Relaxation of Driven Piles in Florida Soils

BED25-977-05

GRIP 2022

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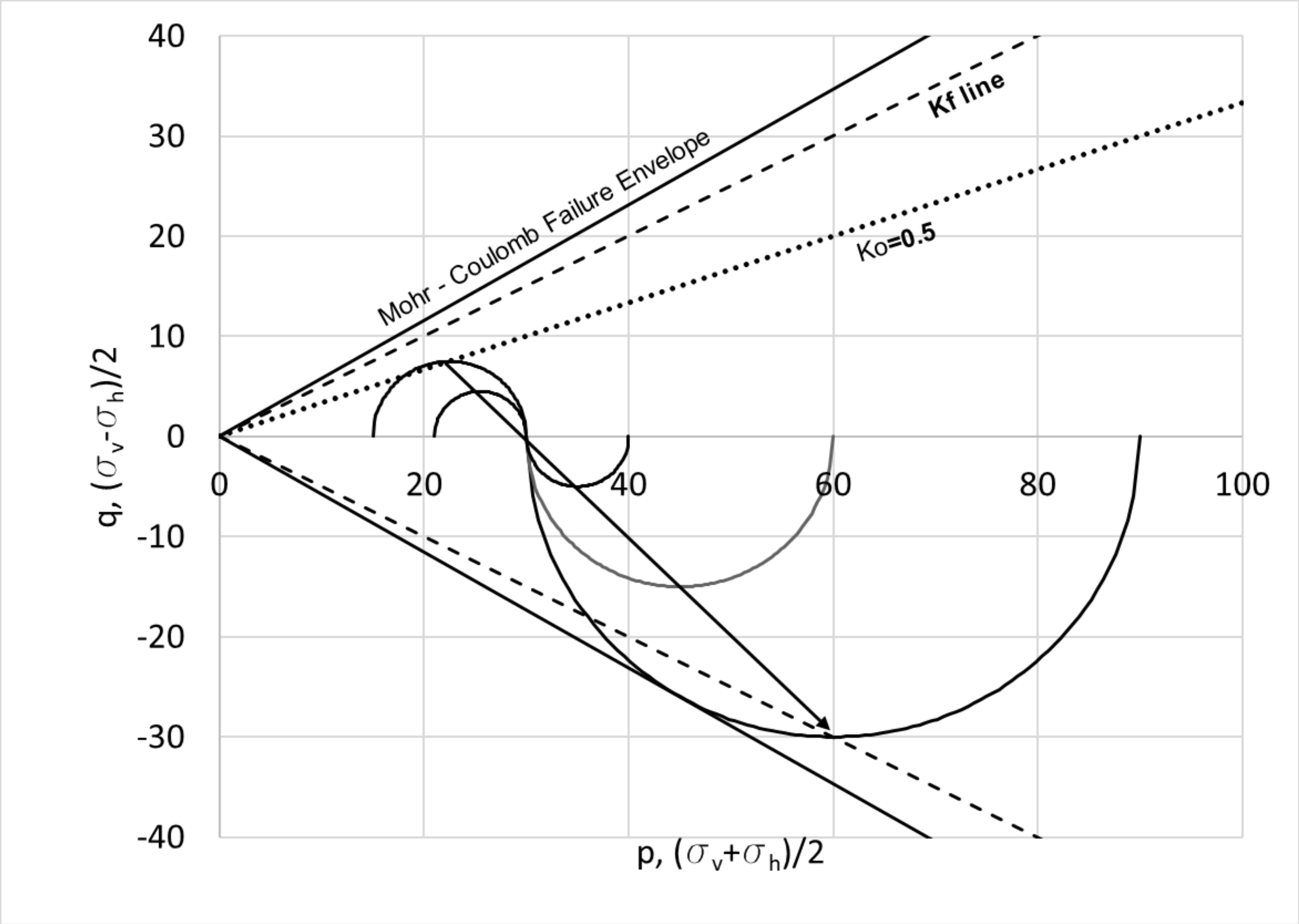
Background/Introduction

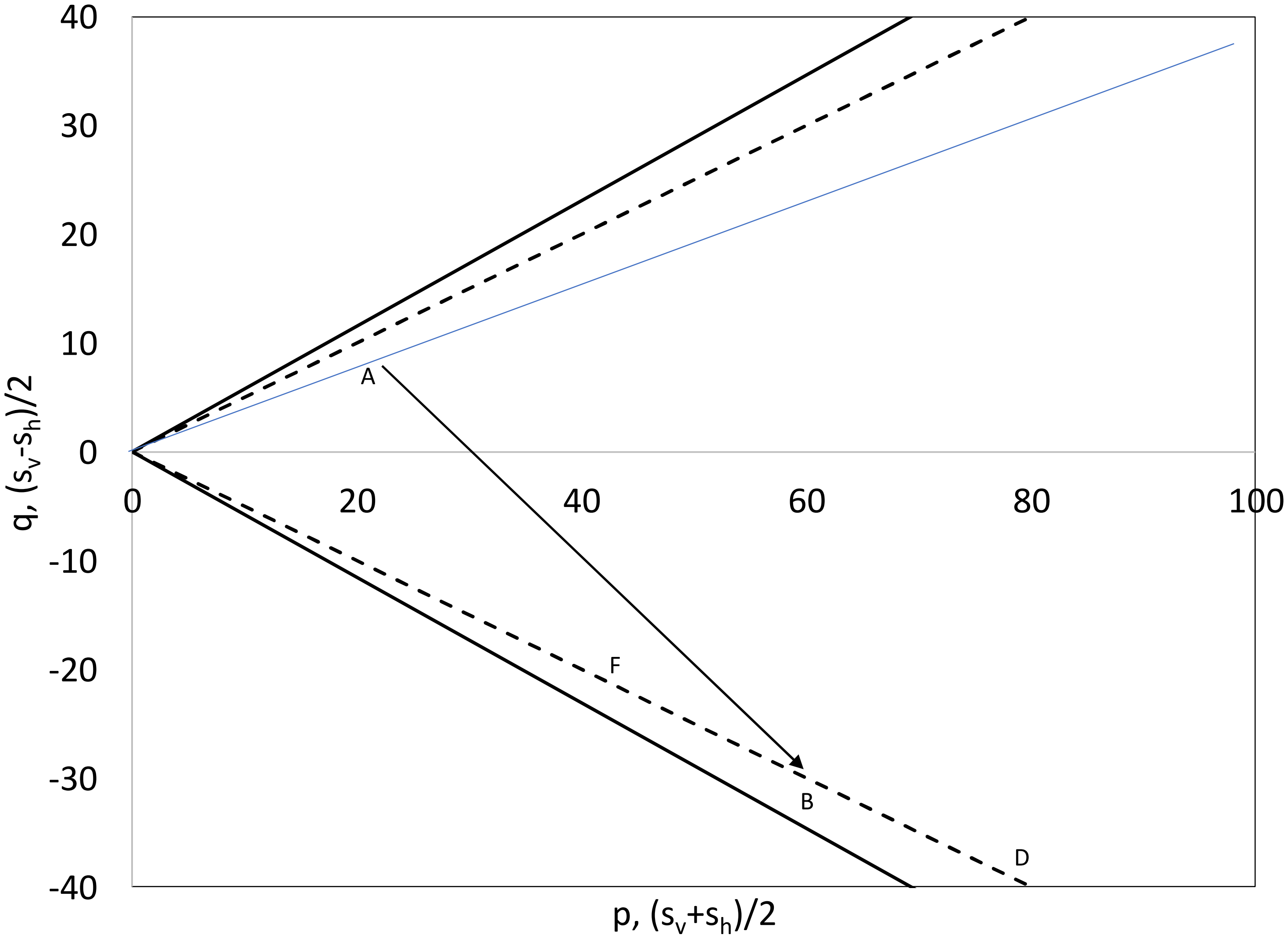
- Driven piles can exhibit an increase or decrease in capacity relative to end of drive conditions defined as *set-up* or *relaxation*, respectively.
- Set-up is beneficial to pile performance; relaxation is not.
- The mechanism of pile relaxation has been attributed to dilative soil conditions that cause negative pore pressure making the soils respond stronger during driving (until the pore pressure dissipates).

Principal Stress Inversion

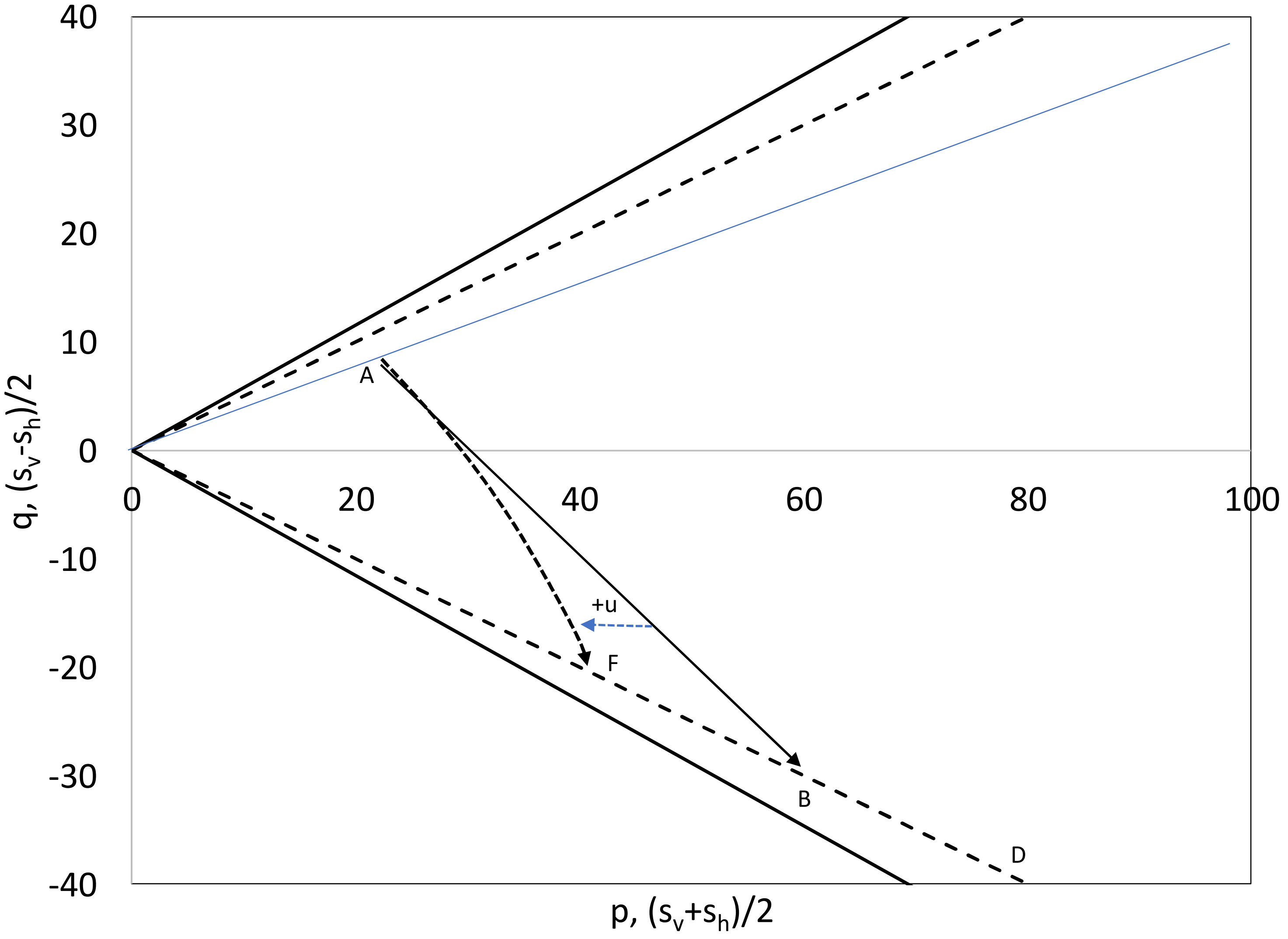
Displacement Piles



Pile Set-up



Pile Set-up



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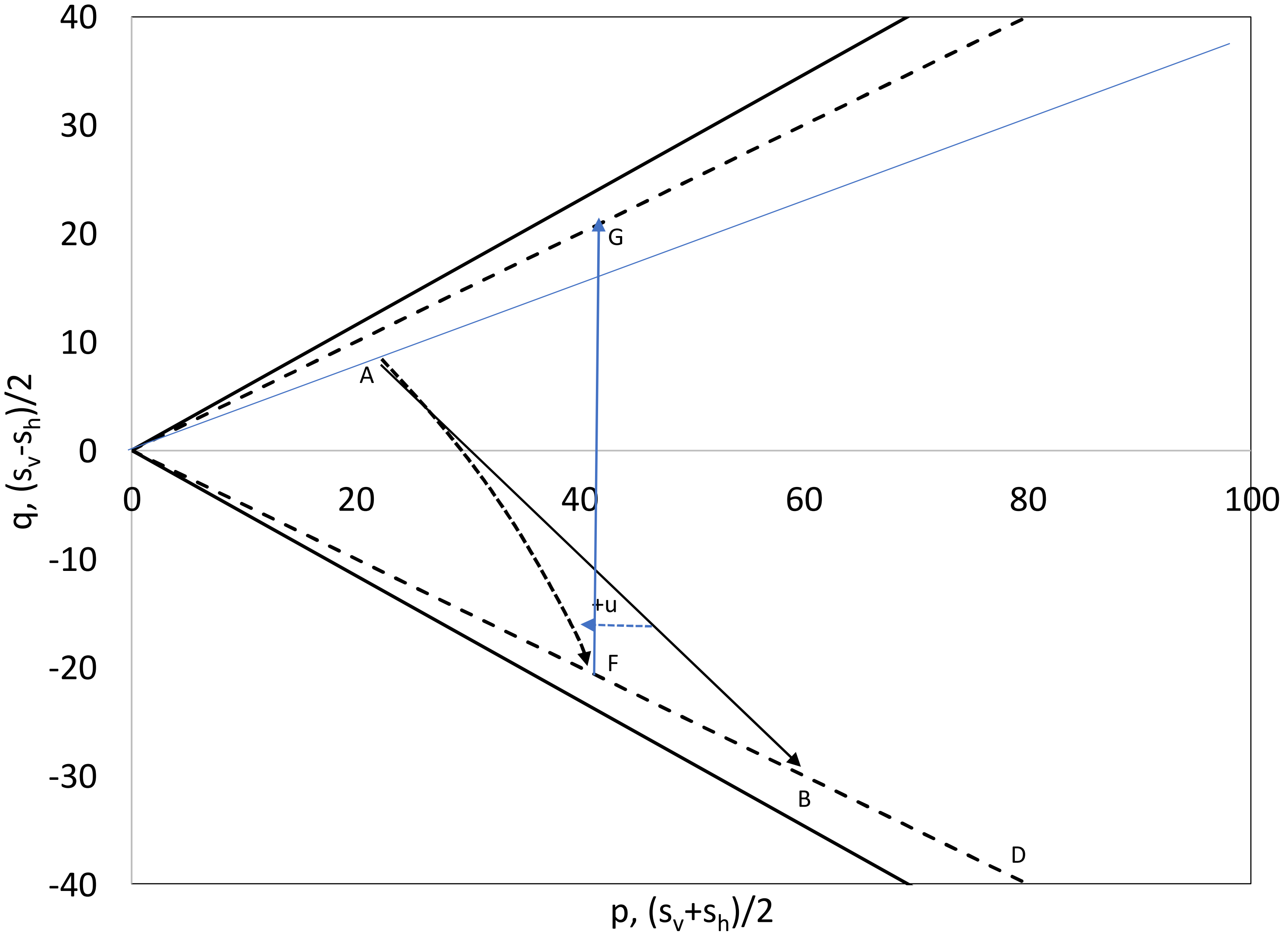

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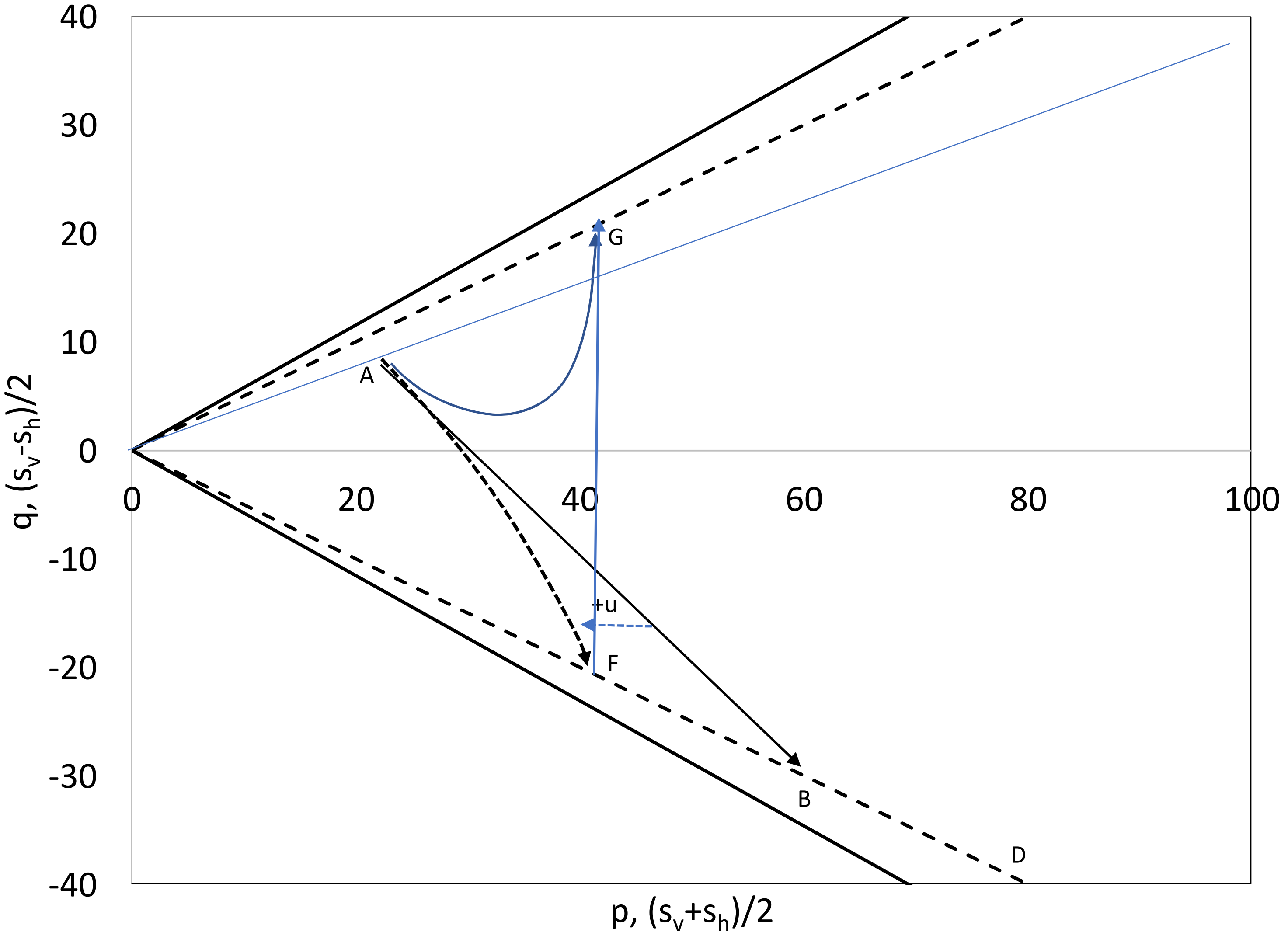
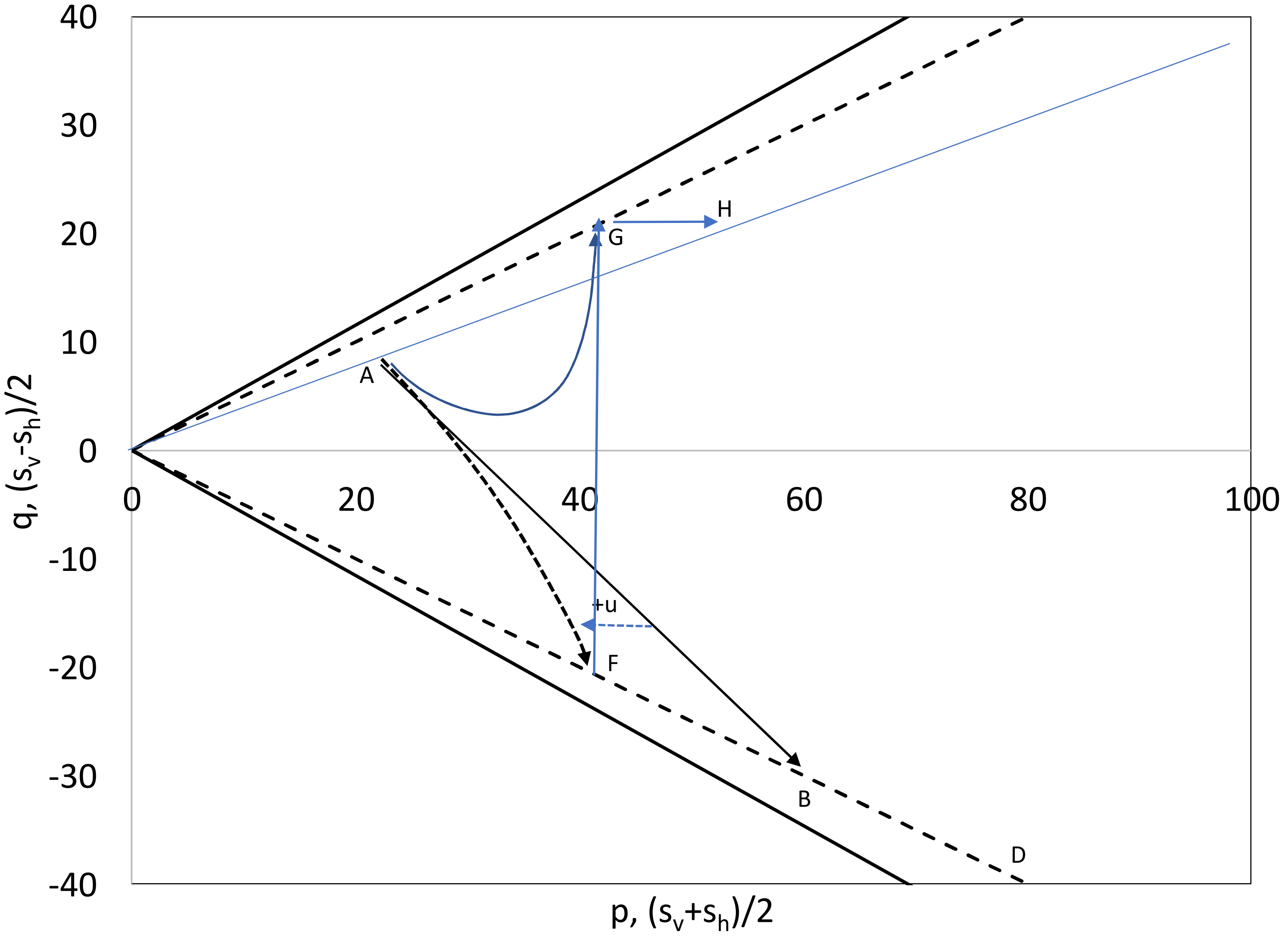
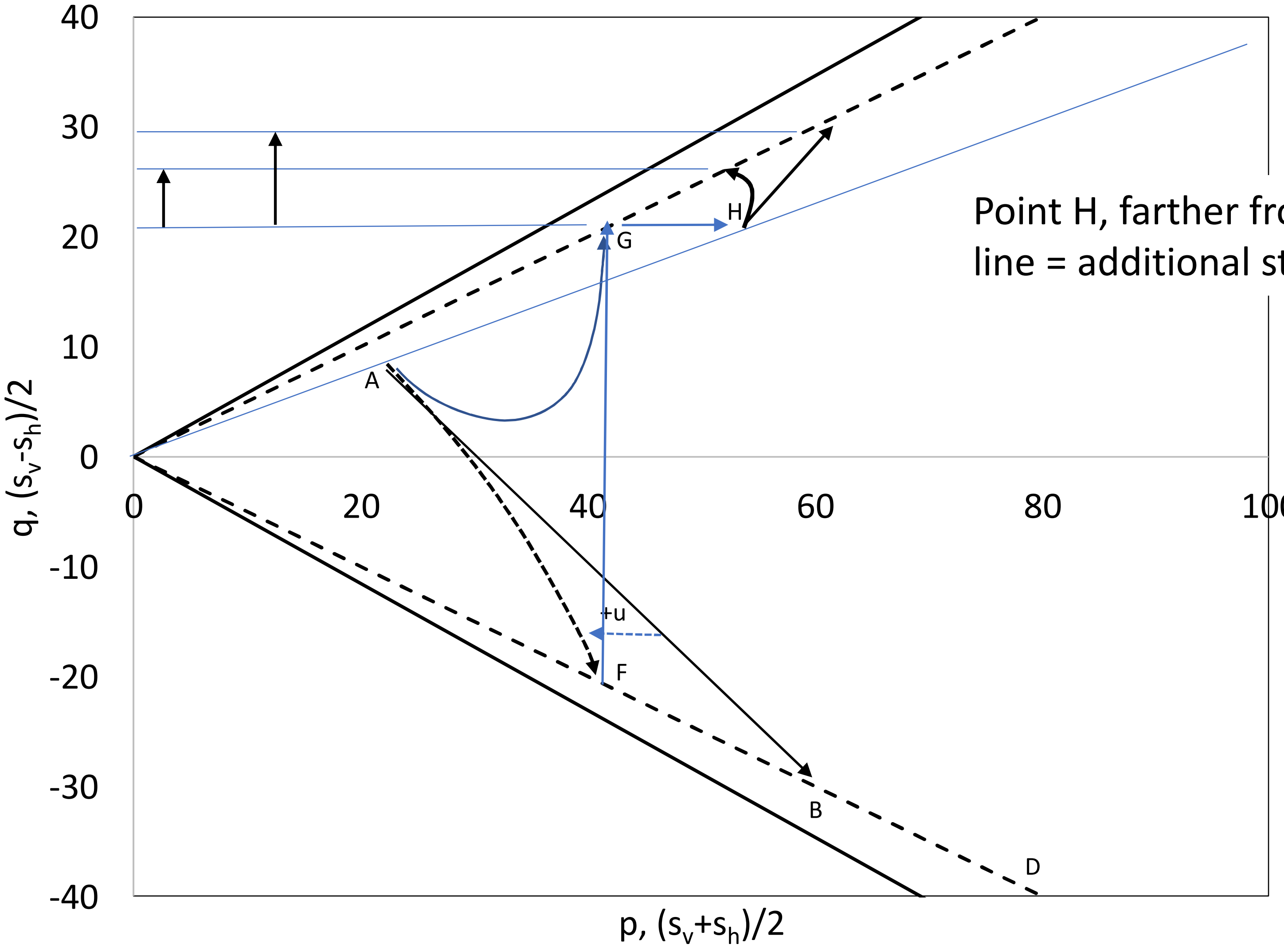


Pile Set-up

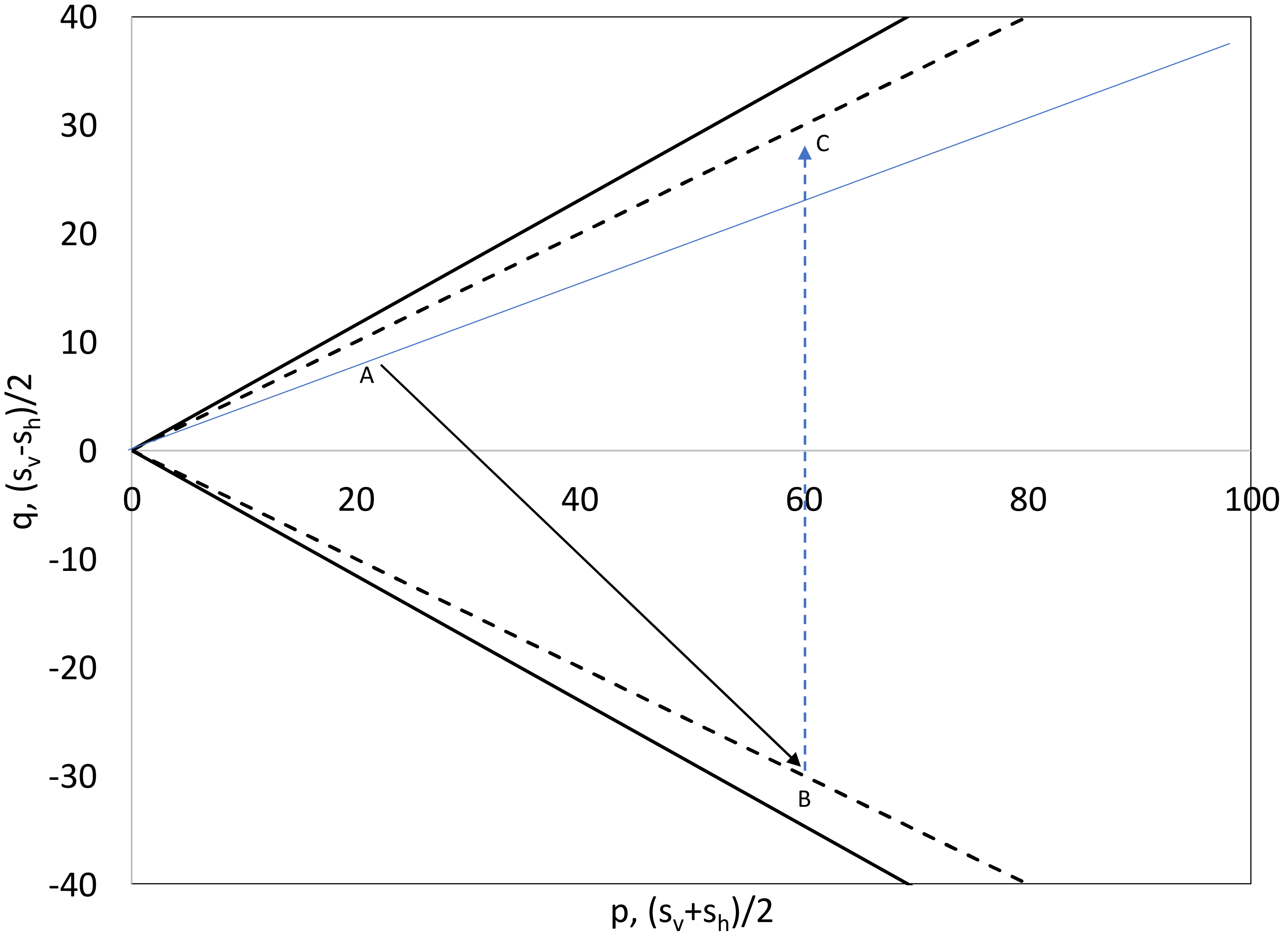


Pile Set-up

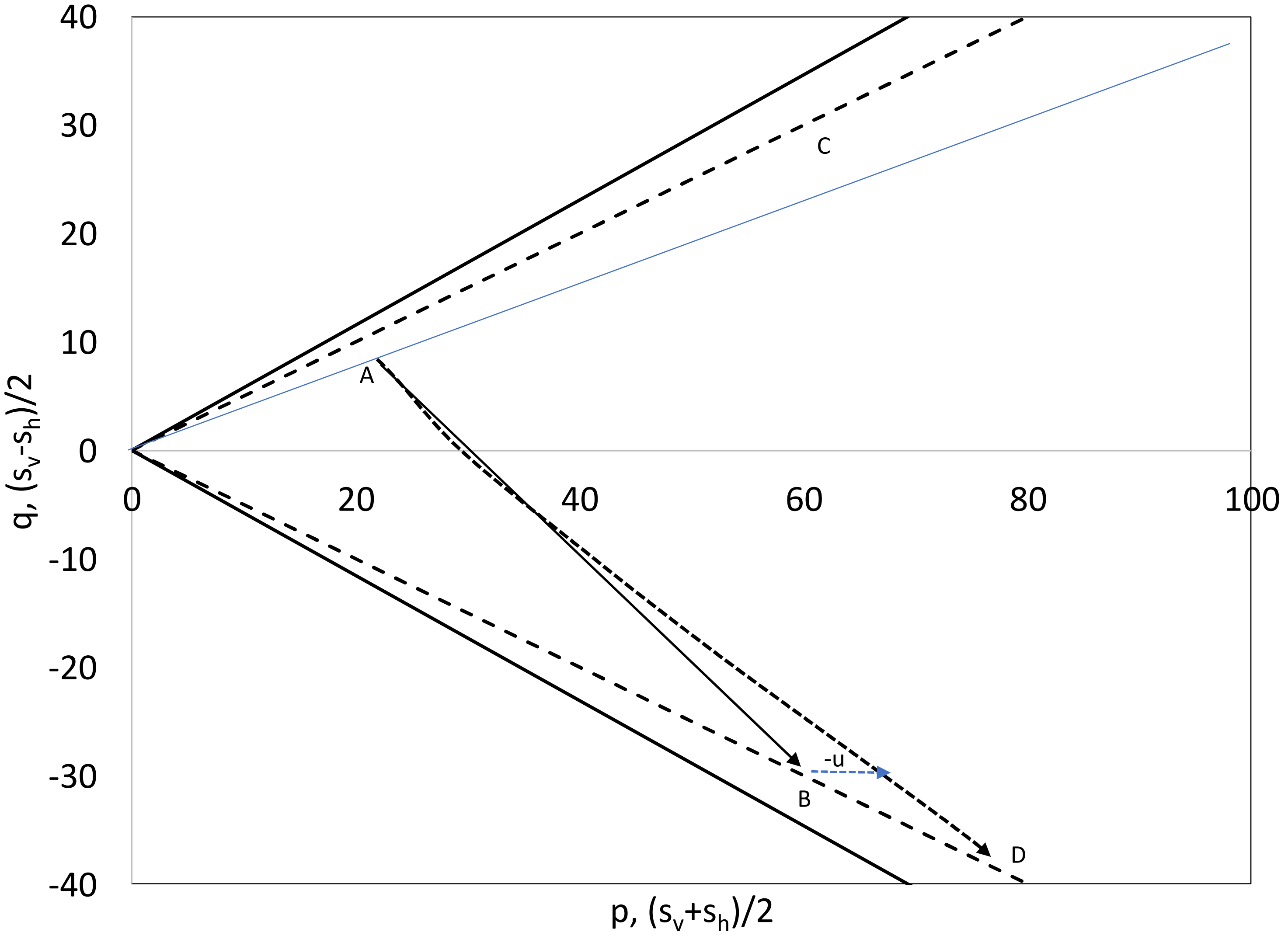


Point H, farther from Kf line = additional strength

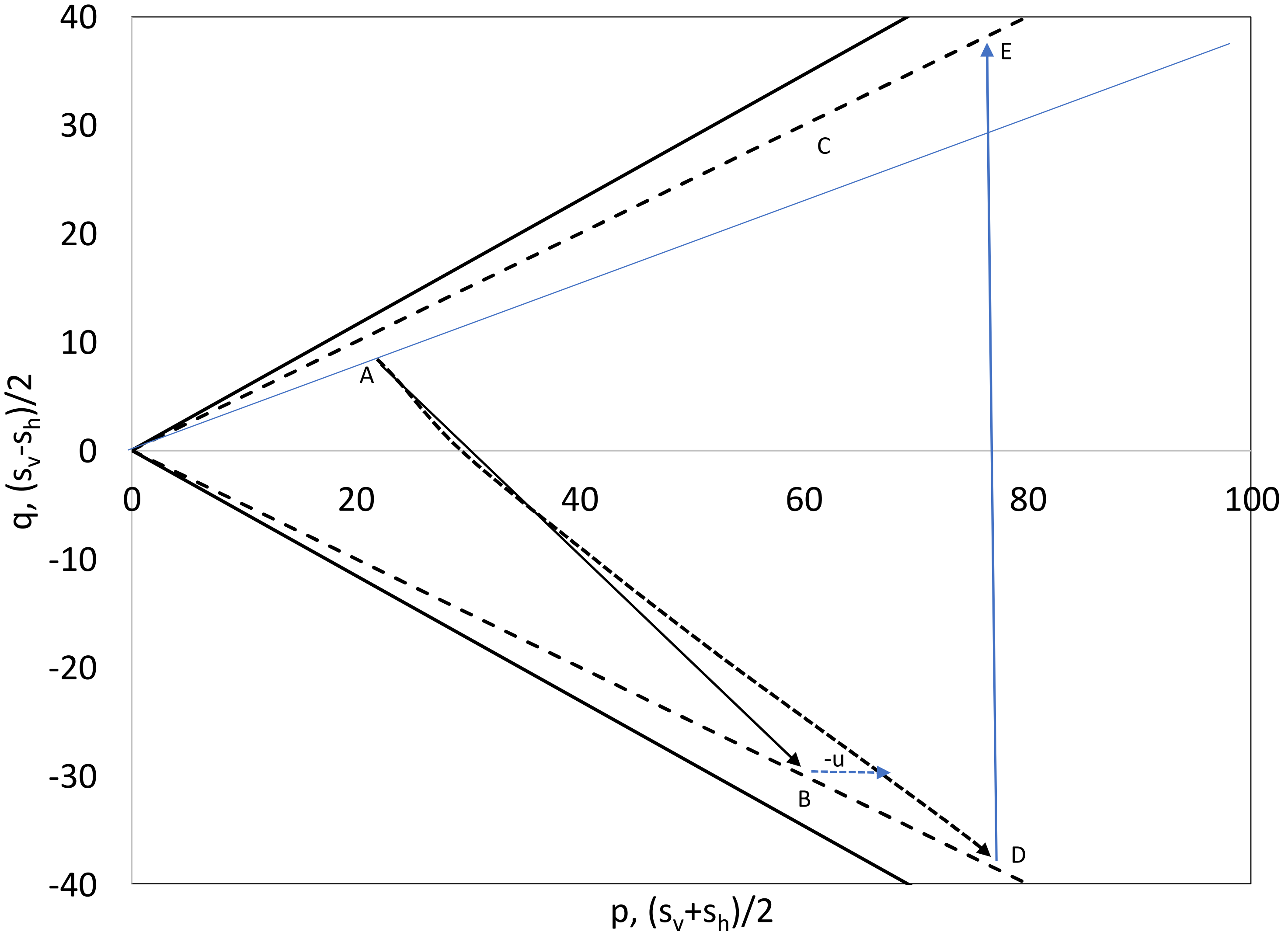
Pile Relaxation



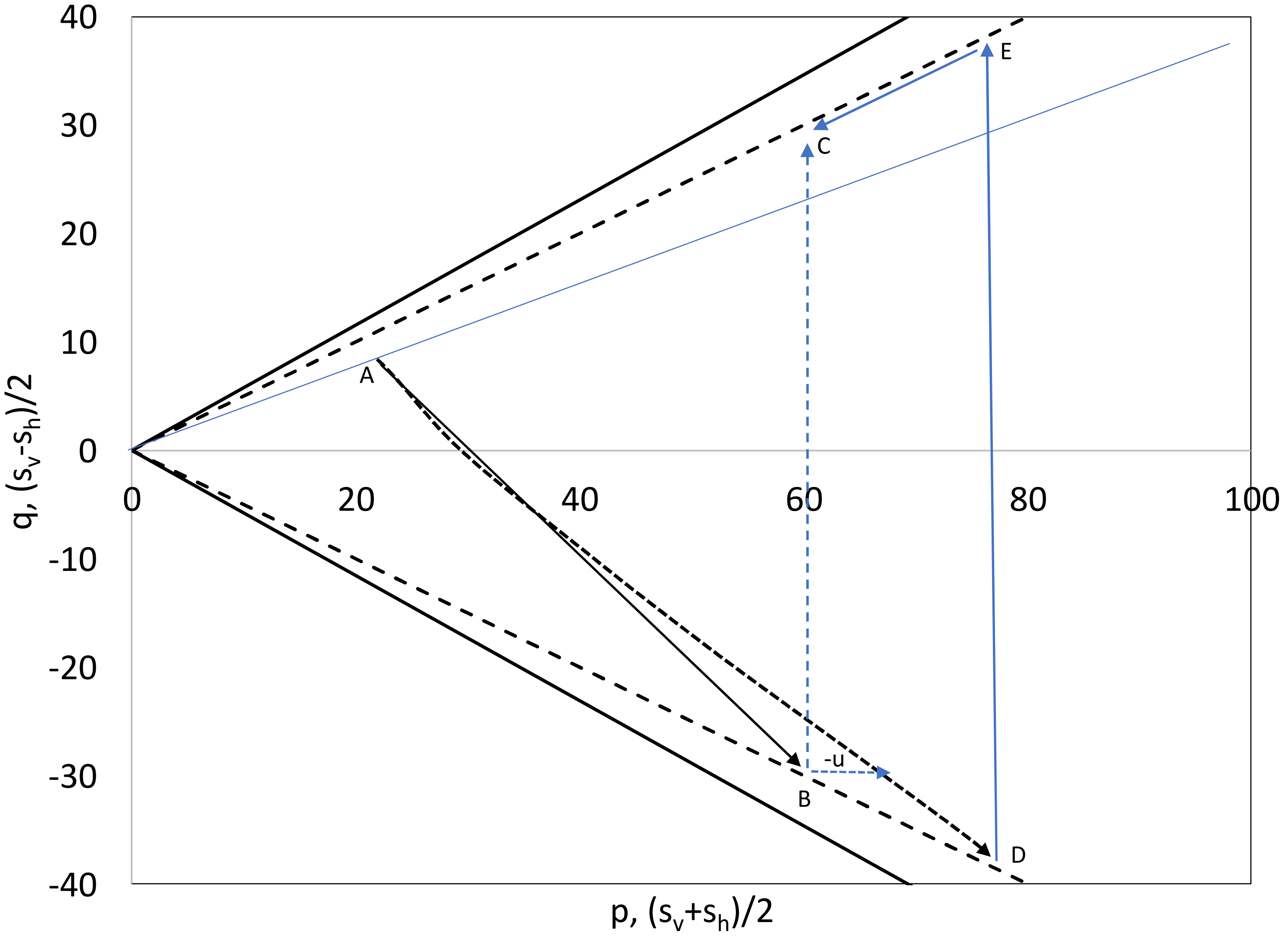
Pile Relaxation



Pile Relaxation

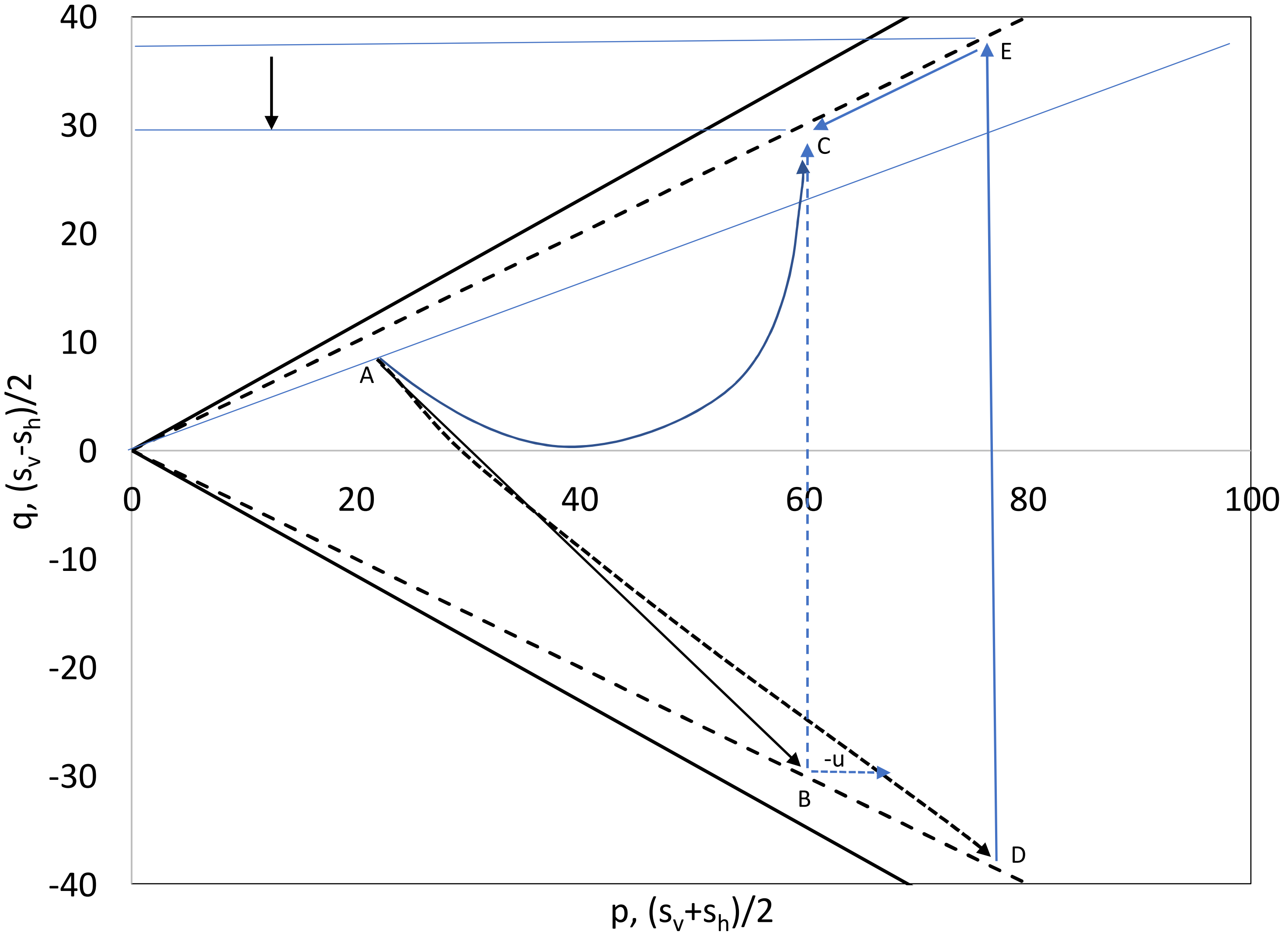


Pile Relaxation

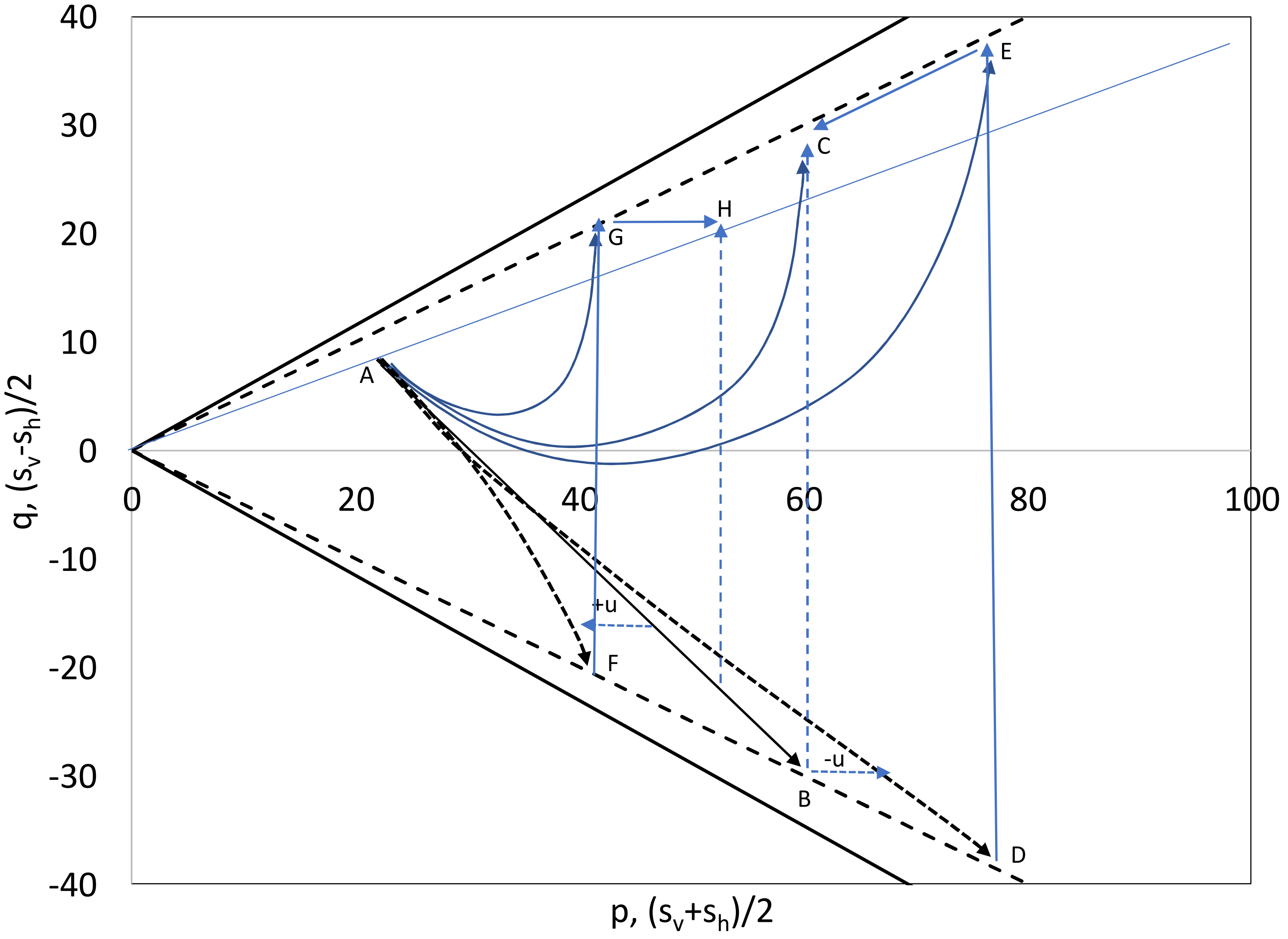


Pile Relaxation

Loss of capacity

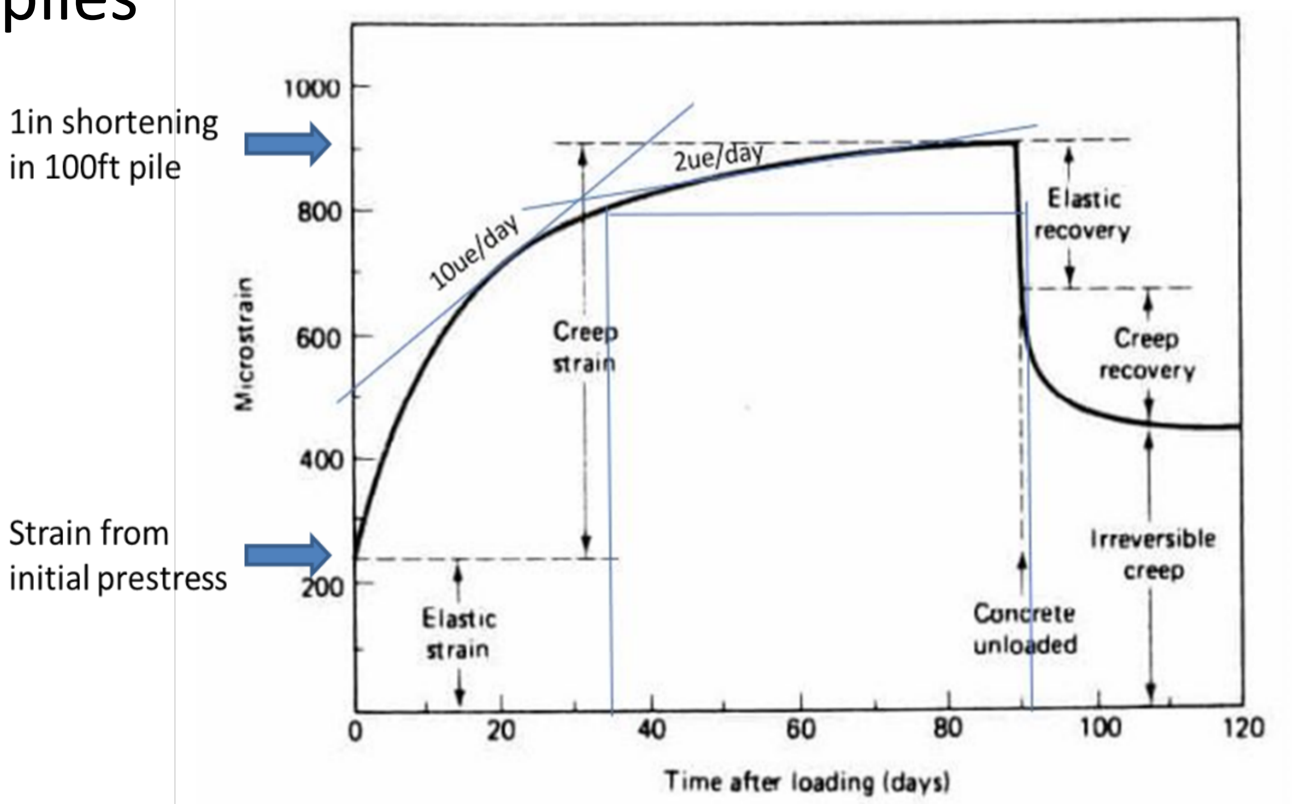


Pile Relaxation



Pile Relaxation

- Case studies have show relaxation up to 48 days which is far longer than expected pore pressure dissipation time in dense sands.
- An alternate mechanism could be concrete creep from young prestress piles



Pile Relaxation

- Case studies have also shown restrikes have regained capacity in as little as 0.5in or as much as 7 ft.
- Large displacements required to regain capacity is likely to be caused by negative pore pressure
- Small displacements required to regain capacity could be due to concrete creep/shortening

- Evaluation of database for soil strata and pile casting information will form the primary effort (Task 2)

Soil conditions change. . .

Problem Statement

Relaxation is the reduction in pile capacity with time. It is a phenomenon that has been observed in several projects, especially Design Build projects as a result of verification testing. There have been reported cases in which over 25% of the ***original measured capacity has been lost*** *after initial pile driving. Currently the Department* ***does not have a methodology*** *to assist designers estimate relaxation (protocols for In-Situ testing or laboratory testing), nor a process to establish a pile driving criteria to accept piles during construction when relaxation occurs.* ***This creates delays, extra testing and extra costs*** *during construction, especially because the problem is typically found after pile driving begins. In most cases the issue has been resolved by additional driving until the piles reach a stable bearing layer.*

Objectives

- The primary objective of this study is to document as many cases as possible from within the state of Florida where pile relaxation has been experienced.
- Determine what soil types and conditions are likely to create relaxation conditions
- Ultimate goal is to determining appropriate field and lab testing and/or protocols suitable for construction and design.

Work Tasks

- Task 1: Literature Search
- Task 2: Data Collection (data mining of the FDOT EDMS)
- Task 3: Data Analysis
- Task 4a: Draft Final Report
- Task 4b: Closeout Meeting / Presentation
- Task 5: Final Report

Work Tasks

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Literature Search

Basu, P., Salgado, R., & Prezzi Tanusree Chakraborty, M. (2009). *Final Report: A Method for Accounting for Pile Set Up and Relaxation in Pile Design and Quality Assurance*. Retrieved from West Lafayette, IN:

Bolton, M. D. (1986). "The strength and dilatancy of sands." *Geotechnique, Volume 36, Issue 1,* pp 65-78.

Bullock, P. J. (2008). *The Easy Button for Driven Pile Setup: Dynamic Testing*. Paper presented at the Civil Engineering at Research to Practice in Geotechnical Engineering Congress 2008, New Orleans, LA.

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Chung, C.-K. *SNU Geotechnical and Geoenvironmental Engineering Lab: Advanced Soil Mechanics I*. Seoul National University.

Giri, D. *Advanced Soil Mechanics Lecture Note*. Veer Surendra Sai University of Technology. Burla, India.

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Literature Search

Hetty. *MAJ 1013 - Advanced Soil Mechanics: Stress Paths, Critical State Soil Mechanics*. University of Southeastern Philippines.

Holtz, R.D. and Kovacs, W.D. (1981). “An Introduction to Geotechnical Engineering,” Prentice Hall, Englewood Cliffs, New Jersey, ISBN0-13-484394-0.

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Sasitharan, S. (1989). *Stress Path Dependency of Dilatancy and Stress-Strain Response of Sand.* (Master of Applied Science). University of British Columbia, Vancouver, British Columbia.

Literature Search

Sawant, V. A., Shukla, S. K., Sivakugan, N., & Das, B. M. (2013). Insight into Pile Set-up and Load Carrying Capacity of Driven Piles. *International Journal of Geotechnical Engineering, 7*(1).

State of California Department of Transportation. (2011). Trenching and Shoring Manual. In. Sacramento, CA: California Department of Transportation.

Tan, S. L. (2012). *A Case History of Pile Relaxation in Recent Alluvium*. Paper presented at the GeoCongress 2021, Oakland, CA.

Whitlow, R. (1990). “Basic Soil Mechanics, 2nd Edition,” John Wiley & Sons, Inc., New York, NY, ISBN 0-582-04564-9.

Plea for Data

- Consultants
- Contractors
- District Engineers

- If you know of past projects / sites let us know

Peak Temperature Determination of Drilled Shafts

Background

- Curing concrete produces heat energy that in turn elevates the internal temperature of the concrete.
- Excessive temperatures can lead to:
  - Differential temperature-induced cracking
  - Delayed ettringite formation (DEF)
- Historically, when the concrete elements were of a *mass*ive size, the internal temperature was found to exceed safe temperature limits potentially rendering the concrete weaker and less durable.
- More recently, when large amounts of cementitious materials were used in the concrete mix design, even smaller elements were shown to achieve unsafe high temperatures.


27163
3591

Mass Concrete Specifications

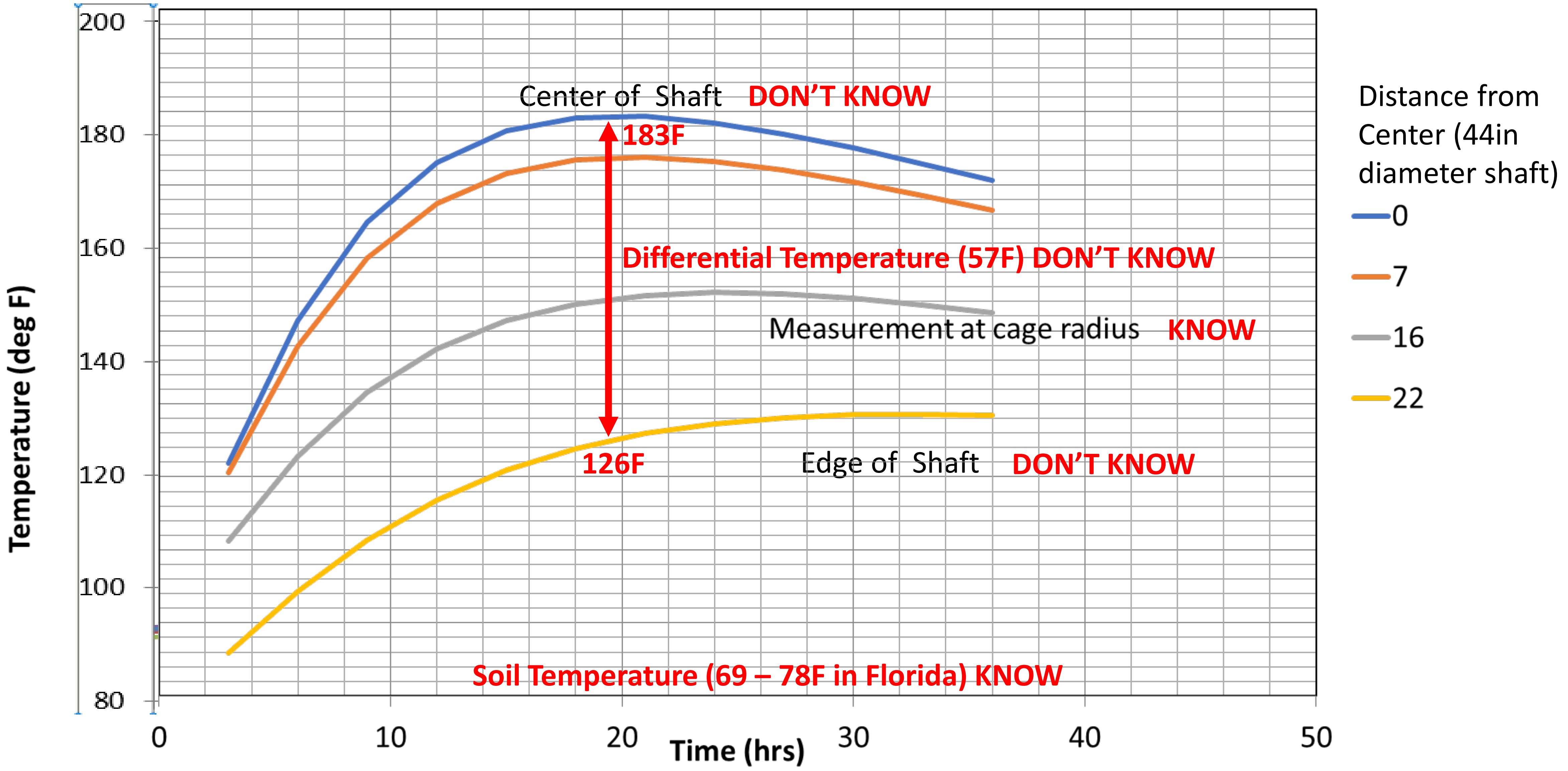
<u>American Concrete Institute</u>

- Performance-based temperature limits
  - 158/160°F peak
  - 35°F differential
- Definitions state concrete physical dimensions and volume that would require mitigation efforts to manage heat energy production

<u>Florida Department of Transportation</u>

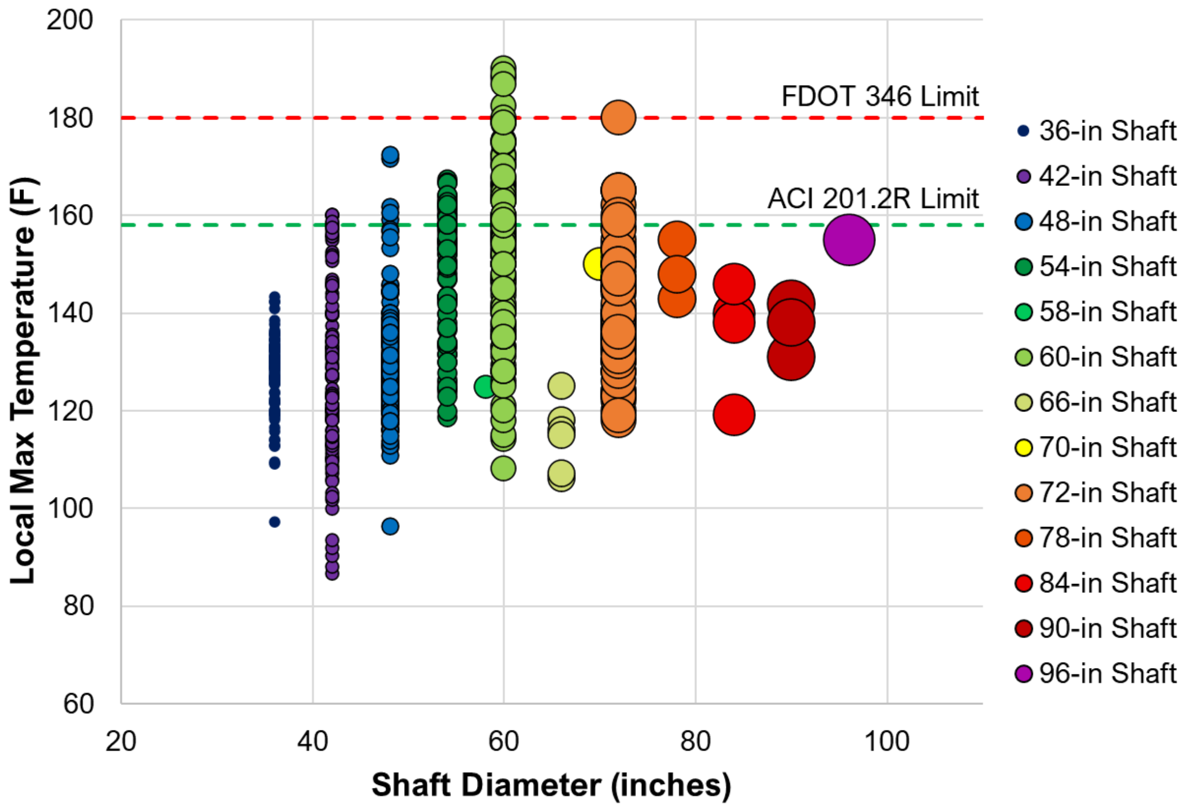
- Performance-based temperature limits
  - 180°F peak
  - 35°F differential
- Many drilled shafts are exempt from mass concrete consideration or conflict with other FDOT mass concrete specifications

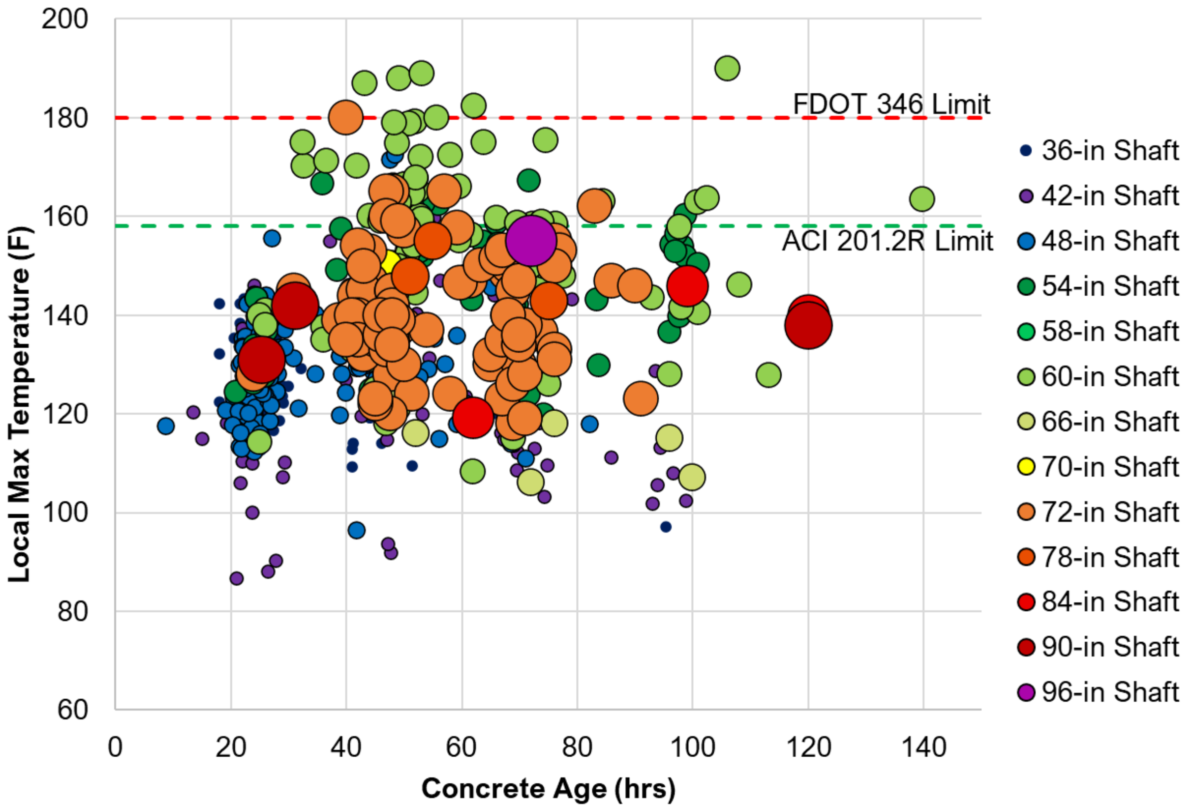
What is Known and Unknown



Previously Collected TIP Data

- 661 drilled shafts with thermal data
  - 78 included concrete supplier and mix design
  - Concrete age ranges from roughly 10 to 140 hours
  - 12% of local maximum temperatures (cage location) exceed ACI 158°F limit.





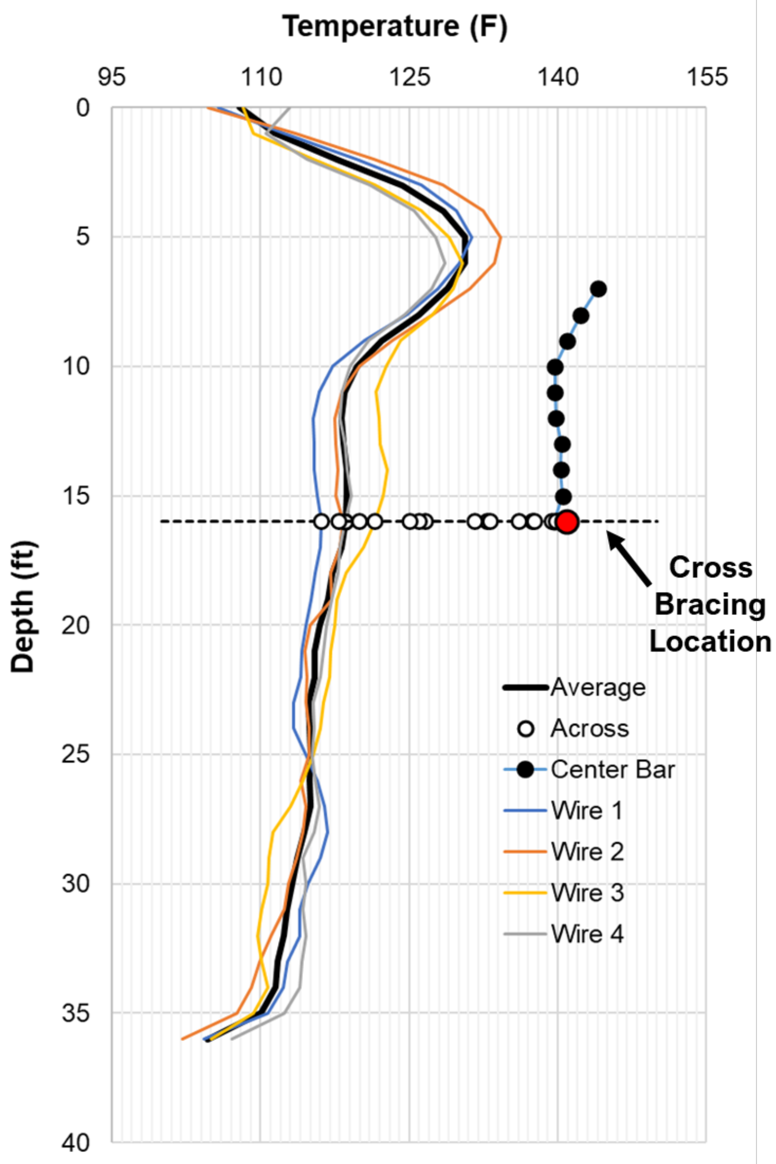
Measured Data Preliminary Results

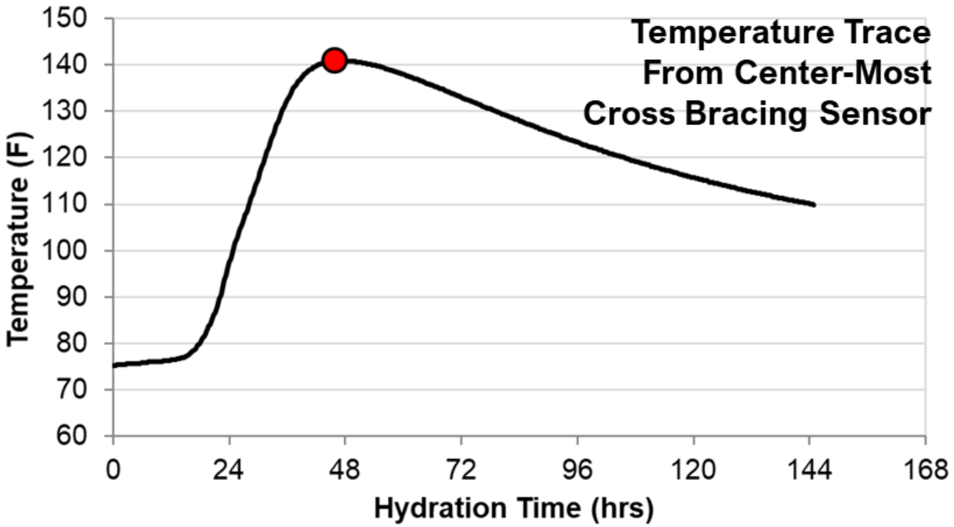
- I-4 Drilled Shaft OC-19
- Constructed on the north side of I-4 just east of the Polk Pkwy in Polk City, FL
- 72-inch diameter
- 37 feet long
- Partial-length, 84-inch diameter temporary casing

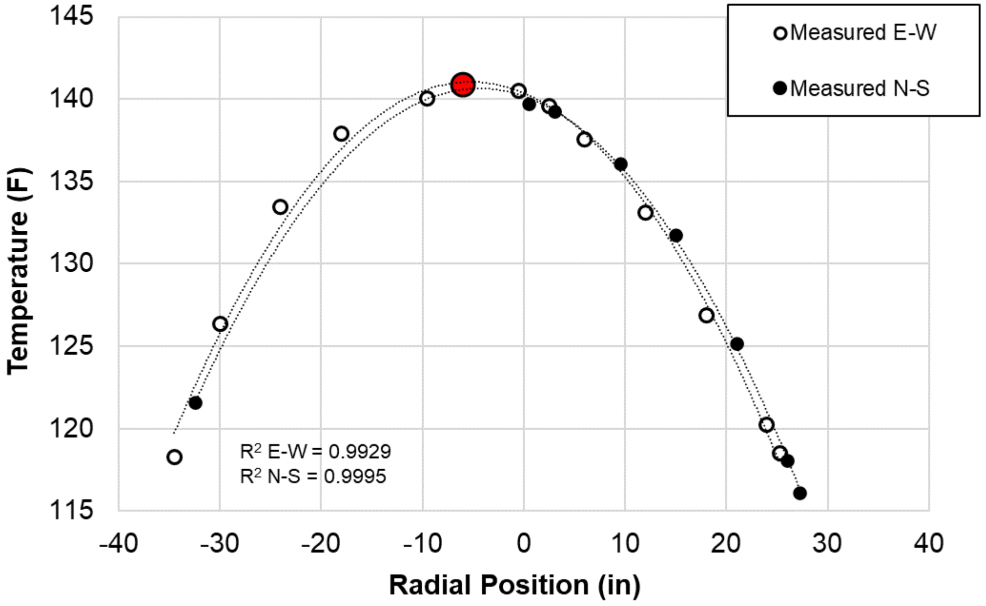
Measured Data
Preliminary Results

Concrete Mix Design: 60% Slag Replacement	
Material	**Amount**
Cement	266.1 lb/yd^3
Slag	393.9 lb/yd^3
Water	177.7 lb/yd^3
Coarse Aggregate	1615.6 lb/yd^3
Fine Aggregate	1322.2 lb/yd^3

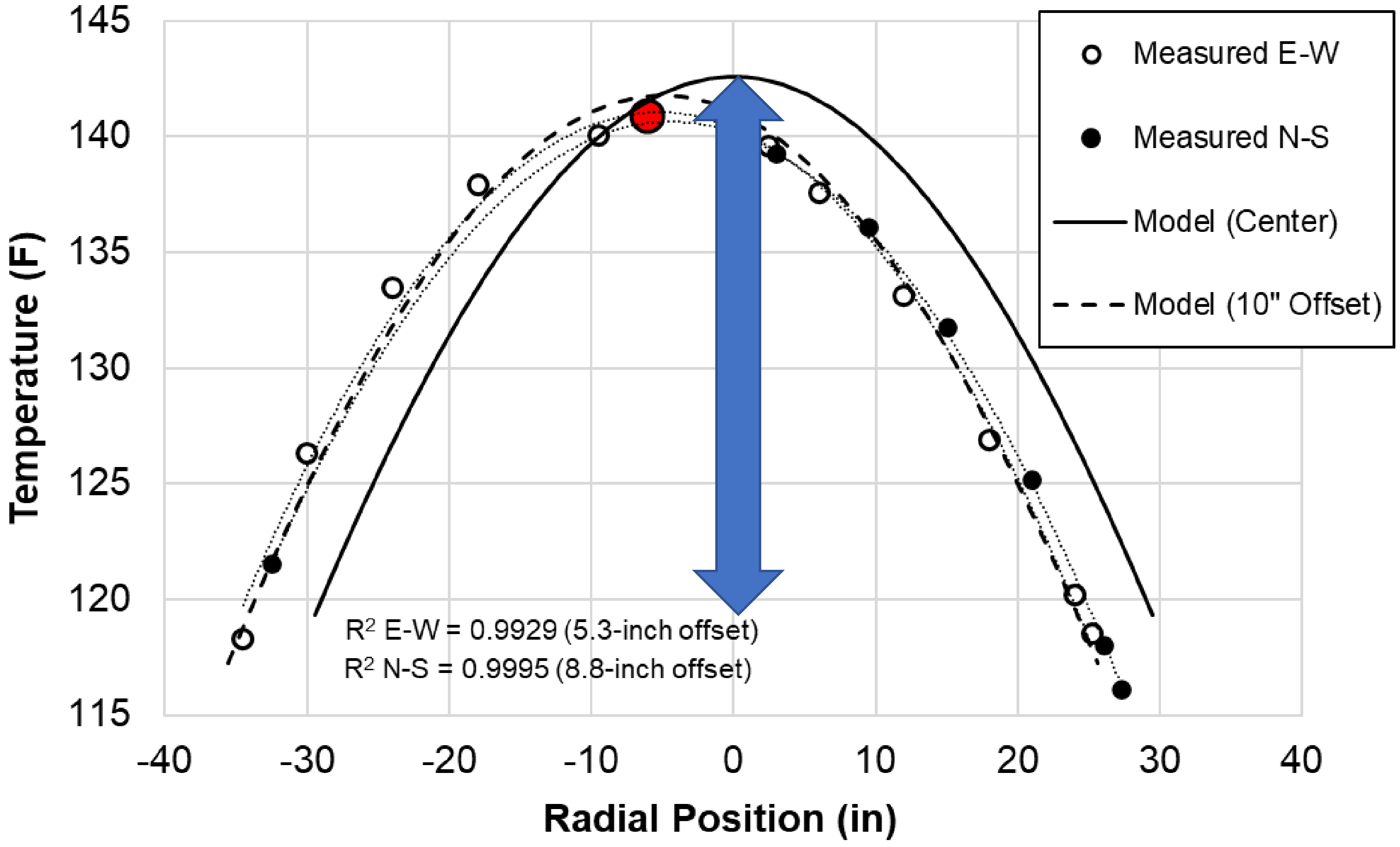
Measured Data Preliminary Results



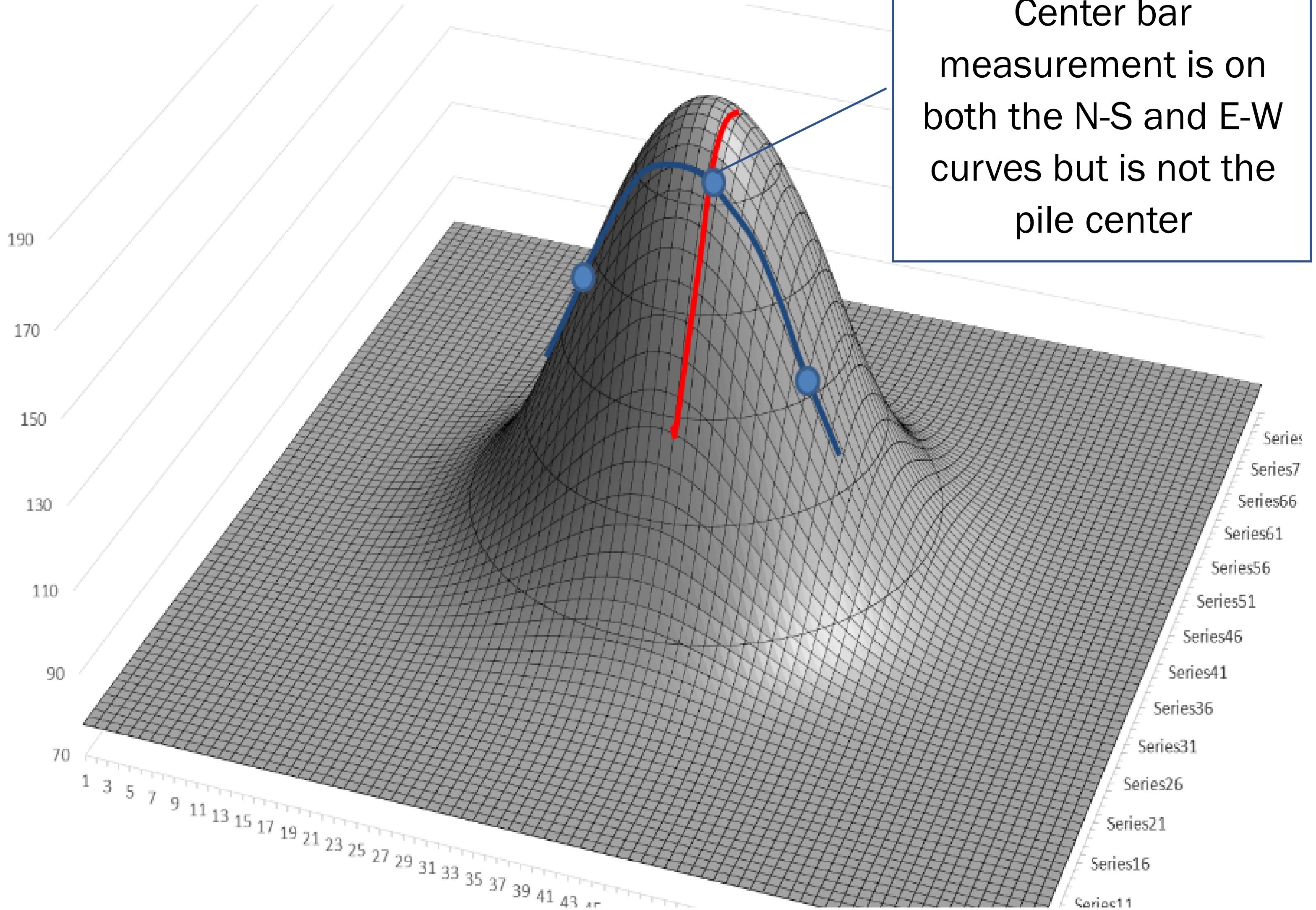




Modeling Preliminary Results

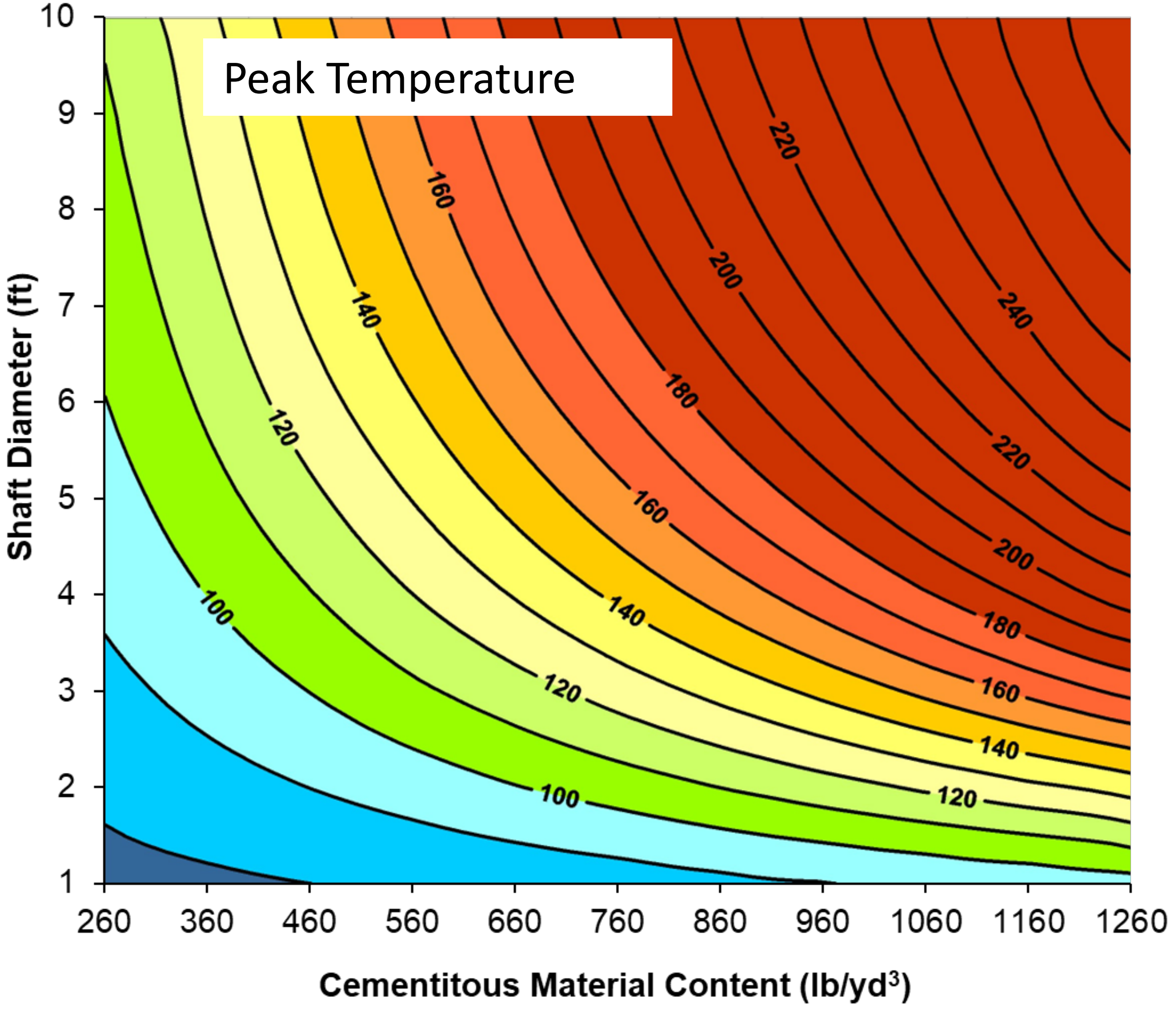


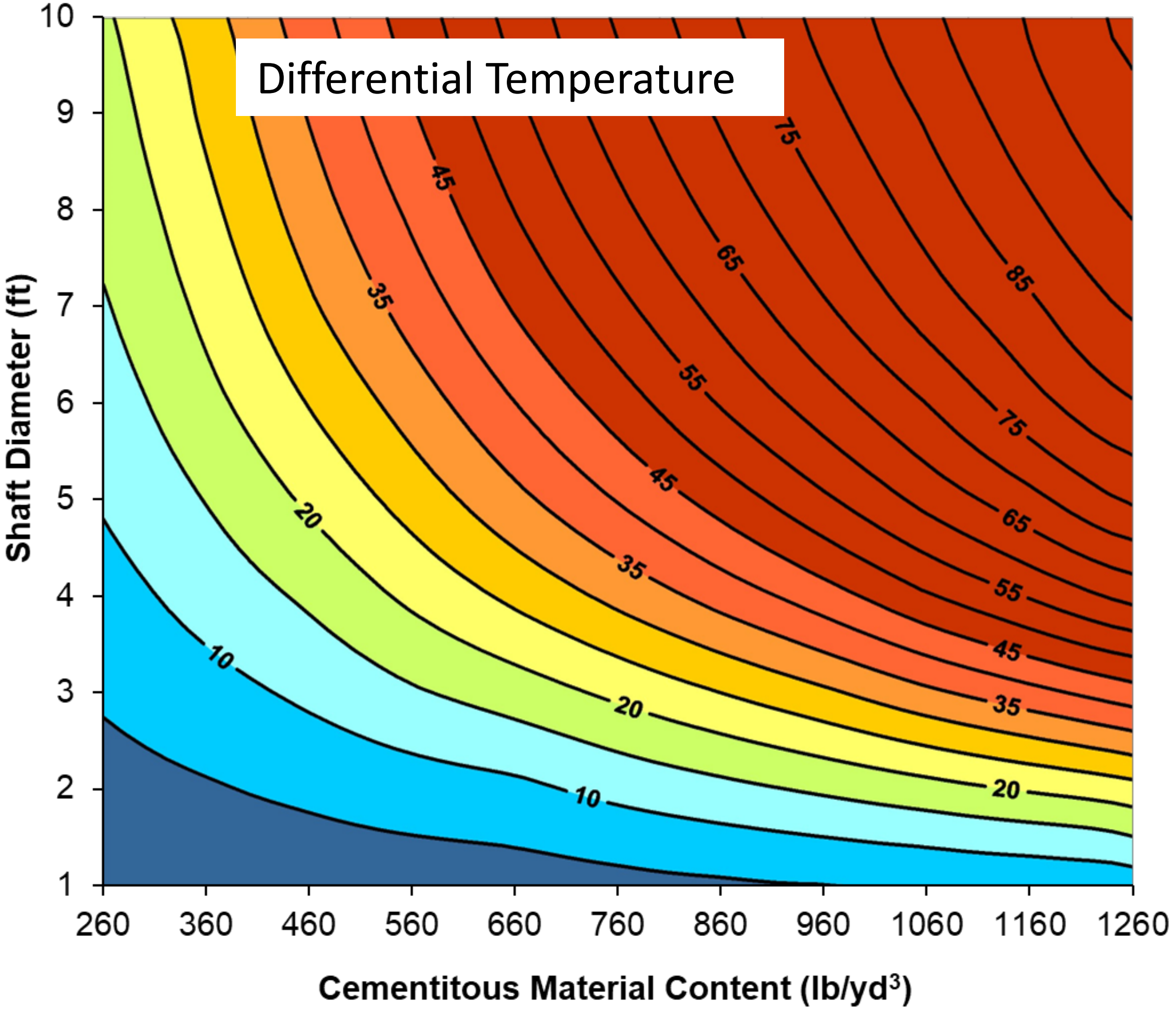
Modeling Preliminary Results



Center bar measurement is on both the N-S and E-W curves but is not the pile center

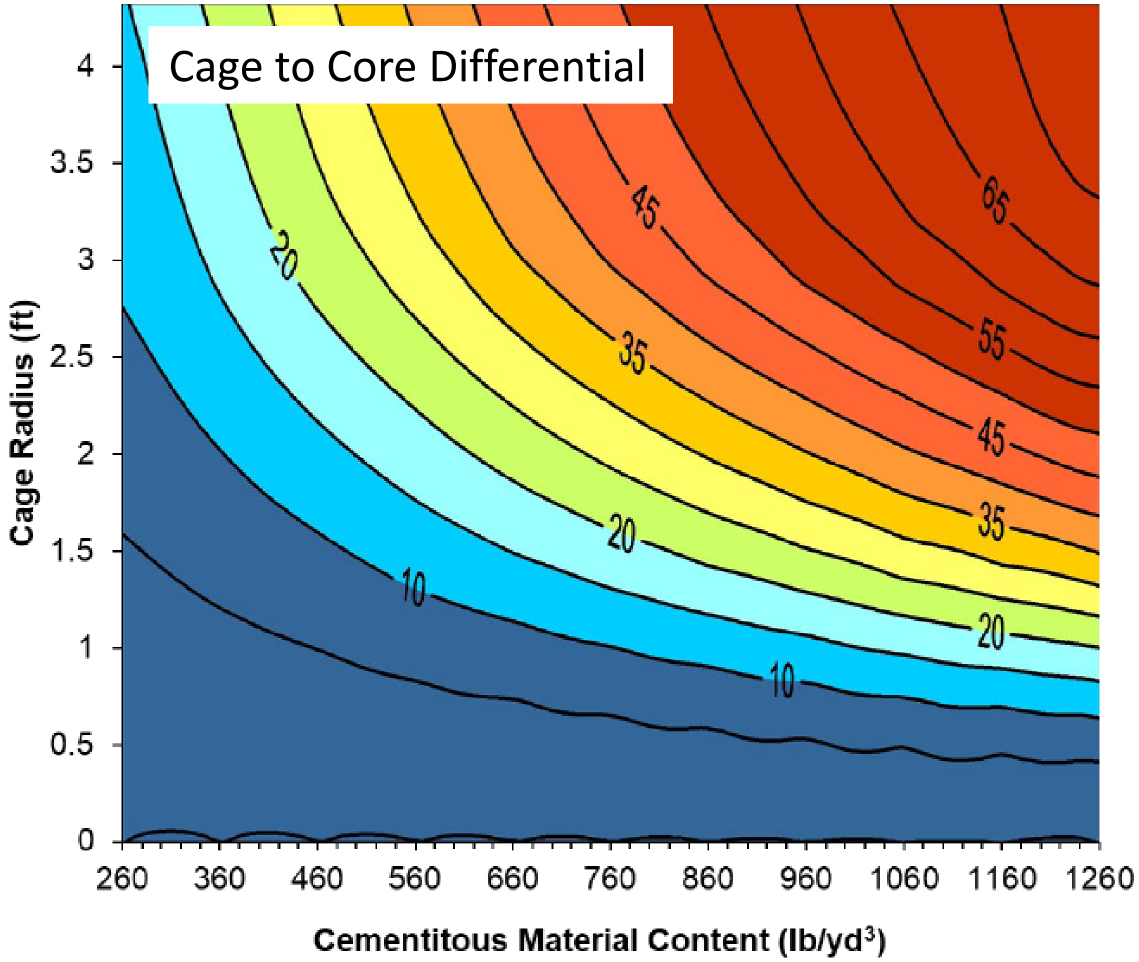
Outcome: predict core and differential temperatures for shafts before construction

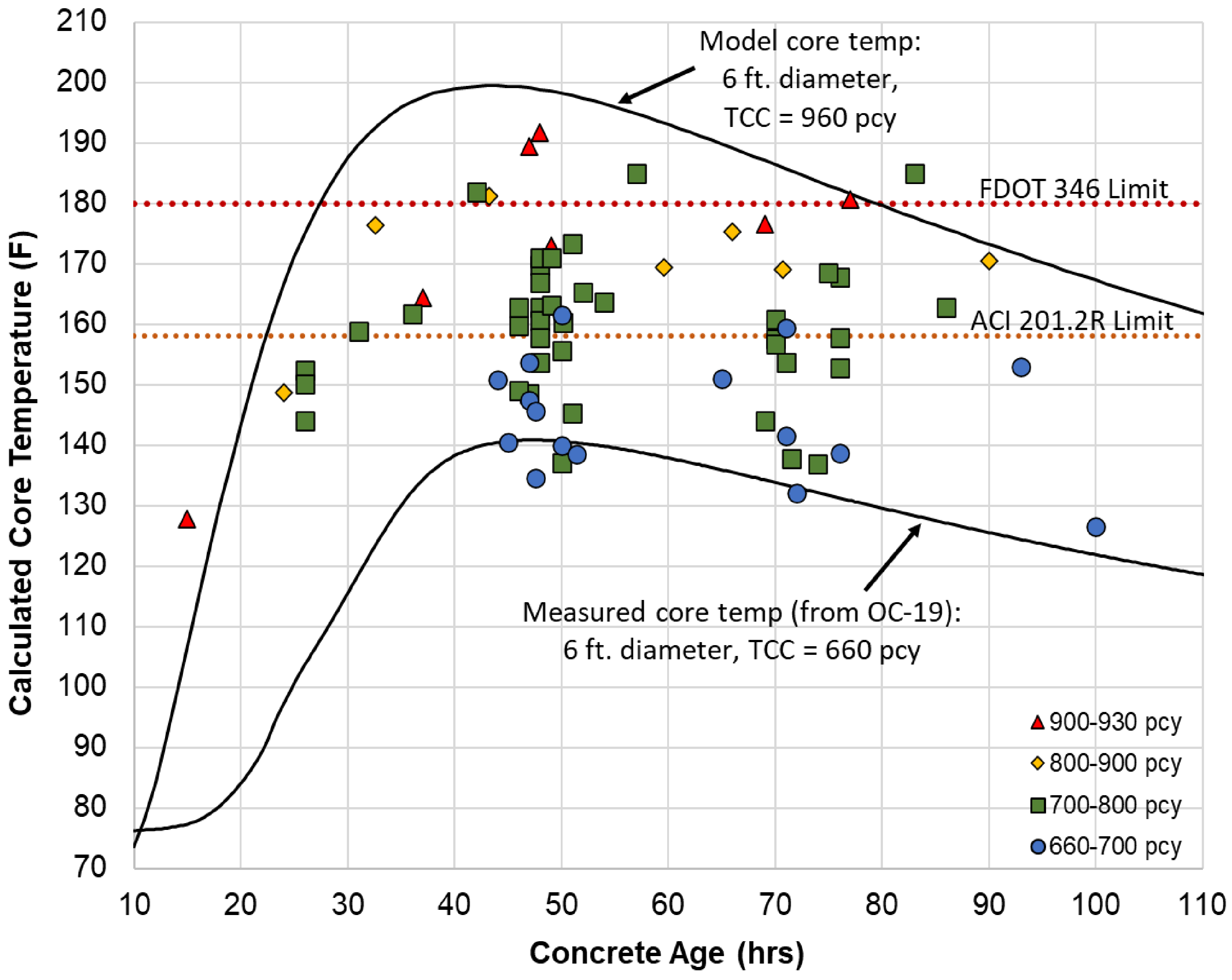


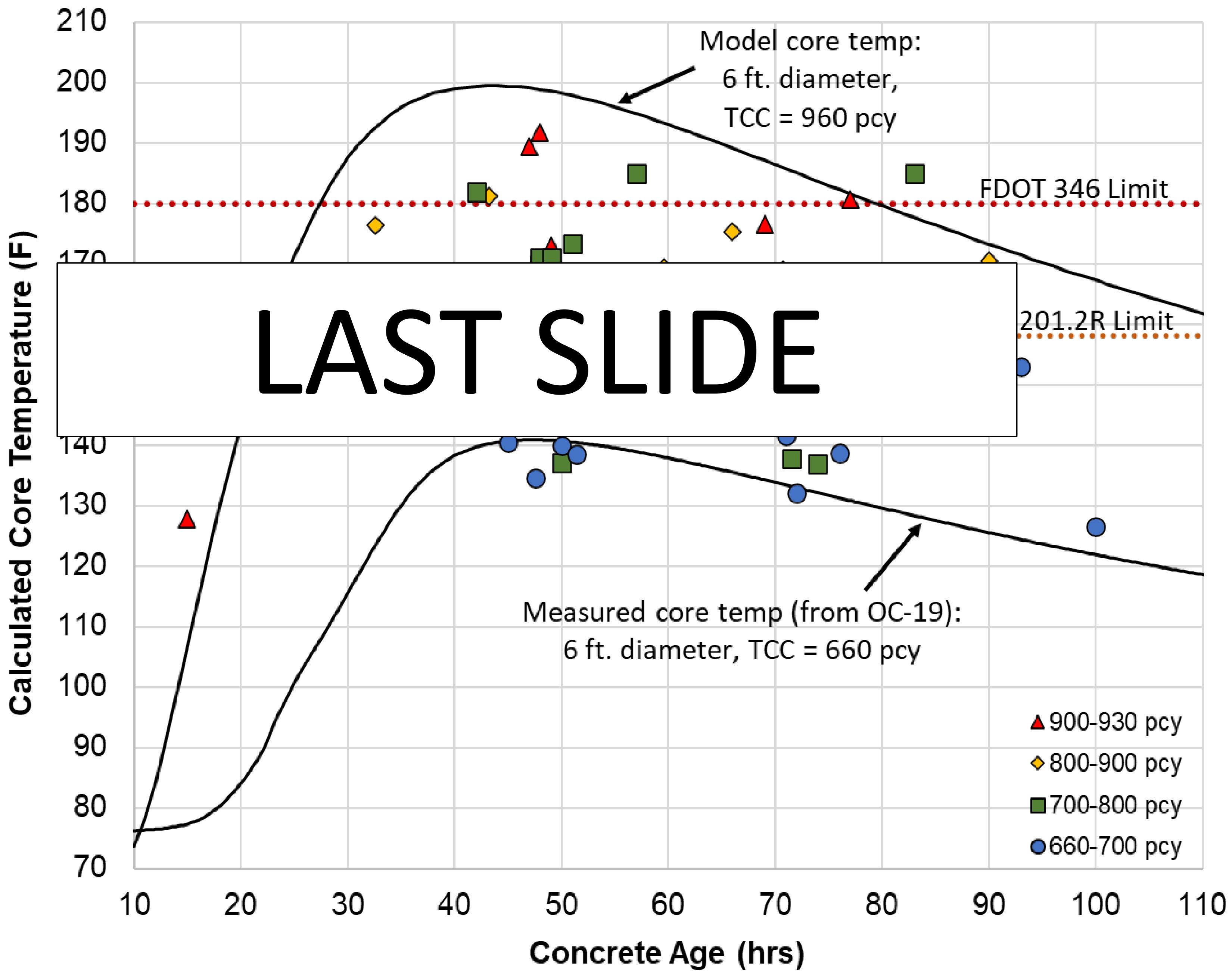


Outcome: predict core temperatures from routine thermal integrity testing after construction

$$\mathit{Delta}\,T_{\text{slag}} = (b_1 T\text{CC} + b_2) R^2_{cage} + (b_3 T\text{CC} + b_4) R_{cage} + (b_5 T\text{CC} + b_6)$$




Model core temp:
6 ft. diameter,
TCC = 960 pcy
FDOT 346 Limit
ACI 201.2R Limit
Measured core temp (from OC-19):
6 ft. diameter, TCC = 660 pcy
900-930 pcy
800-900 pcy
700-800 pcy
660-700 pcy
Calculated Core Temperature (F)
Concrete Age (hrs)
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
10
20
30
40
50
60
70
80
90
100
110


LAST SLIDE
Model core temp:
6 ft. diameter,
TCC = 960 pcy
FDOT 346 Limit
201.2R Limit
Measured core temp (from OC-19):
6 ft. diameter, TCC = 660 pcy
900-930 pcy
800-900 pcy
700-800 pcy
660-700 pcy
Calculated Core Temperature (F)
Concrete Age (hrs)
210
200
190
180
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