Evaluating the Effect of Temporary Casing on Drilled Shaft Rock Socket Friction

GRIP 2016

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Civil & Environmental Engineering

Ultimate Side Resistance

- Usually designed as a function of the parent rock properties and characteristics:
  - UCS
  - Unconfined Compression Strength
  - Recovery
  - RQD
  - Split Tensile Strength

Ultimate Side Resistance

- O'Neill and Reese (1999) – AASHTO (2012)

$$fmax = 0.65pa\sqrt{\frac{q_u}{p_a}} \quad and\ qu \ \leq f'c$$

- Kulhawy et al. (2005) – Base of FHWA (2010)

$$fmax = C * p_a\sqrt{\frac{q_u}{p_a}} \quad and\ qu \ \leq f'c$$

- McVay et al. (1992) – Base of FDOT (2015)

$$fmax = \frac{1}{2}\sqrt{q_u}\sqrt{q_t} \quad and\ qu \ \leq f'c$$

Construction Effects (GRIP 2015)
not addressed by design

- Excavation Equipment
- Reinforcement Bar Size and Cage Spacing
- Concrete properties
- Cased or Slurry Supported
- Vibrated or Oscillated Casing
- Slurry Type
- Slurry Exposure
- Temporary or Permanent Casing

Problem Statement

- Construction methods affect drilled shaft side shear resistance which is not fully addressed by design.
- The effects from full length or partial length temporary casing can present the same concern.
- The primary objective of this study is to **quantify the effects of temporary casing** installation and extraction on the resulting side shear in the portions of the rock sockets used to embed and seal the casing.

Study Motivation

455-15.7 Casings. Ensure casings are metal . . .

*. . . . **<u>If temporary casing is advanced deeper</u>** than the minimum top of rock socket elevation shown in the Plans or actual top of rock elevation is deeper, withdraw the casing from the rock socket and overream the shaft. If the temporary casing cannot be withdrawn from the rock socket before final cleaning, **<u>extend the length of rock socket</u>** below the authorized tip elevation one-half of the distance between the minimum top of rock socket elevation or actual elevation if deeper, and the temporary casing tip elevation.*

Scenarios

- Top of rock is not where the borings put it and so the rock socket has to start deeper,
- Operator inadvertently forces the casing deeper than planned although the “rock” is really pretty good
- Top of rock is technically where the borings put it, but the quality is so bad the casing must be advanced deeper to ensure a tight/adequate seal.

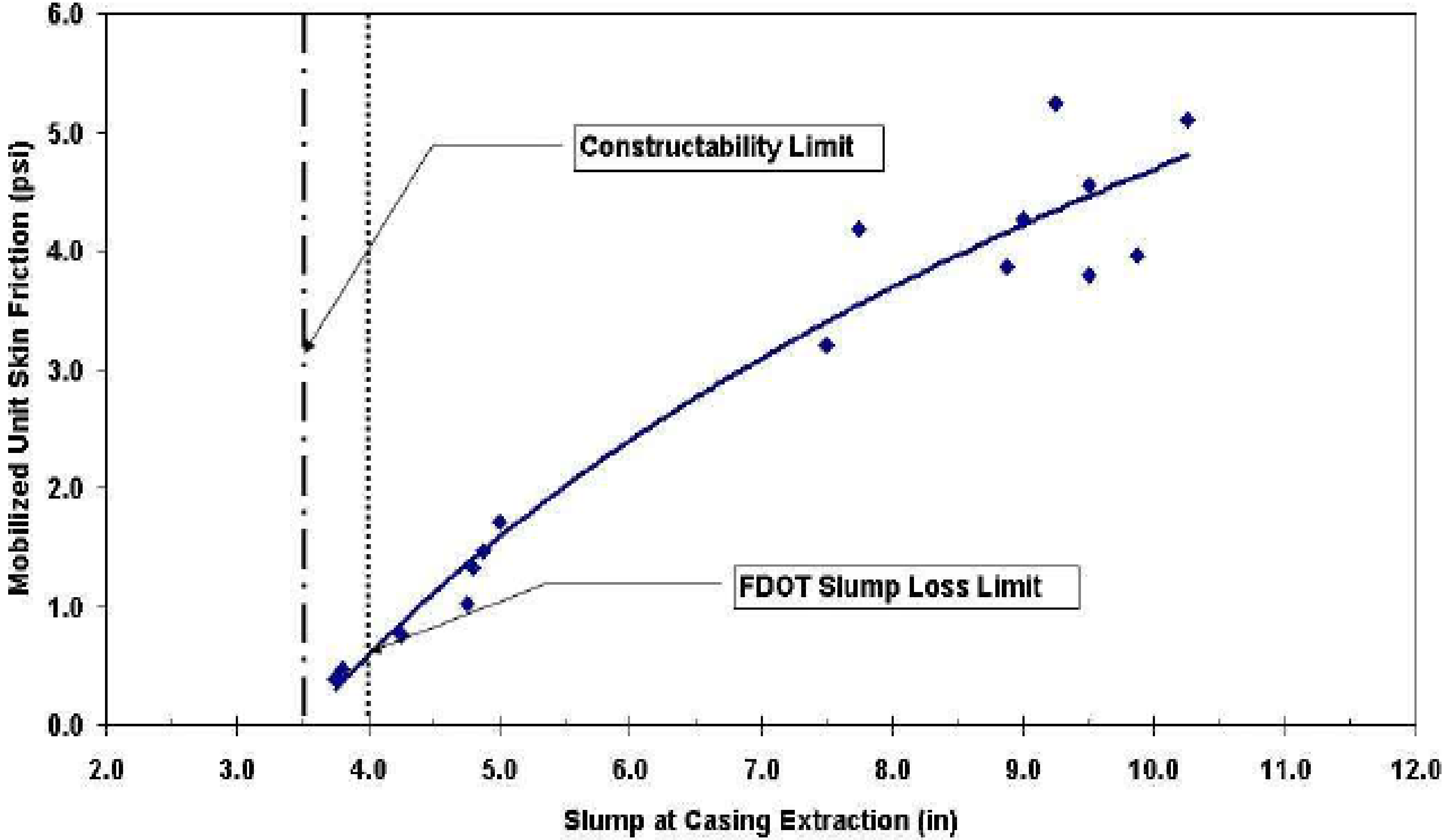
Casing Conditions

- Permanent
  - Full length
  - Partial length
- Temporary
  - Full length
  - Partial length
- Telescoping / Combination

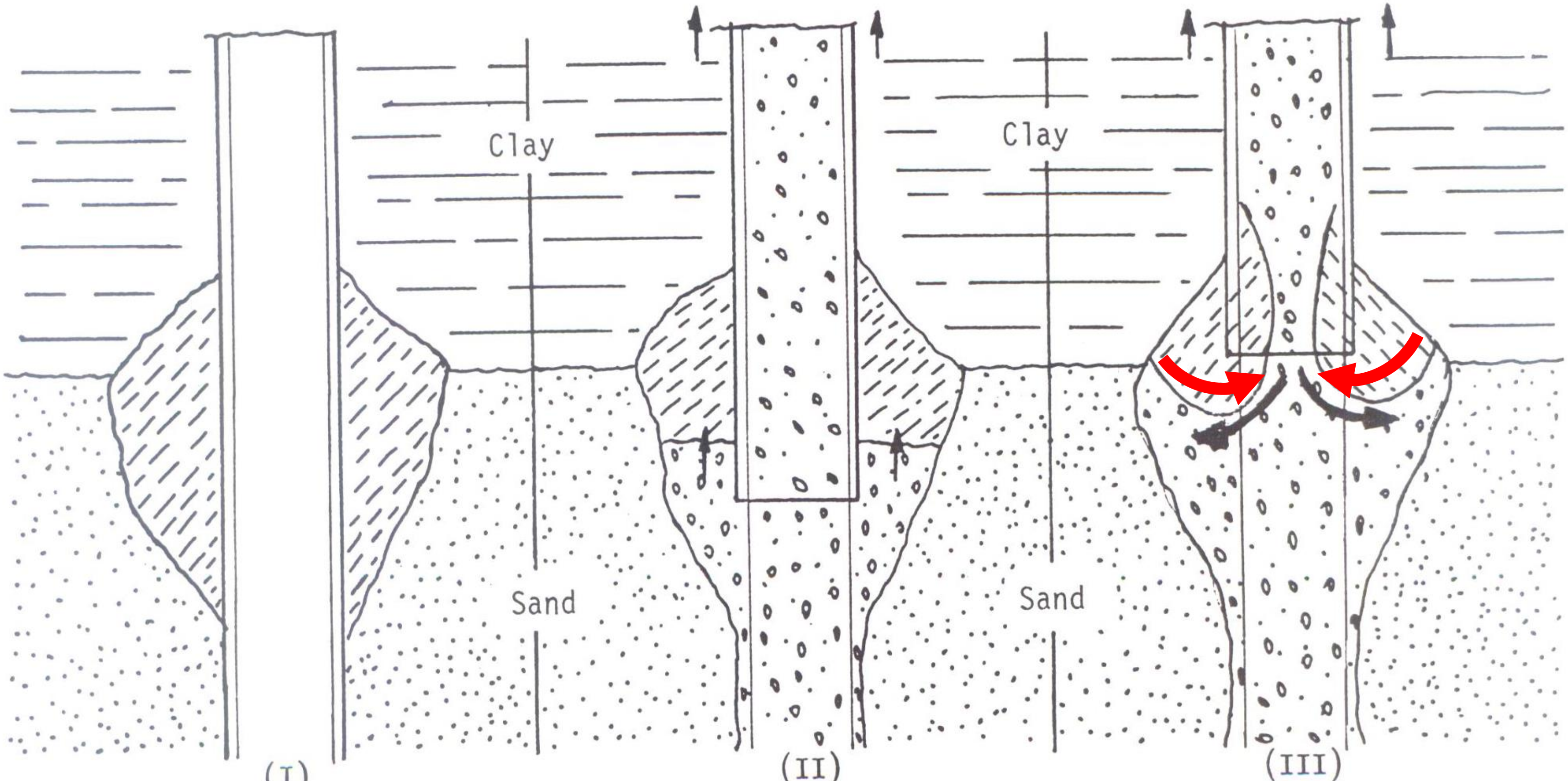
Misconceptions

- Use of casing makes more predicable shaft
- No anomalies occur within permanent cased regions
- Temporary cased sections have more reliable cross sections

Slump Loss in Temporary Casing



Temporary Casing Removal



SLURRY FILLED CAVITY FORMED OUTSIDE THE CASING

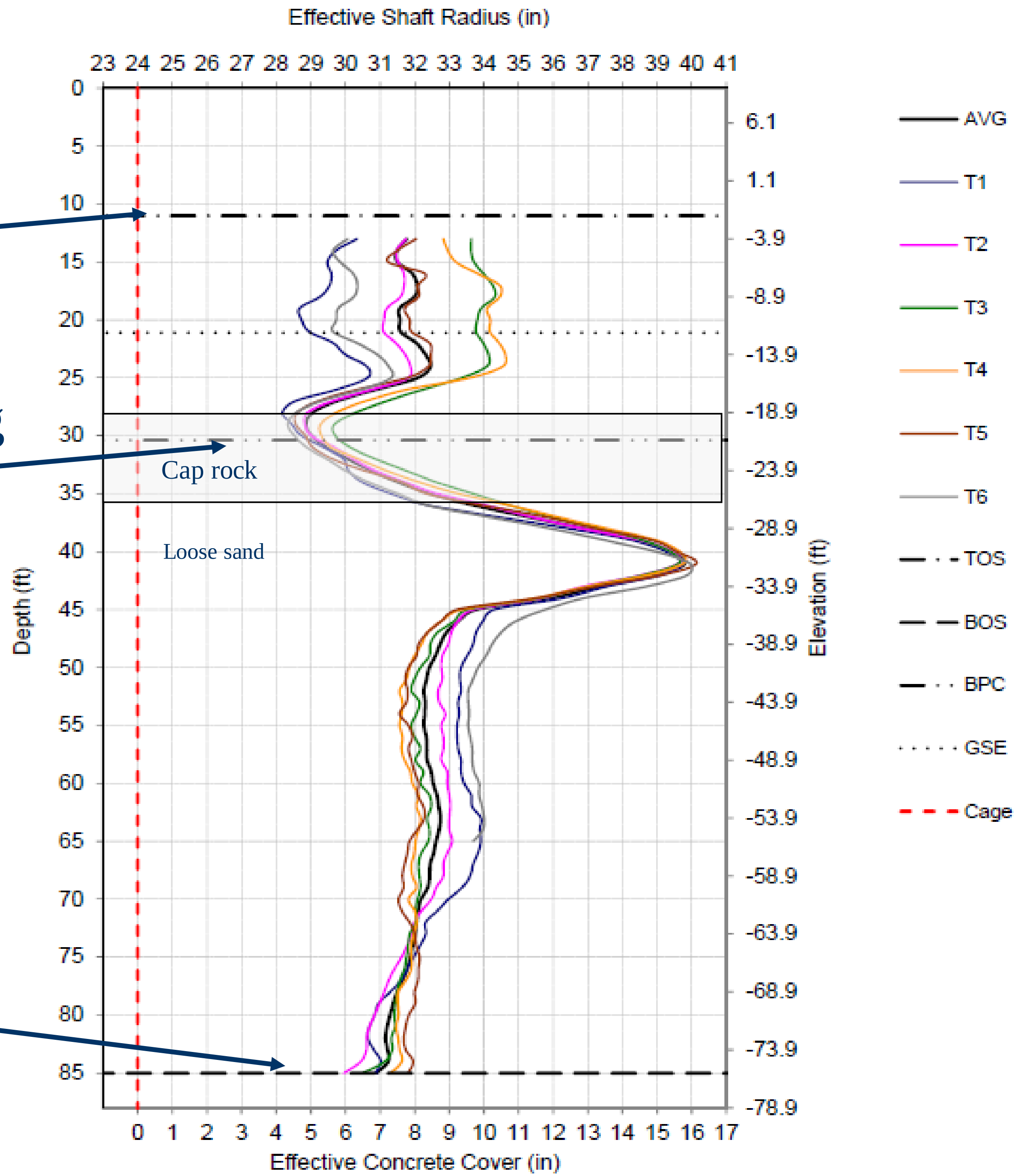
PILE CONCRETED, CASING LIFTED IN CAVITY UNDER PRESSURE

CASING IS LIFTED HIGHER CONCRETE SLUMPS INTO THE VOID CONTAMINATED SLURRY FLOWS INTO PILE

Permanent casing (top)

Permanent casing (bottom)

Temporary full length casing



Quantifying the Effects

- How does temporary casing affect the resulting side shear?
- Does concrete flow out and form intimate bond with surrounding rock?

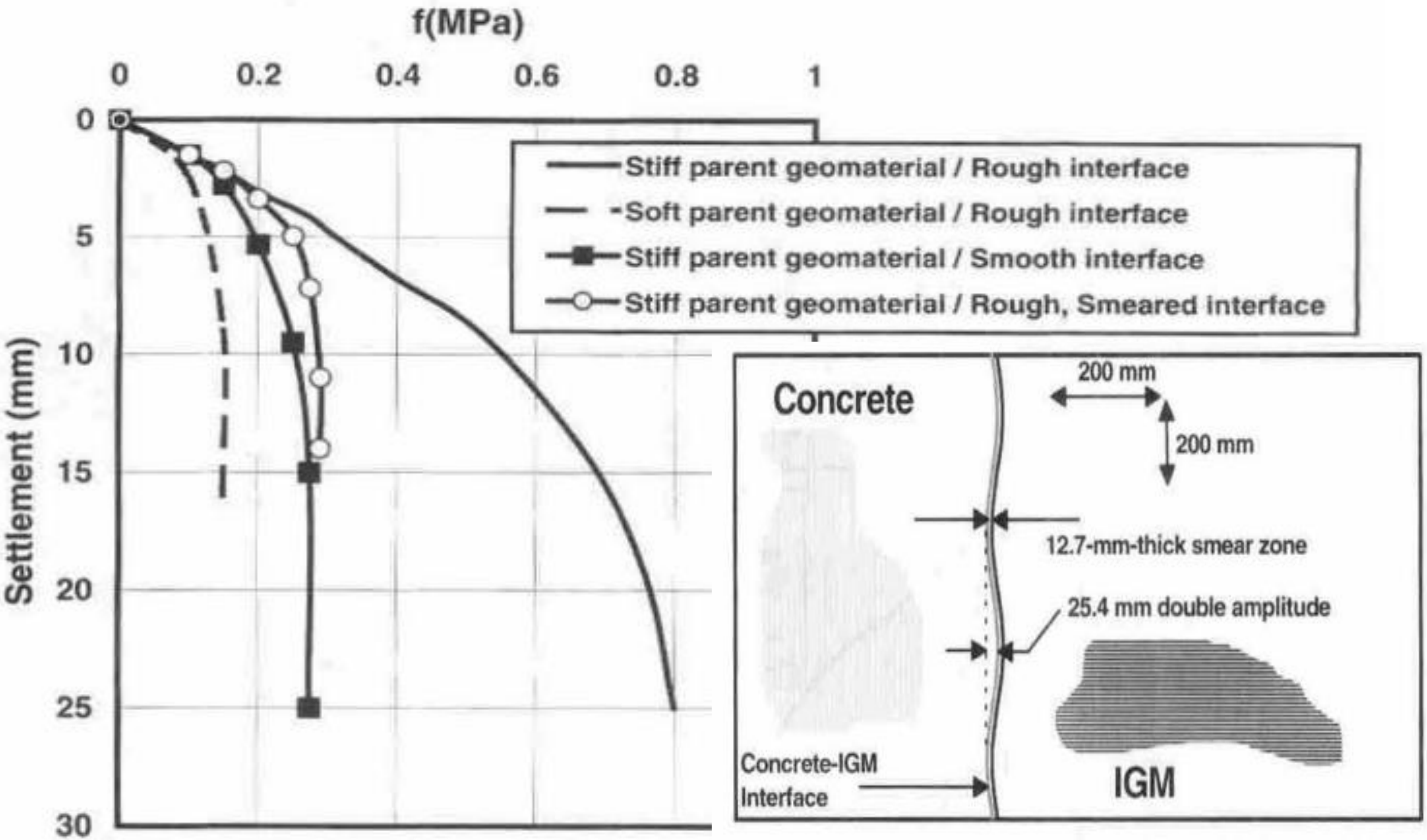
or

- Do residual fragments of crushed rock remain and get squeezed/trapped between outward flowing concrete?

Construction with temporary casing
Effects of casing extraction

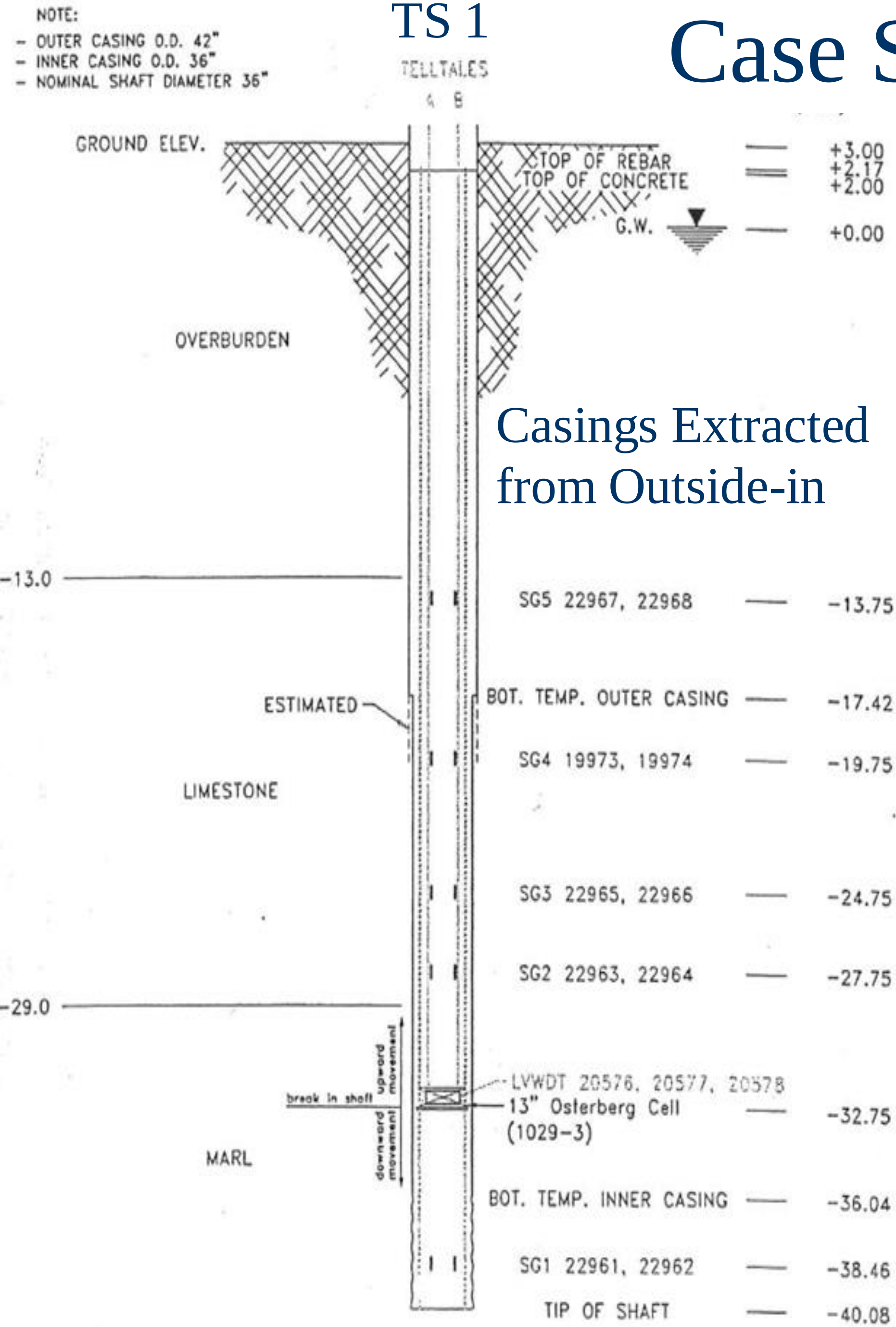
Construction of rock sockets

Effects on the side resistance (O'Neill and Hassan, 1994)



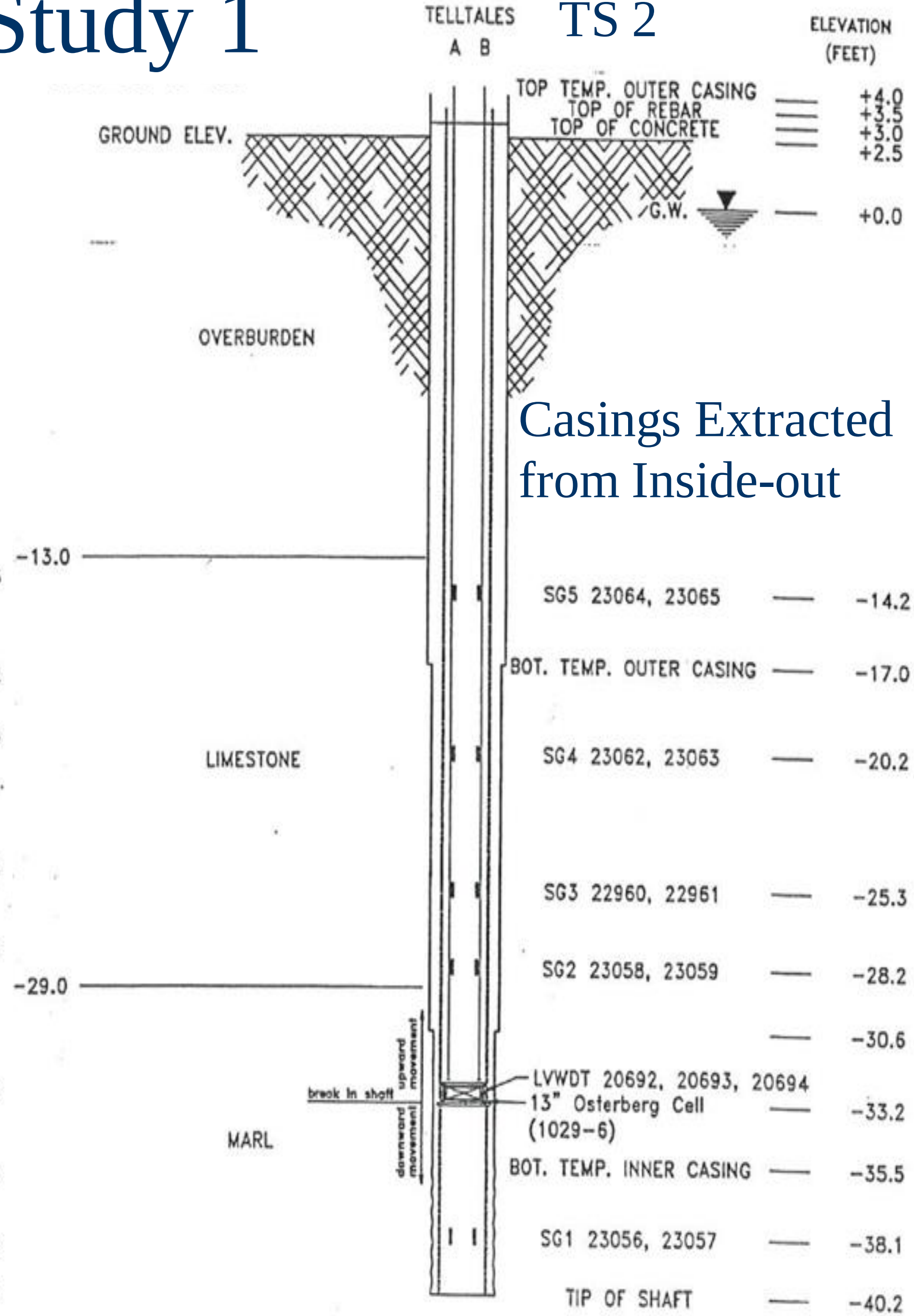
Case Study 1

TS 1

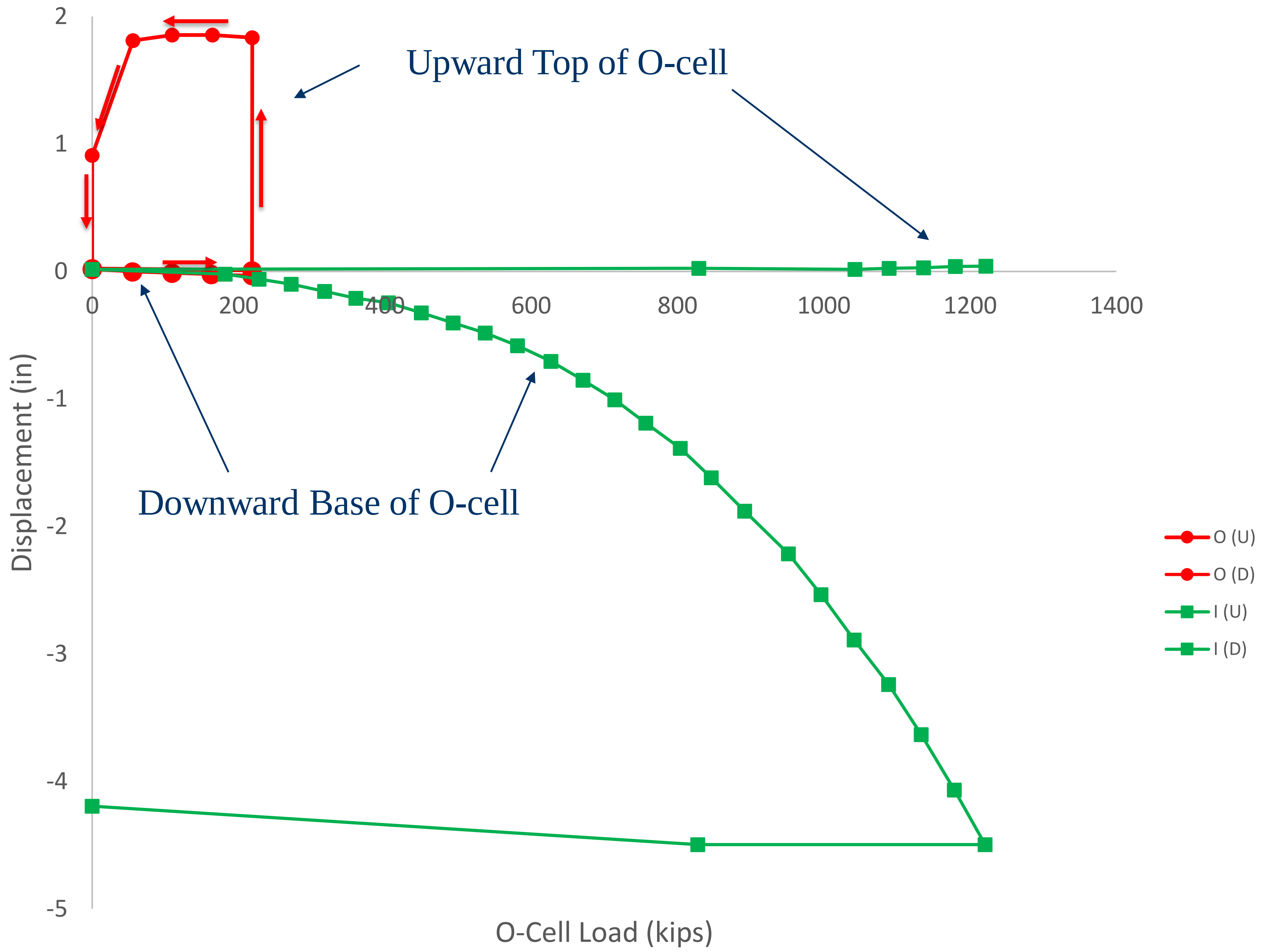


Casings Extracted from Outside-in

TS 2

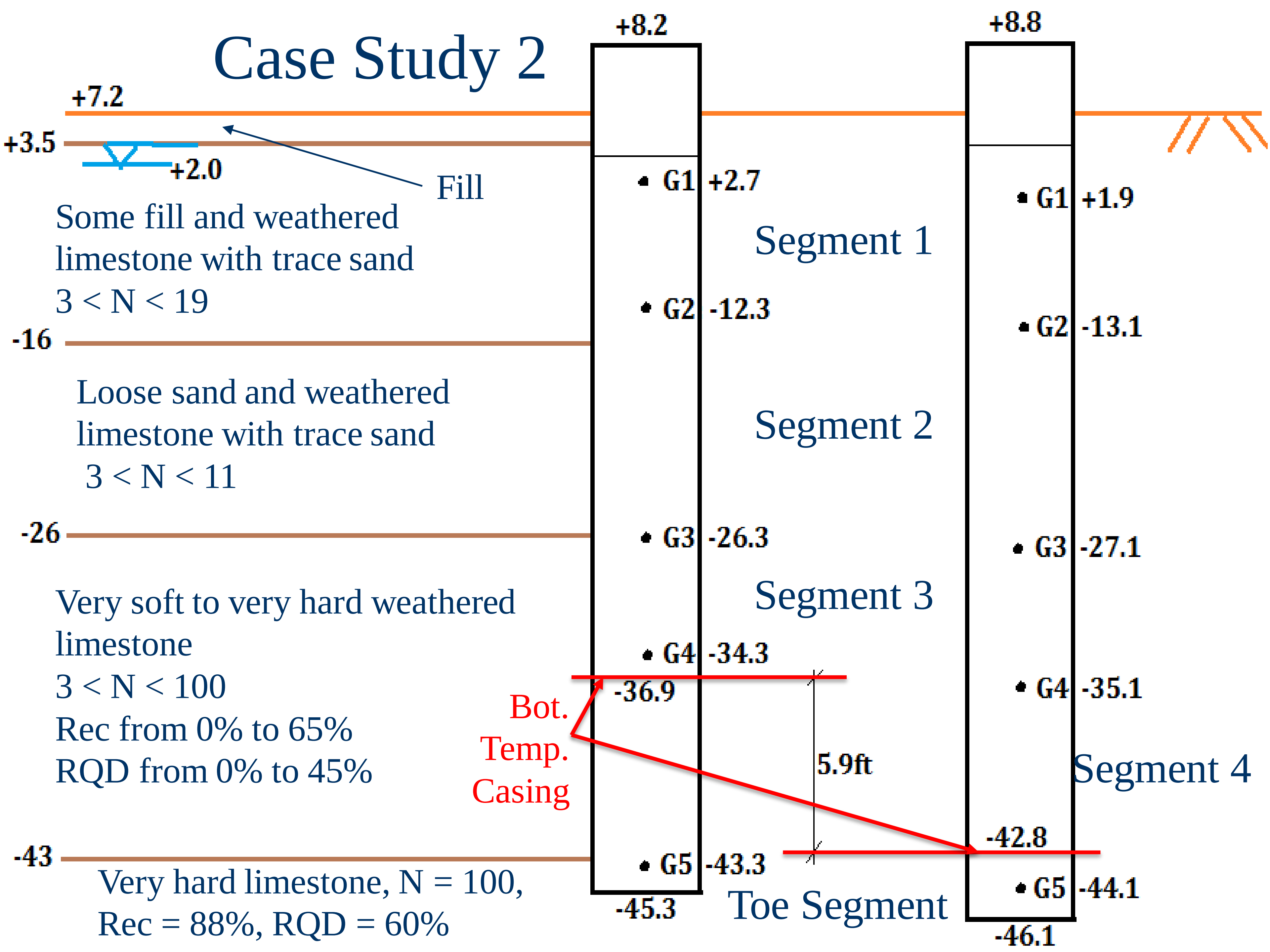


Casings Extracted from Inside-out



Upward Top of O-cell
Downward Base of O-cell
Displacement (in)
O-Cell Load (kips)
2
1
0
-1
-2
-3
-4
-5
0
200
400
600
800
1000
1200
1400
O (U)
O (D)
I (U)
I (D)

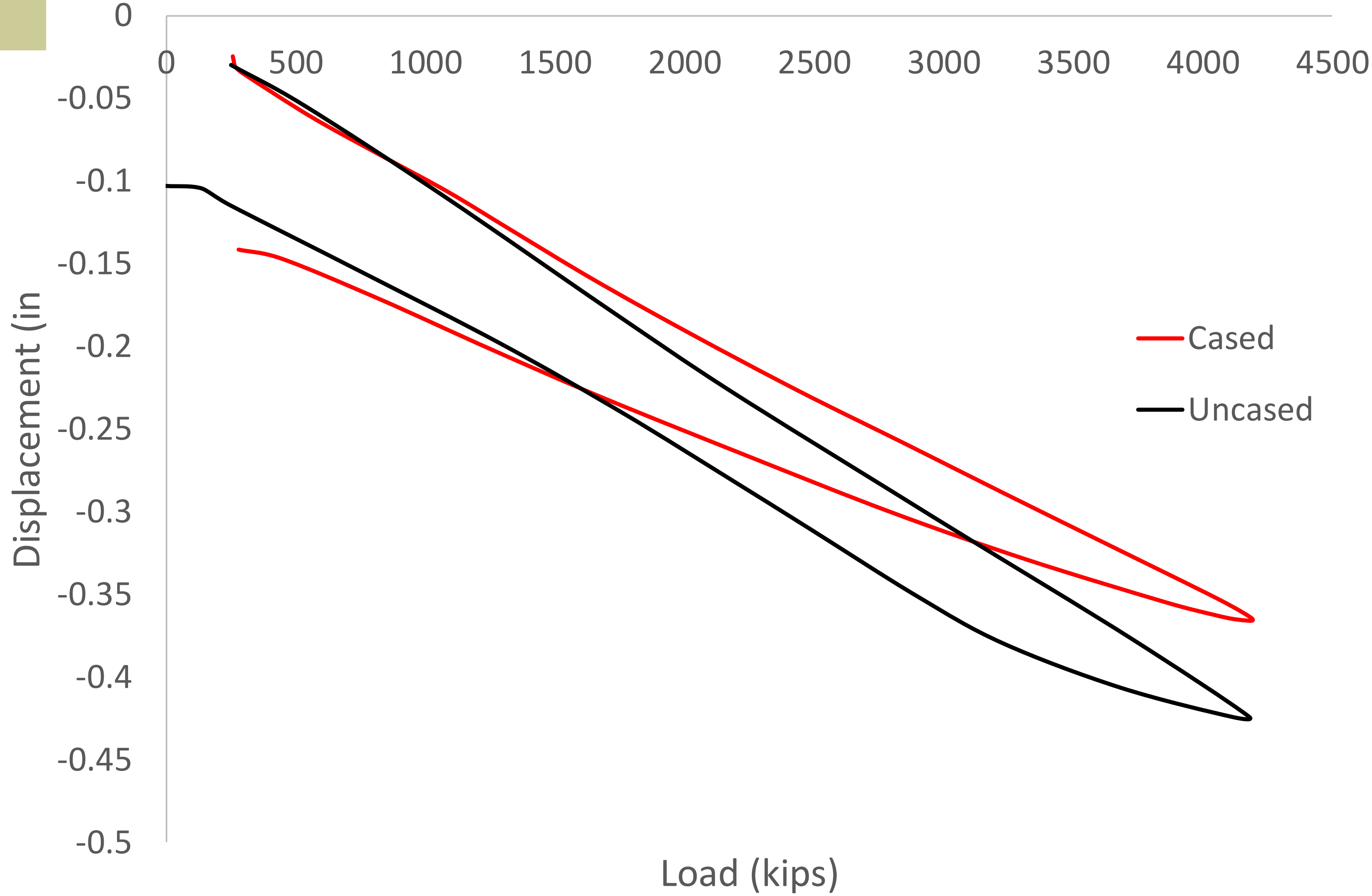
Case Study 2


+8.2
+8.8
+7.2
+3.5
+2.0
Fill
Some fill and weathered limestone with trace sand
3 < N < 19
-16
Loose sand and weathered limestone with trace sand
3 < N < 11
-26
Very soft to very hard weathered limestone
3 < N < 100
Rec from 0% to 65%
RQD from 0% to 45%
-43
Very hard limestone, N = 100,
Rec = 88%, RQD = 60%
G1 +2.7
G2 -12.3
G3 -26.3
G4 -34.3
-36.9
G5 -43.3
-45.3
G1 +1.9
G2 -13.1
G3 -27.1
G4 -35.1
-42.8
G5 -44.1
-46.1
Segment 1
Segment 2
Segment 3
Segment 4
Toe Segment
Bot. Temp. Casing
5.9ft

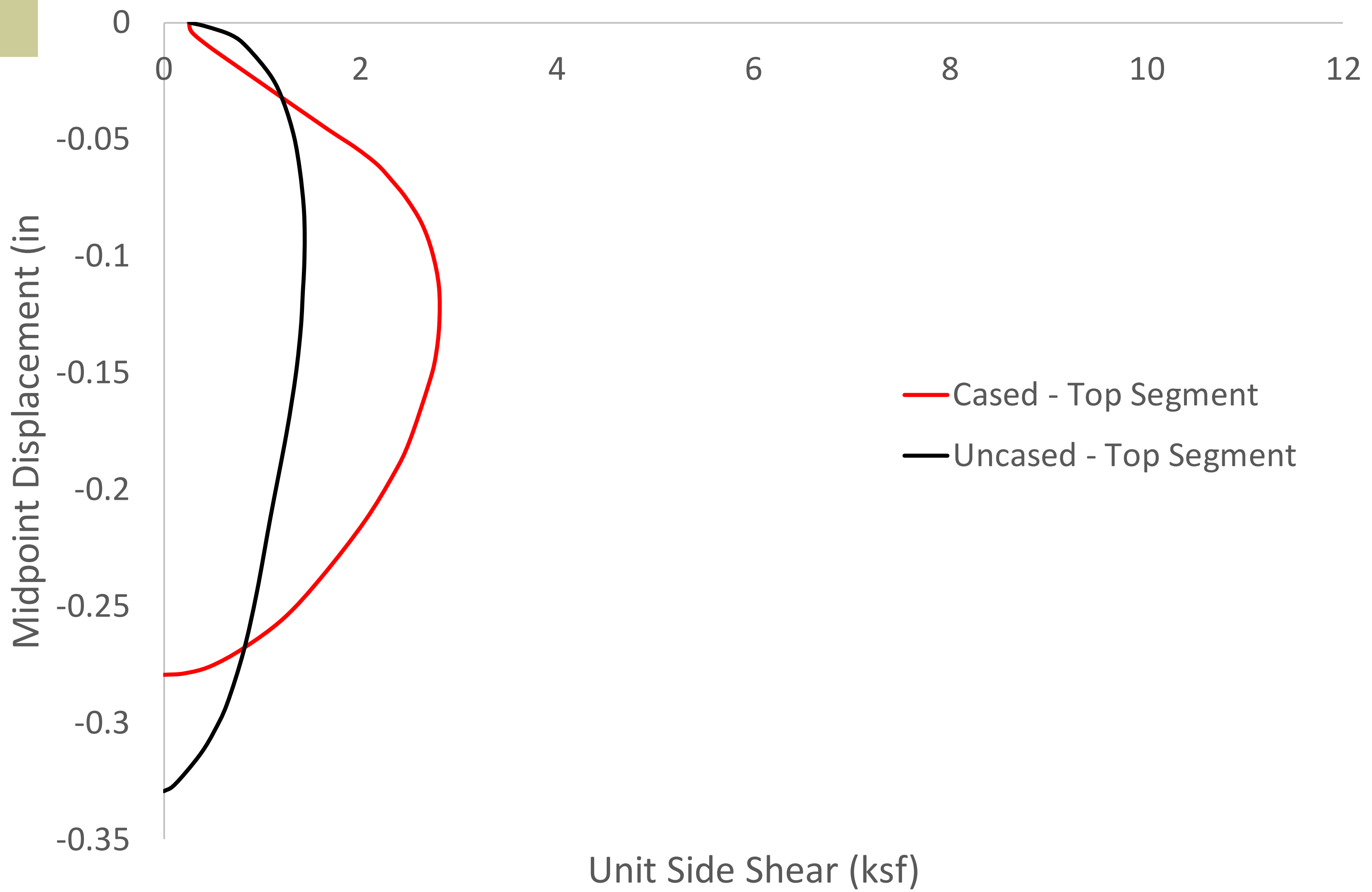
Case Study 2

	Uncased	Cased
Date constructed	7/15 and 7/16/09	7/20/09
Load test date	7/31/09	8/3/09
Reported Mobilized Capacity	4,183 kips	4,189 kips
Maximum displacement	0.43in	0.37in
Permanent displacement	0.10in	0.15in

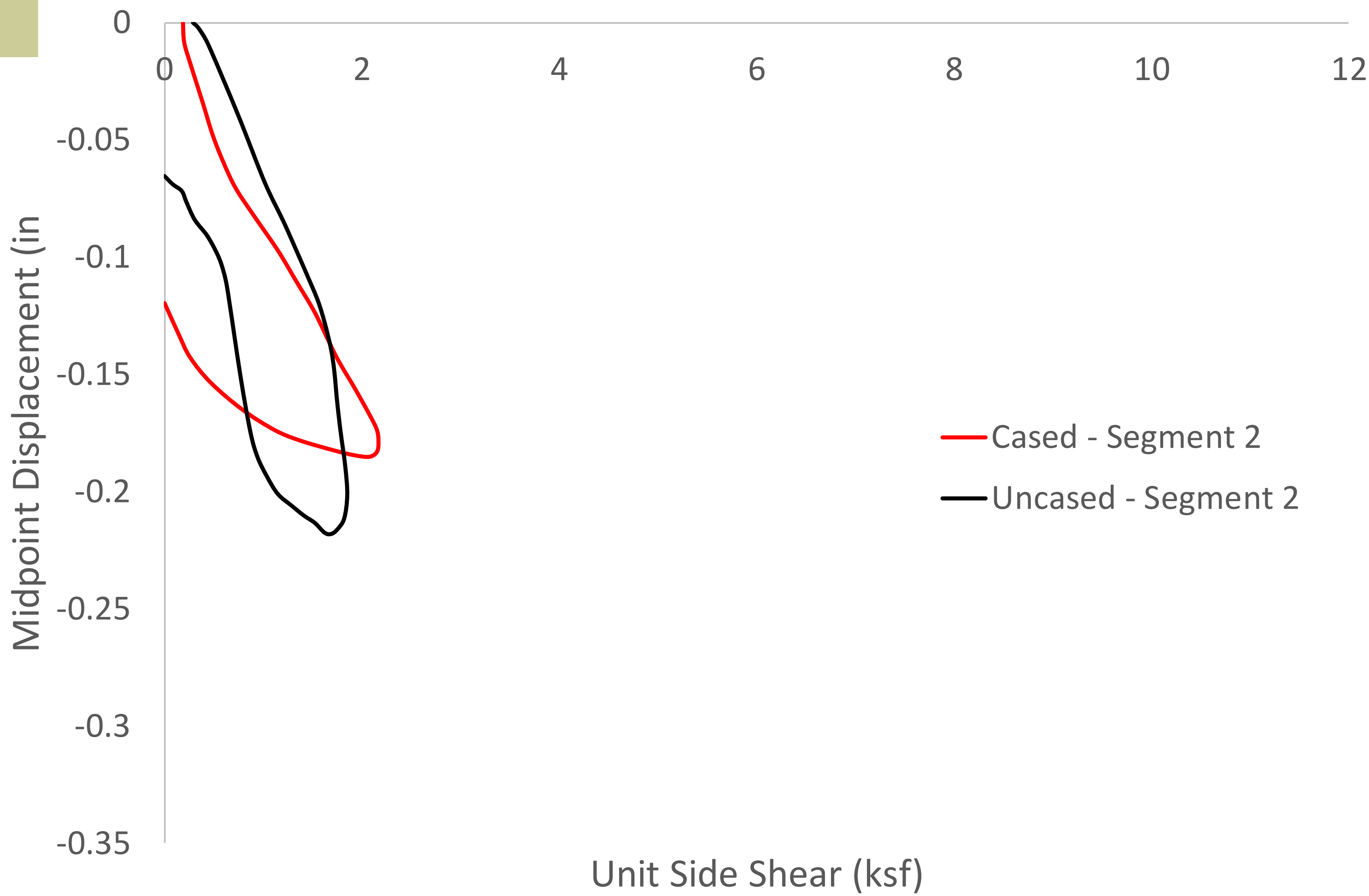
Top of Shaft Load – Displacement



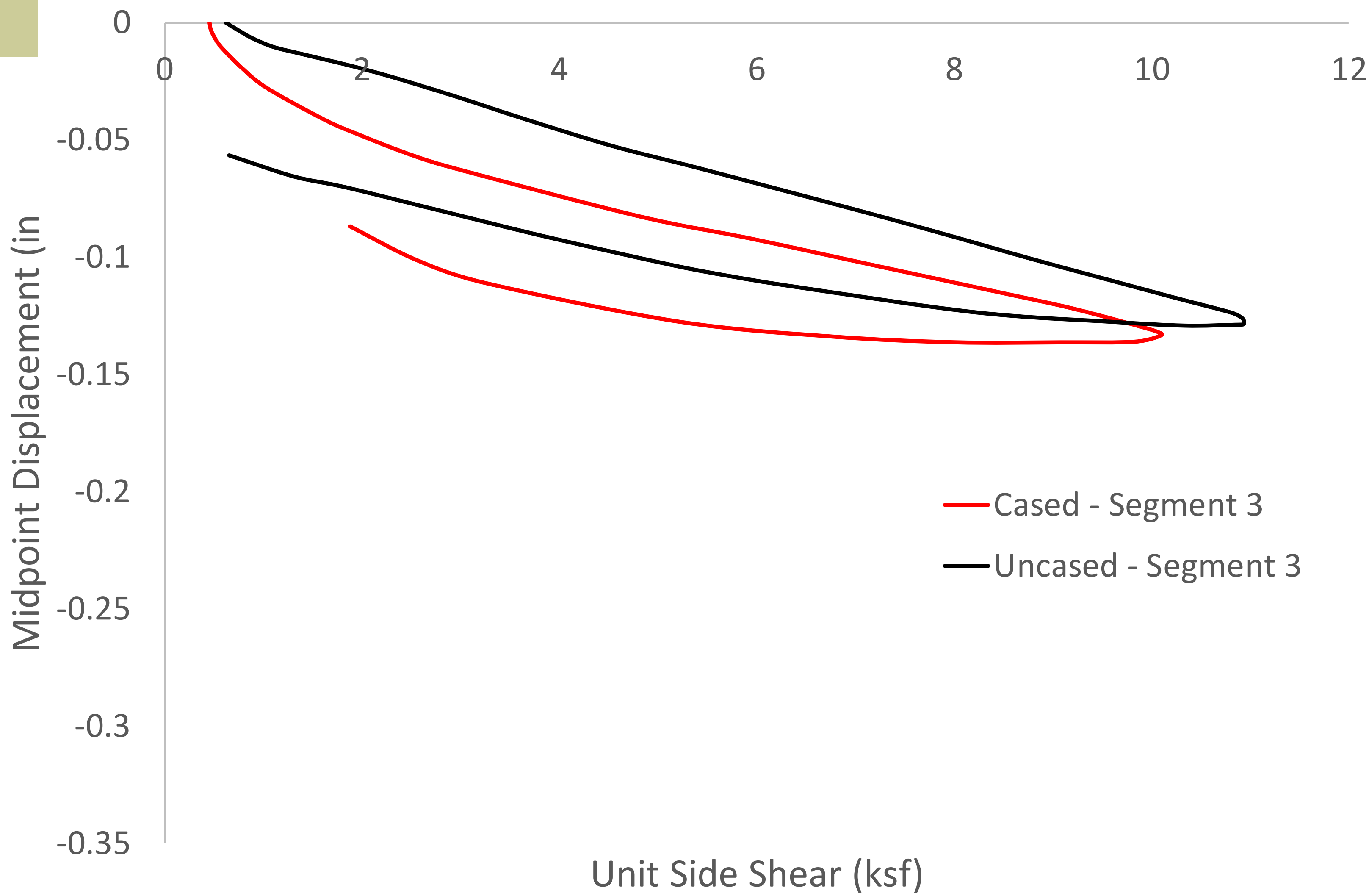
Top Segment Unit Side Shear



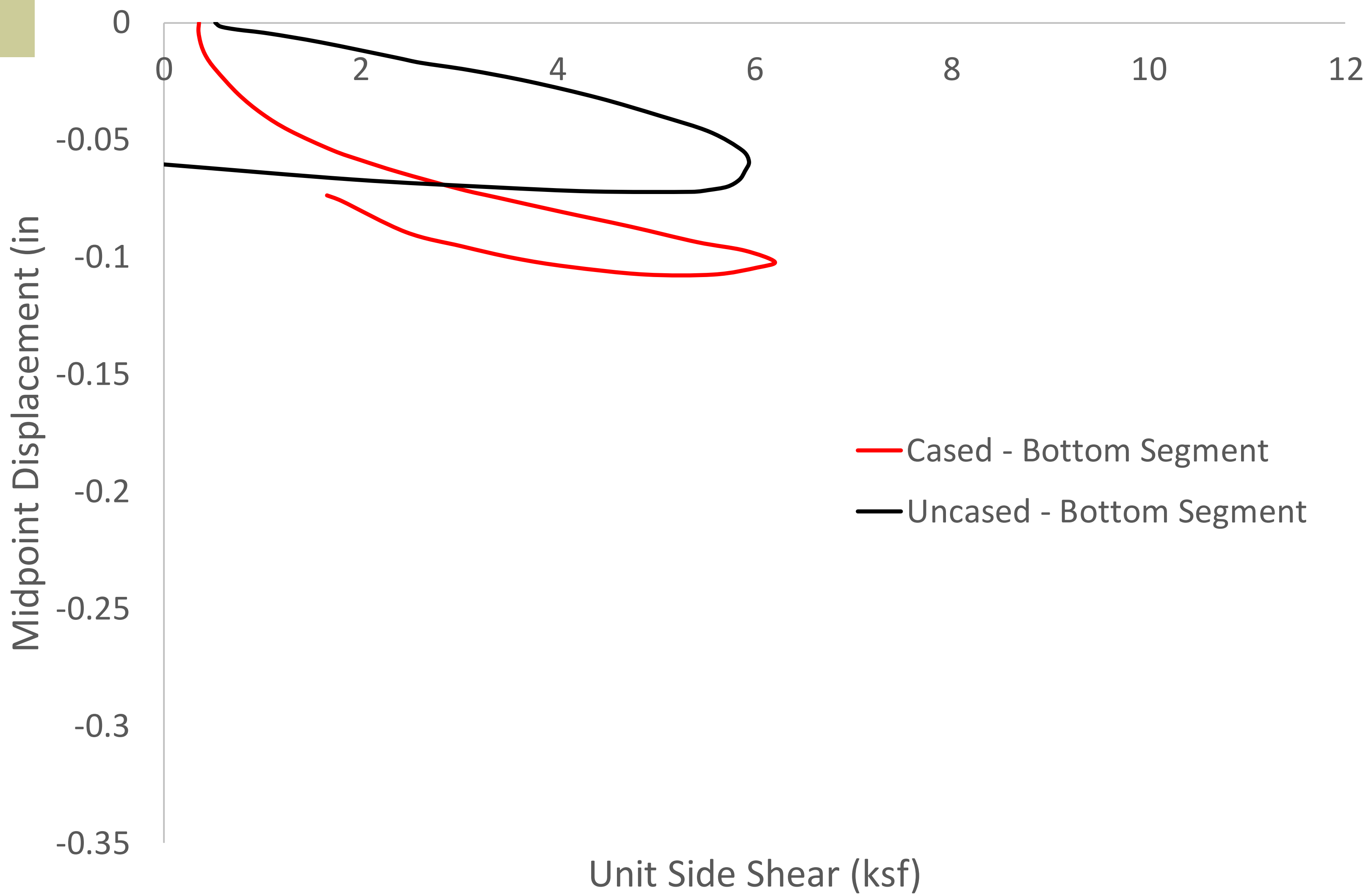
Segment 2 Unit Side Shear



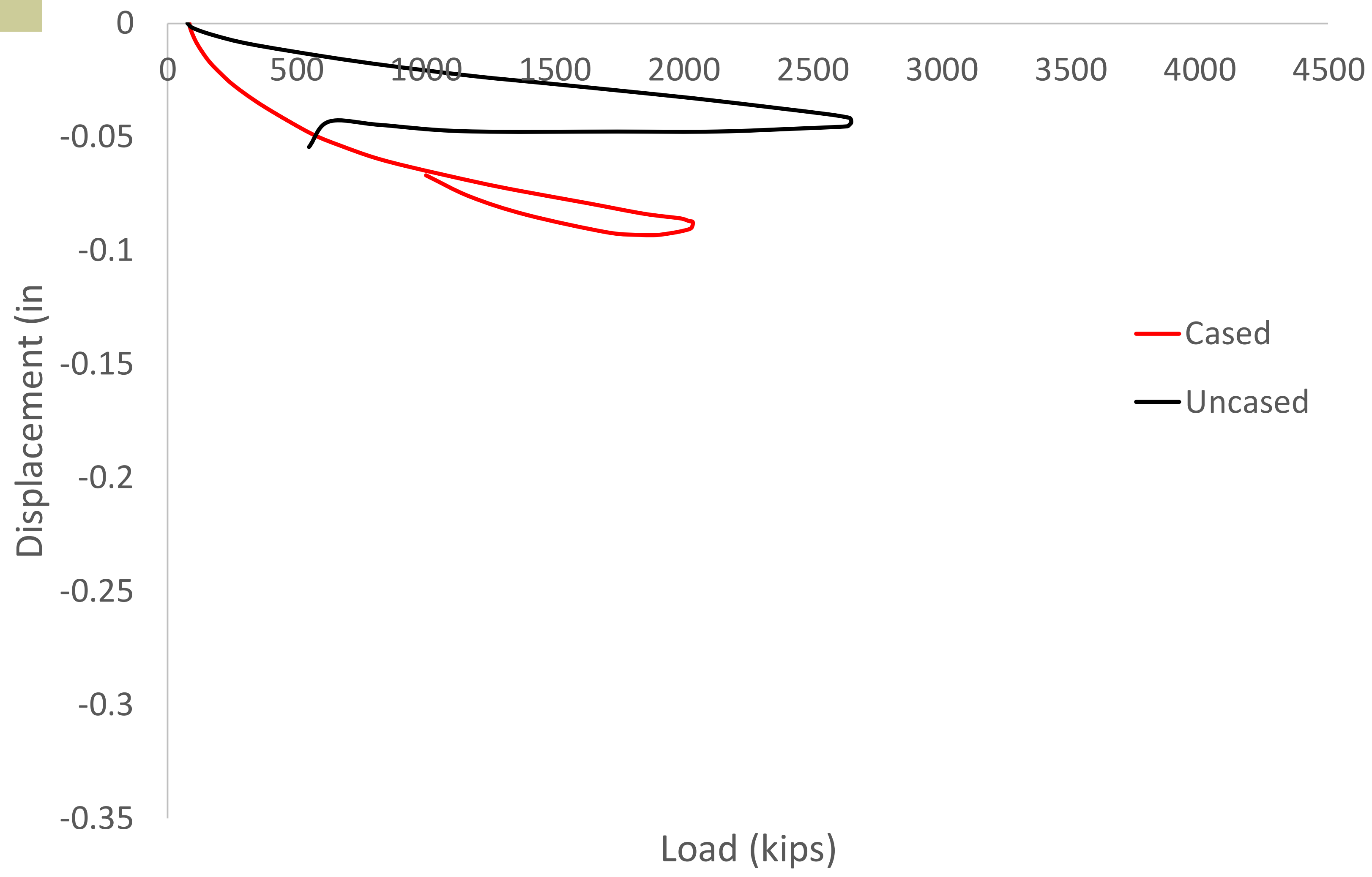
Segment 3 Unit Side Shear



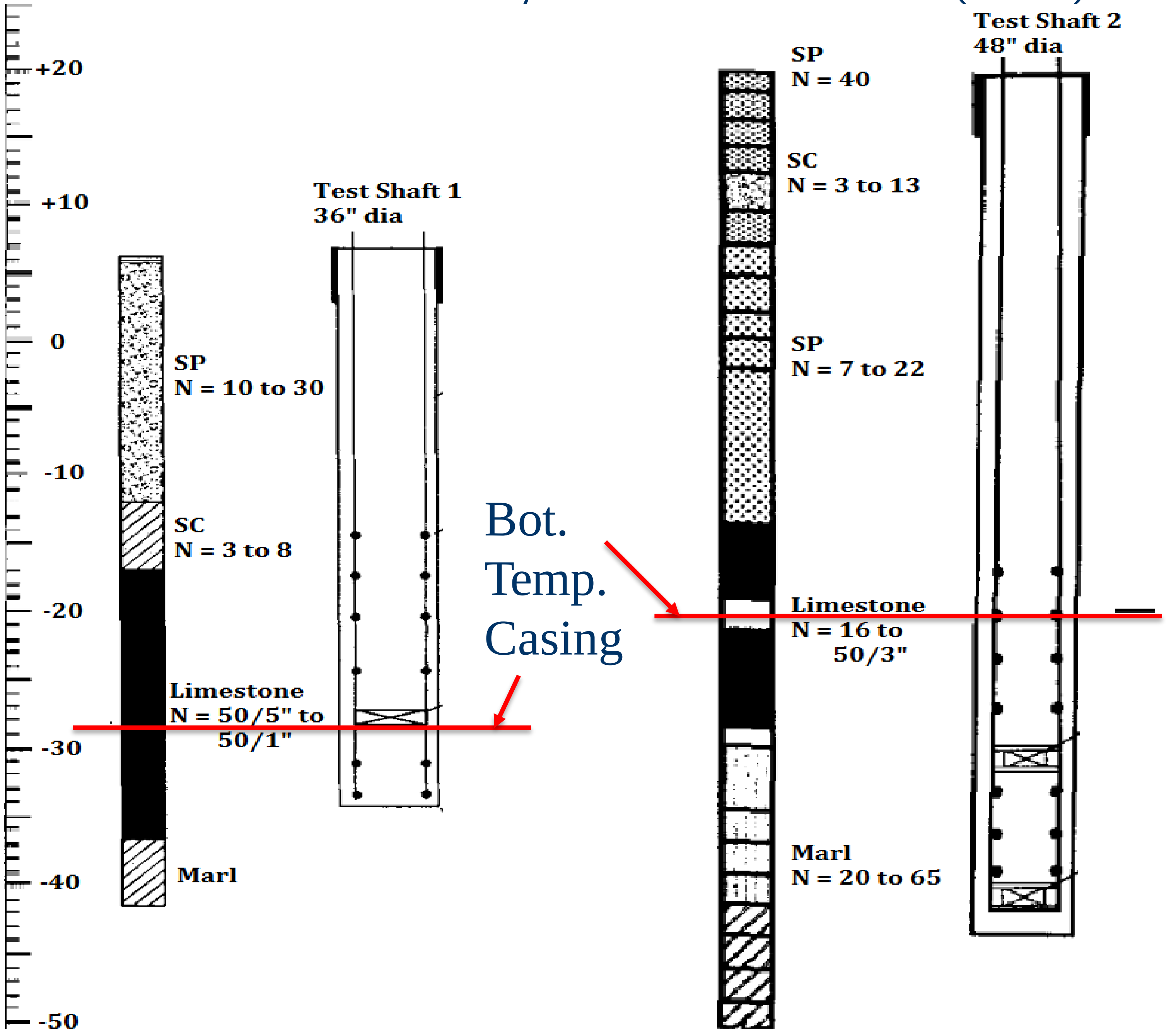
Bottom Segment Unit Side Shear



Toe of Shaft Load – Displacement



Case Study 3 Castelli and Fan (2002)

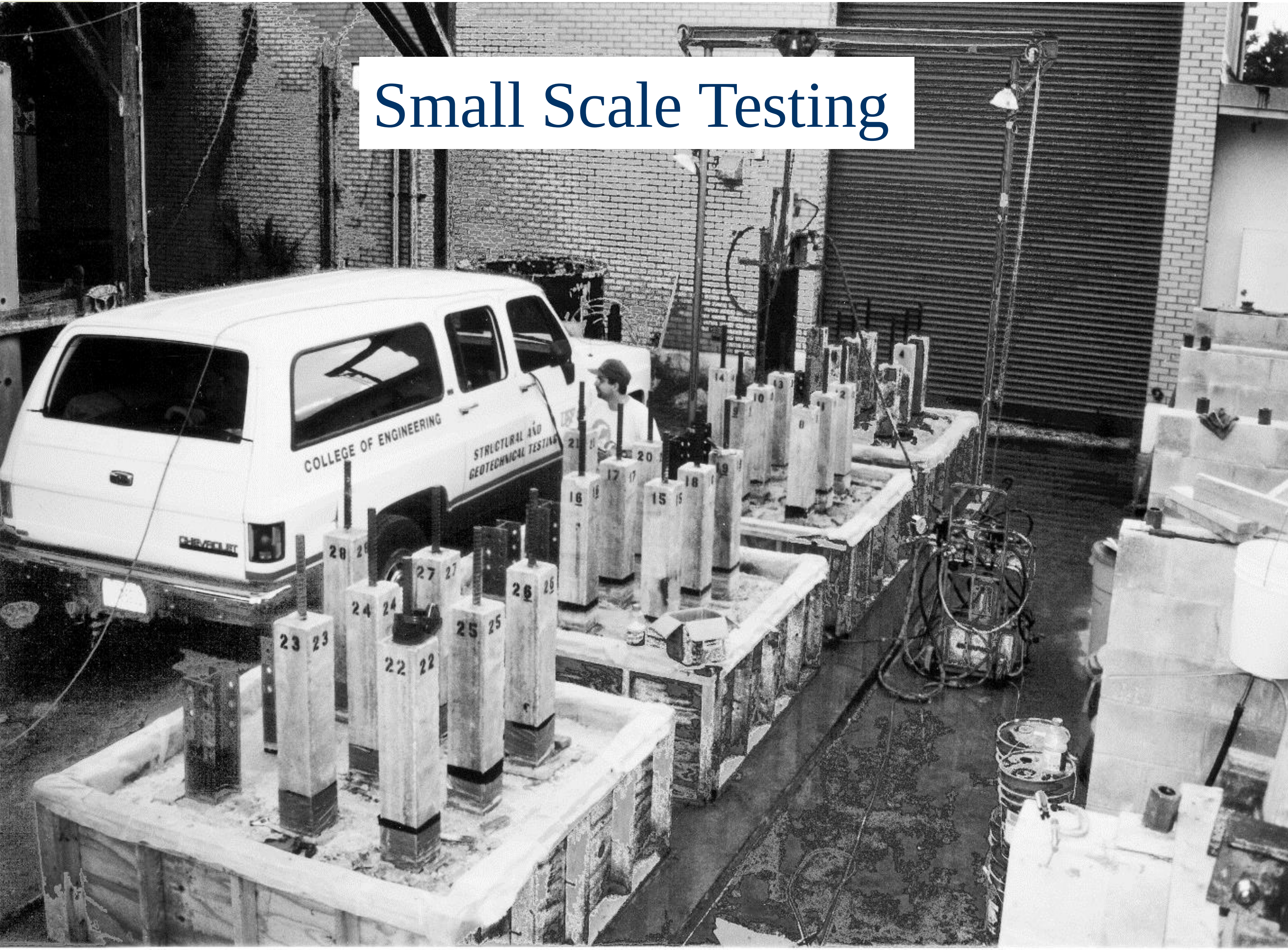


Castelli and Fan (2002)

Test Shaft No	Shaft Diameter (inches)	Maximum O-cell load (tons)	Strain Gage Elevation (ft)	Limestone Classification and SPT N-Value	Mobilized Side Shear (tsf)	Upward Disp. (inches)
1	36	970	-18 to -21	Decomposed Limestone, N ≈ 7	0.5	0.94
			-21 to -25	Cemented Limestone, N ≈ 50/1in to 50/5in	8.2	
			-25 to -28		19.0	
			-29 to -34.3		5.6*	
2	48	1465	-17.7 to -21.7	Decomposed Limestone, N ≈ 16	2.1*	0.50
			-21.7 to -25.6	Cemented Limestone, N ≈ 50/3in	6.2*	
			-25.6 to -29.5	Cemented Limestone, N ≈ 50/3in	14.1*	
			-29.5 to -32.3	Weakly Cemented Limestone, N ≈ 20 to 50/4in	4.1*	

* Failure was not observed on these segments.

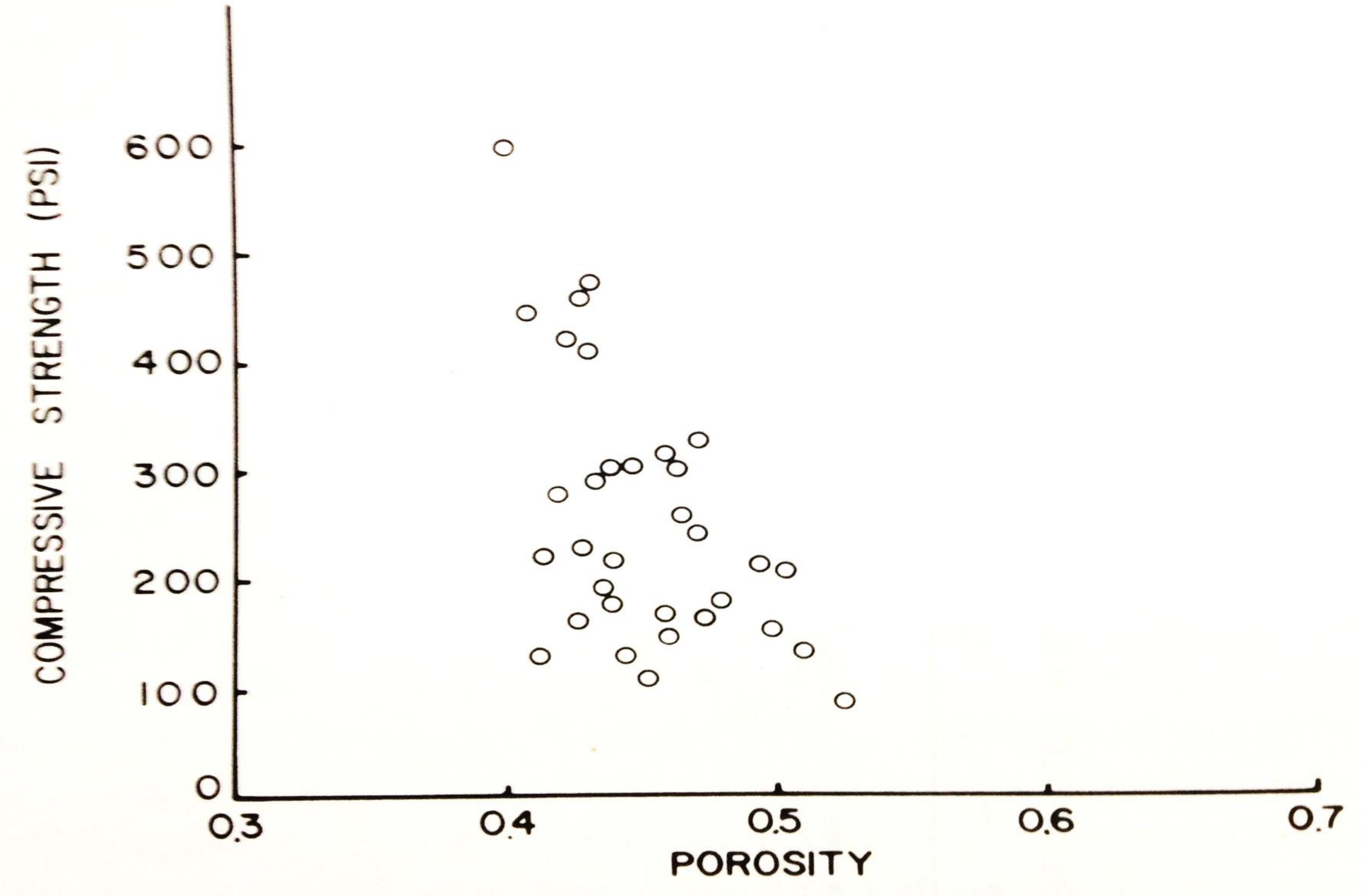
Small Scale Testing



Test Bed Preparation

- Target weaker limestone vulnerable to extended casing embedment
- Simulated limestone made from calcium carbonate / coquina shell combinations
- Casing installed with vibratory or drop hammer
- Use high strength pull out anchor rods

Target Simulated Limestone



Saxena, 1982

Lime Chemical Reactions

$$CaO + H_2O \rightarrow Ca(OH)_2 + heat\ (slaked\ lime)$$

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

In Pounds:

$$1.00[Ca(OH)_2] + 0.6[CO_2] \rightarrow 1.35[CaCO_3] + 0.25[H_2O] + heat$$

Full Scale Tests

- RW Harris' Miami Office has limestone near surface
- Pull out frame or Simply supported beam D1143 or D3689
- Rapid Load Test ASTM D7383

100 kip pullout frame

500 ton RLT system

Questions?