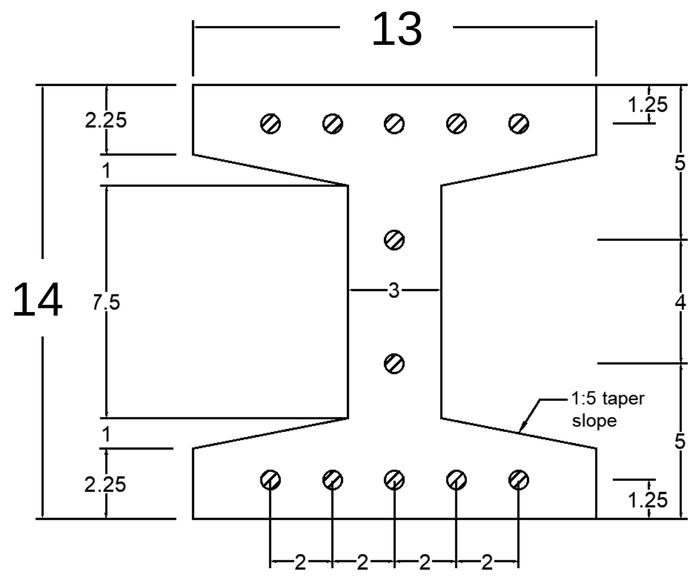
Section Development

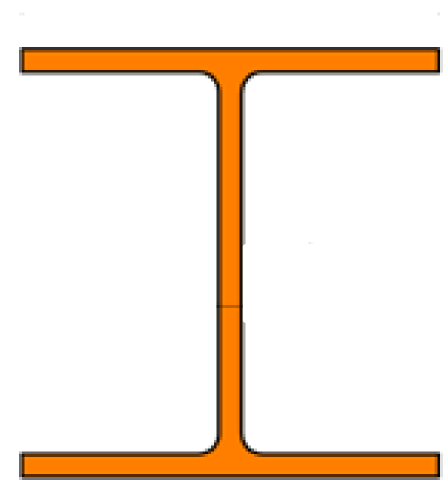
- UH12x71
  - (8) 0.6” 270 ksi strands





- UH14x105
  - (12) 0.6” 270 ksi strands





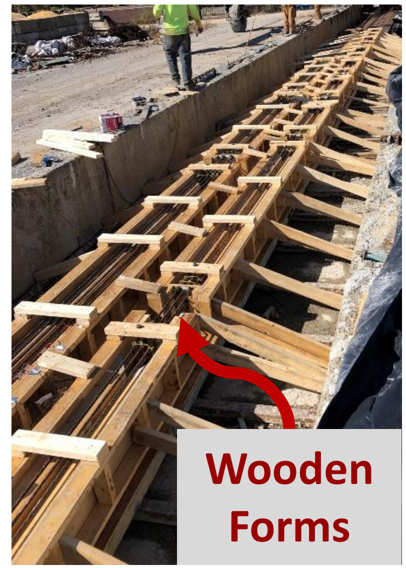
Section Development

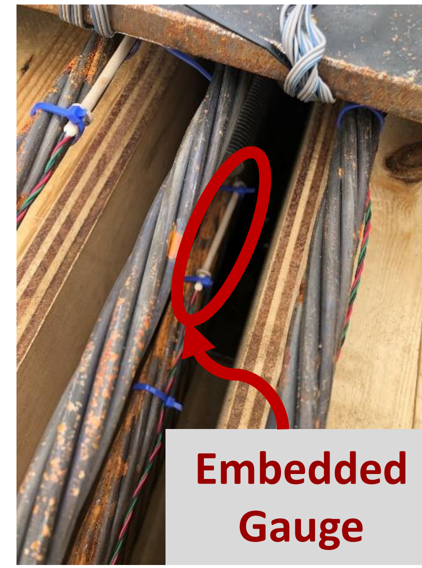
	HP 12x53	UH 12x71	12” PCPS square Pile
Weight	53 lb/ft	71 lb/ft	150 lb/ft
Area	15.5 in^2	65.6 in^2	144 in^2
ALDOT Allowed Load	300 kips	Expected: 460 kips	Not typically used for ALDOT

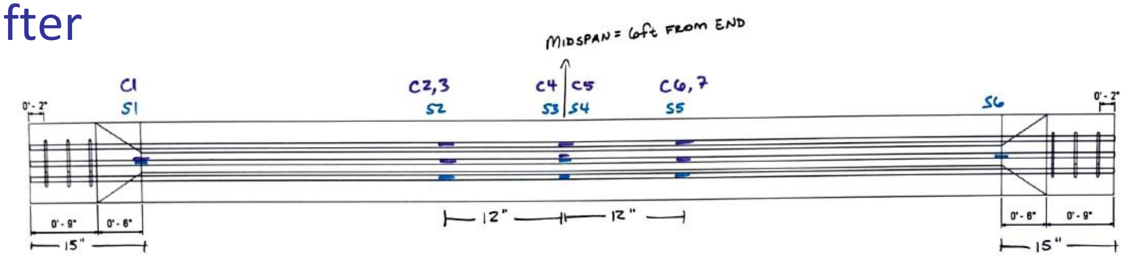
	HP 14x89	UH 14x105	14” PCPS square Pile
Weight	89 lb/ft	105 lb/ft	204 lb/ft
Area	26.3 in^2	97 in^2	196 in^2
ALDOT Allowed Load	500 kips	Expected: 650 kips	310 kips

Pile Fabrication

- 13 specimens cast, 133 feet total
  - 12” piles: (6) 6.5 foot splices, (3) 12 foot piles
  - 14” piles: (2) 12 foot, (1) 14 foot, and (1) 20 foot piles
- Instrumentation:
  - Foil and embedded gauges placed at transfer length on each end, and at mid-span
  - Gauges monitored before and after pour, as well as during and after detensioning
  - Short-term losses measured







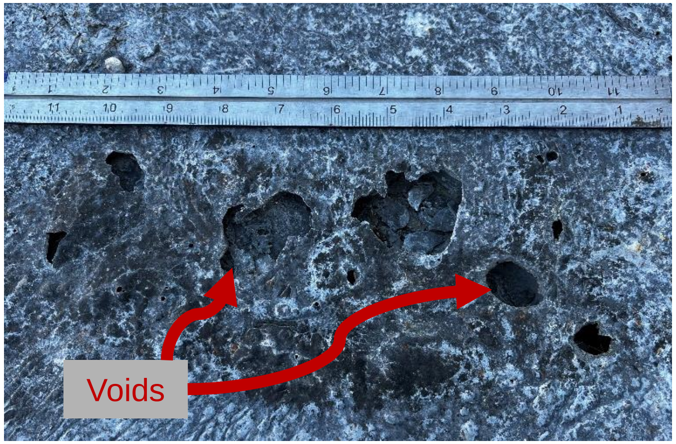
Sample pile instrumentation

Pile Fabrication

- UHPC mixed according to standard protocols
  - Company representatives present to lead mixing process
  - UHPC flow checked according to ASTM C1437
- Poured using overhead bucket
- UHPC able to flow around strands in narrow web
- Piles covered after all were poured
- Allowed to cure in ambient temperature, propane heaters placed on bed ends first two nights

Pile Fabrication

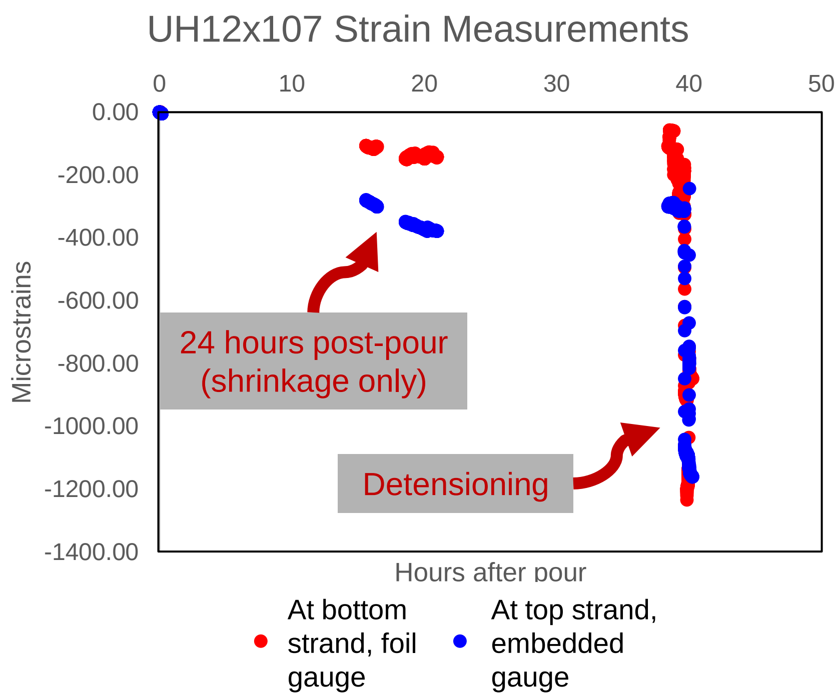
- Some shrinkage cracks, "elephant skin," and voids observed on top flange
  - Possible reason: some piles were not immediately covered after pouring



- Piles detensioned after 2 days
  - Concrete strength at detensioning: 13.9 ksi
  - Required strength: 9 ksi

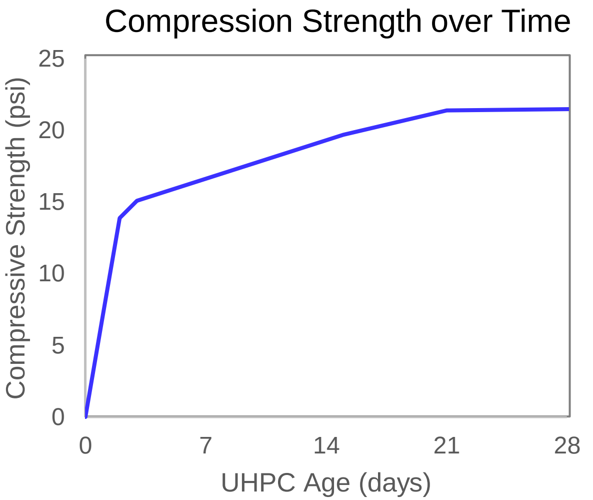
Short-term Losses

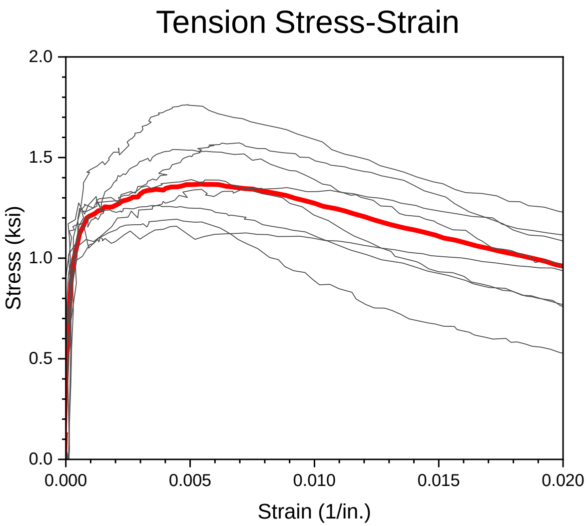
- Losses in select pile
  - Total losses observed over the first two days, including detensioning
  - Elastic shortening losses measured at an average of 23.1 ksi at midspan
    - 25 ksi expected
  - We also see higher shrinkage losses toward the top of the pile, which is less restrained than the bottom

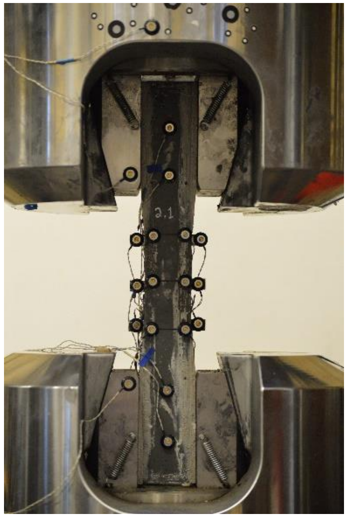


Material Testing

- Compressive Strength
  - 3x6 cylinders tested (ASTM C39, C1856)
  - 1 day strength of 7.0 ksi
  - Release strength of 13.9 ksi
  - Reached 21 ksi by 21 days
- Elastic Modulus
  - 3x6 cylinders tested (ASTM C469, C1856)
  - Elastic Modulus at 3 days: 6100 ksi
- Tensile Strength
  - (8) Direct Tension specimens tested
  - Average strength of 1.4 ksi

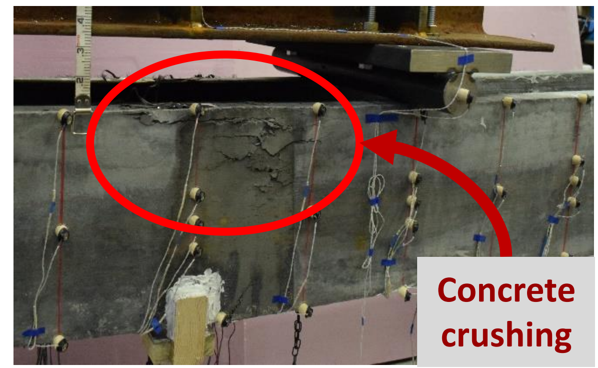


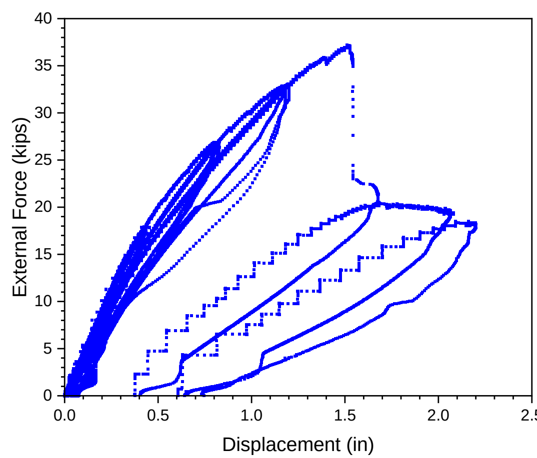


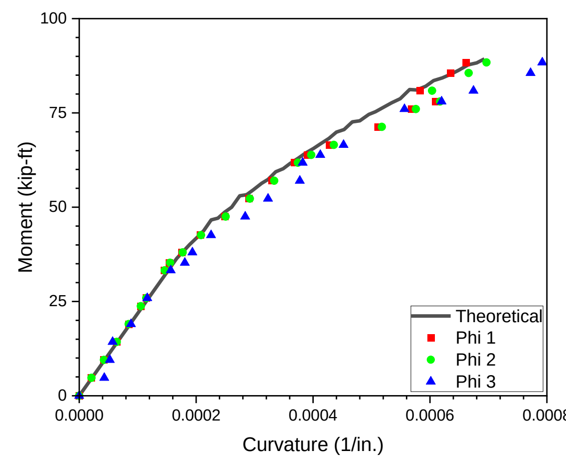


Flexural Testing

- Four-point bending used for flexural testing
  - 11.5 foot span, 2 foot spaced load points
- 12-inch pile, weak axis:
  - Expected failure at 37.6 kips, calculated using first principles
  - Actual failure at 37.2 kips
  - Compression controlled failure
  - More than half of capacity retained after failure
  - Theoretical curvature matches well with various experimental curvature measurements







Preliminary Conclusions

- Pile fabrication:
  - Piles must be covered immediately to avoid elephant skin and drying shrinkage cracks
  - Web thickness dictates constructability
  - Expected losses are realistic
- Flexural testing:
  - First principles analysis using measured material properties can capture behaviour

Next Steps

- Continued flexural testing
- Shear capacity testing
- Pile splice testing
- Cast piles into abutments → test with axial load

Thank you!