Soil Mixing Design Methods and Construction Techniques for Use in High Organic Soils

GRIP 2014

Gray Mullins, Ph.D., P.E.

USF UNIVERSITY OF SOUTH FLORIDA

Civil & Environmental Engineering

Problem Statement

- Organic soils are problematic for roadway construction; typically, the material is replaced, modified, or bridged.
- In-situ soil mixing is one method that can be used to stabilize the material but the high moisture content and low pH necessitates high binder contents.
- Design and quality control methodologies are required.

Project Overview

- Existing Soil Mixing Methods
- Case Histories with Long-Term Performance
- Various Binder Materials
- Techniques for New and Existing Roadways
- Lab / Field Tests to Evaluate Long Term Performance
- Cost Evaluation
- Guidelines for Soil Mixing

Research Approach

- Task 1 Literature Review
- Task 2 Laboratory Testing
- Task 3 Field Testing and Exploration
- Task 4 Cost Evaluation / Guidelines and Recommendations
- Task 5 Reporting

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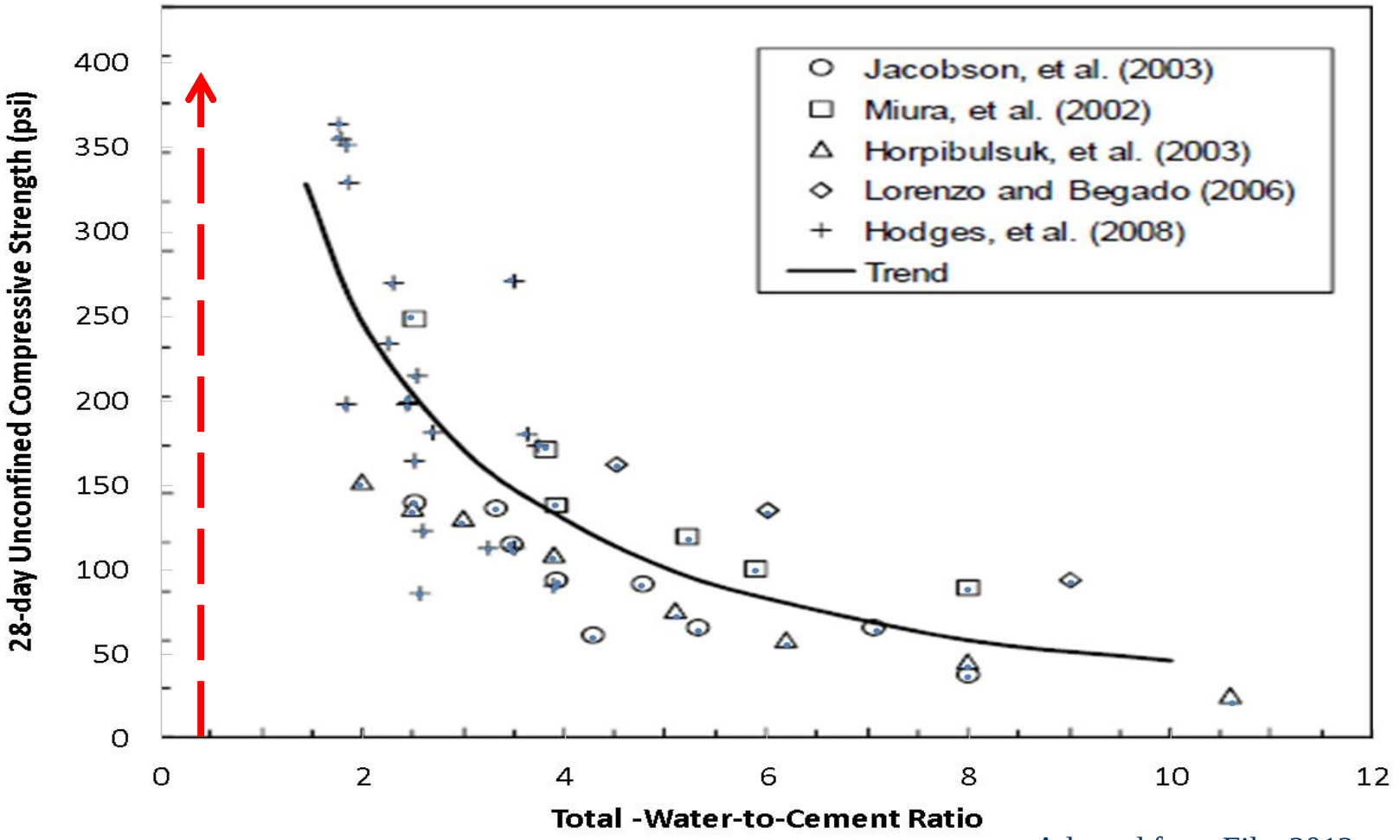
Wet Soil Mixing

Dry Soil Mixing

Strength Considerations

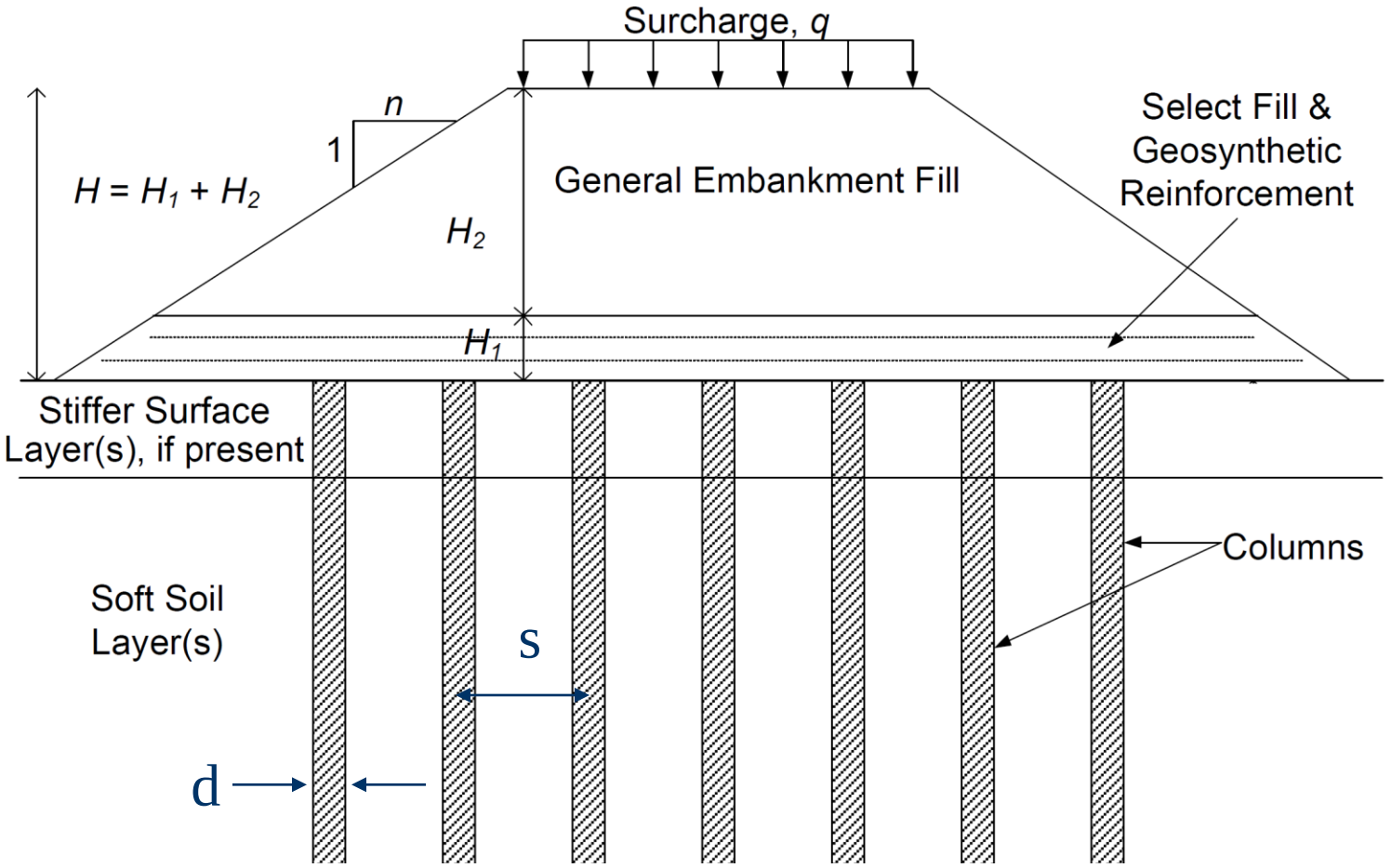


Adapted from Filz, 2012

Design Considerations

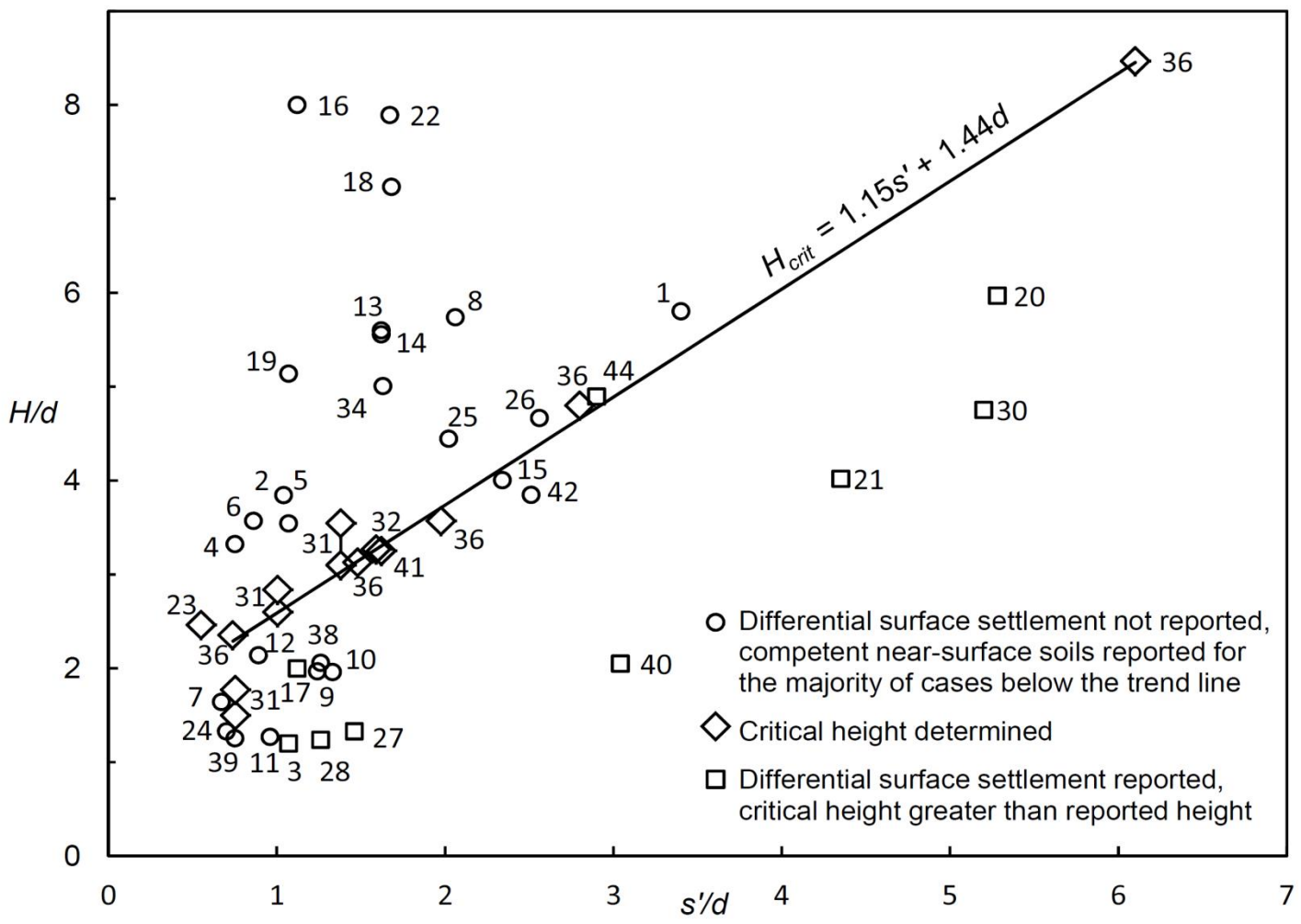
- Bulk or mass soil treatment, or
- Treated deep column supported embankments
- Transfer platform or geo-fabrics may be needed
- Strength of treated soil dictates available quality control measures (e.g. post treatment coring not feasible in weakly treated soils)

Column Supported Embankments



(Filz, 2012)

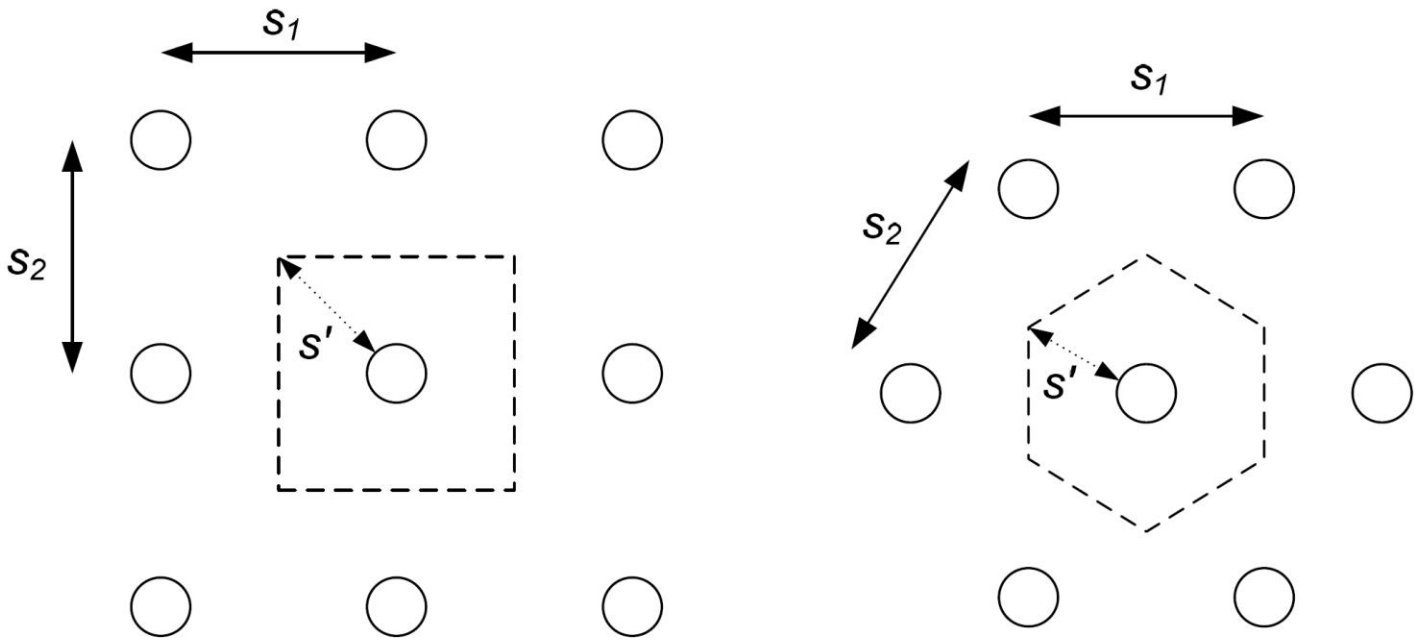
Transfer Platform Thickness
(without geo-fabric)



(Filz, 2012)

Transfer Platform Thickness
(without geo-fabric)

$$H_{crit} = 1.15s' + 1.44d$$



(Filz, 2012)

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Organic Laboratory Samples

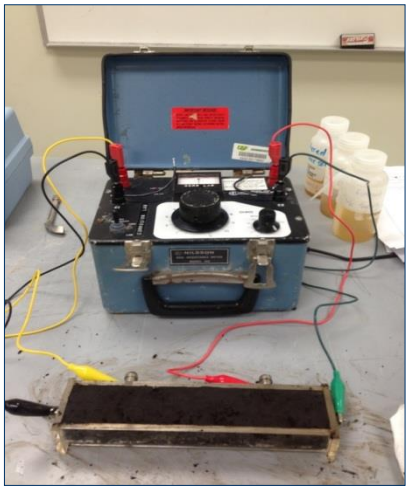
Organic Laboratory Samples

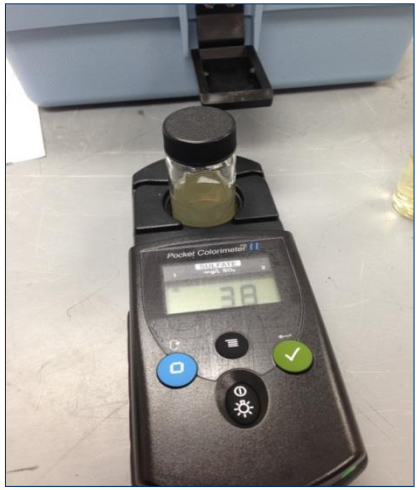
Organic Laboratory Samples

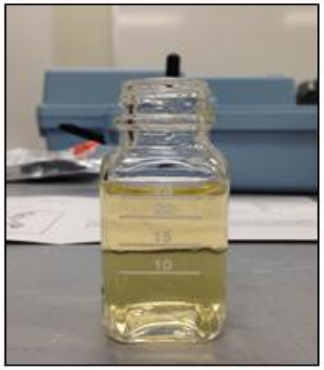
Organic Soil Properties

- Organic Content = 50-65% (ASTM D 2947-00)
- Moisture Content = 260-300% (ASTM D 2974-00)
- pH = 5.5-7 (ASTM D 4972)
- Resistivity = 5 kΩ-cm (FM 5-551)
- Chloride Content = 590 ppm (FM 5-552)
- Sulfate Content = 35 ppm (FM 5-553)

Laboratory Testing



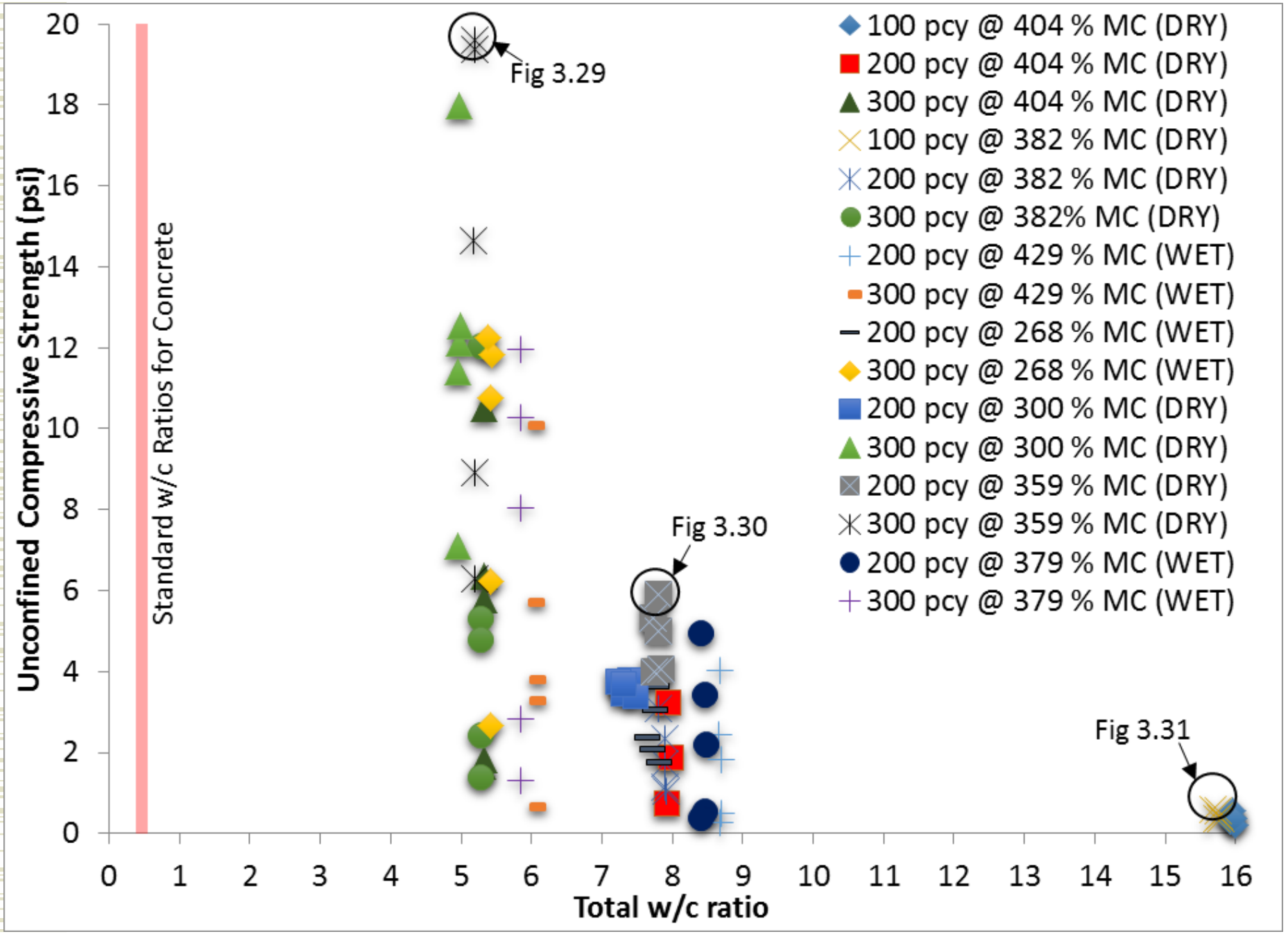




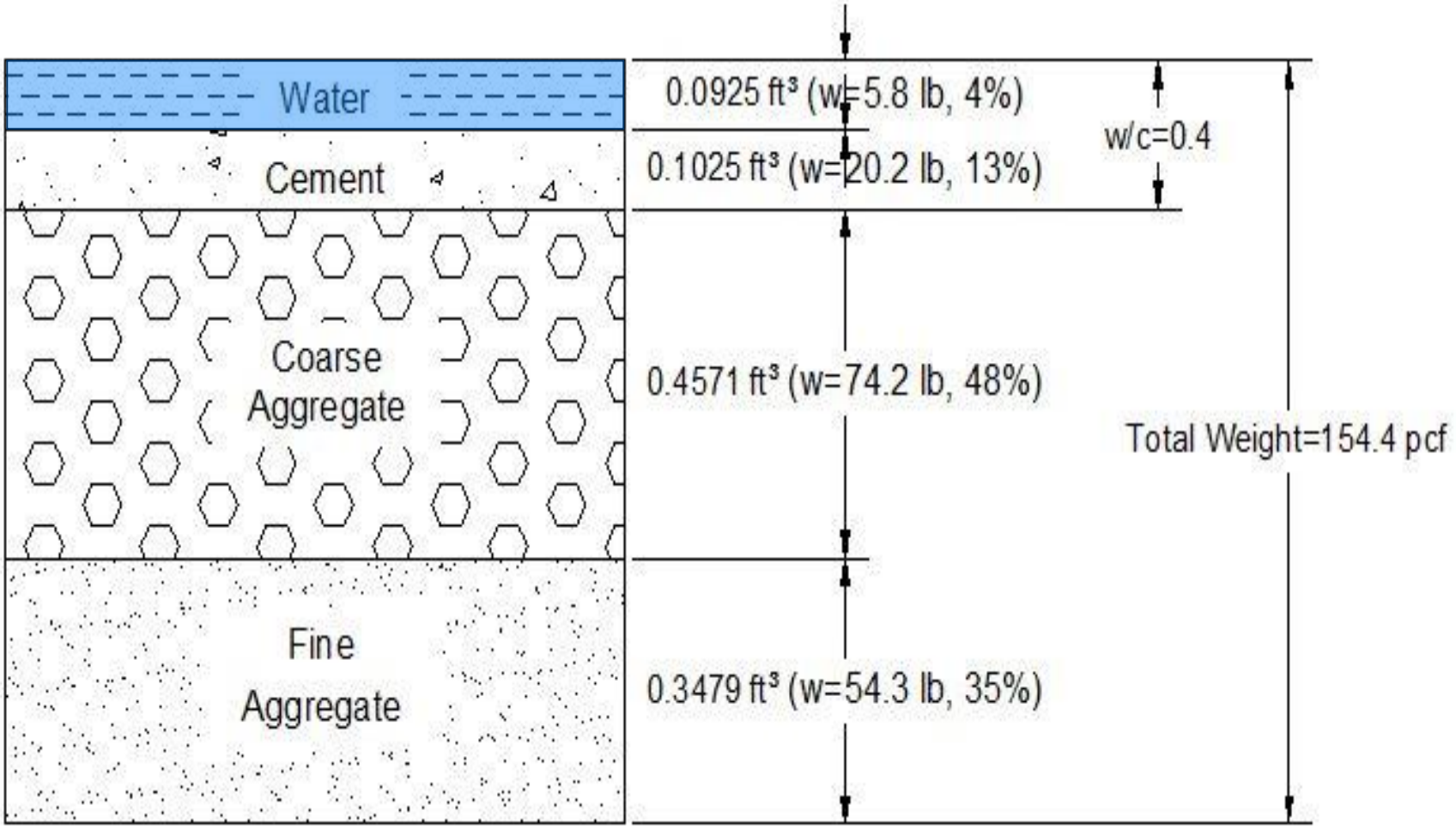
Soil Mixing Test Matrix

- UC tests on 4x8 inch Cylinders
- 100 – 300 pcy cement content
- Dry & Wet Mixing
- Starting Soil pH Range from 6 to 9
  - Soda Ash
- Moisture Content (265 to 450%)

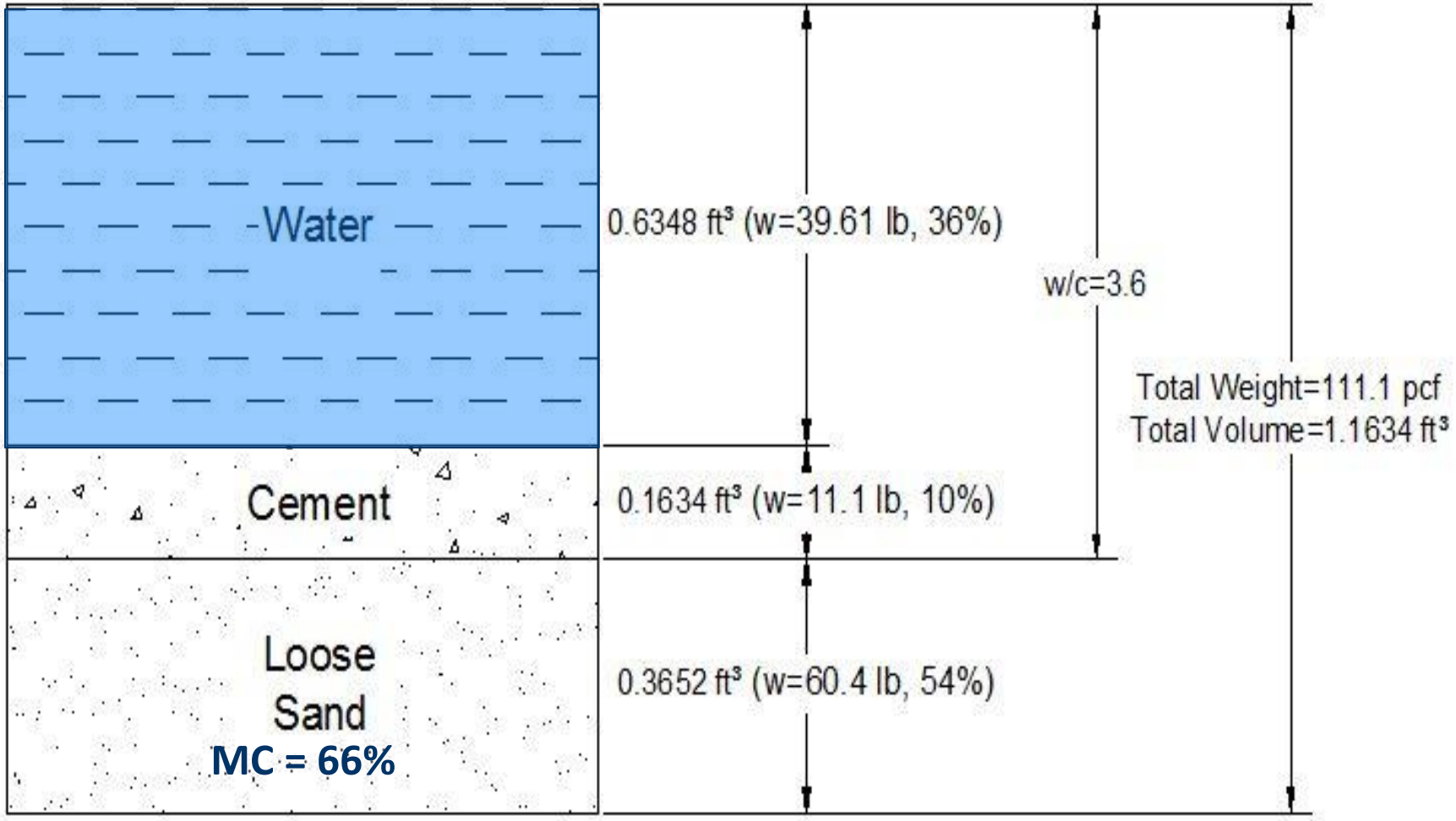
Unconfined Compression Testing


Unconfined Compressive Strength (psi)
Total w/c ratio
Standard w/c Ratios for Concrete
Fig 3.29
Fig 3.30
Fig 3.31
100 pcy @ 404 % MC (DRY)
200 pcy @ 404 % MC (DRY)
300 pcy @ 404 % MC (DRY)
100 pcy @ 382 % MC (DRY)
200 pcy @ 382 % MC (DRY)
300 pcy @ 382% MC (DRY)
200 pcy @ 429 % MC (WET)
300 pcy @ 429 % MC (WET)
200 pcy @ 268 % MC (WET)
300 pcy @ 268 % MC (WET)
200 pcy @ 300 % MC (DRY)
300 pcy @ 300 % MC (DRY)
200 pcy @ 359 % MC (DRY)
300 pcy @ 359 % MC (DRY)
200 pcy @ 379 % MC (WET)
300 pcy @ 379 % MC (WET)

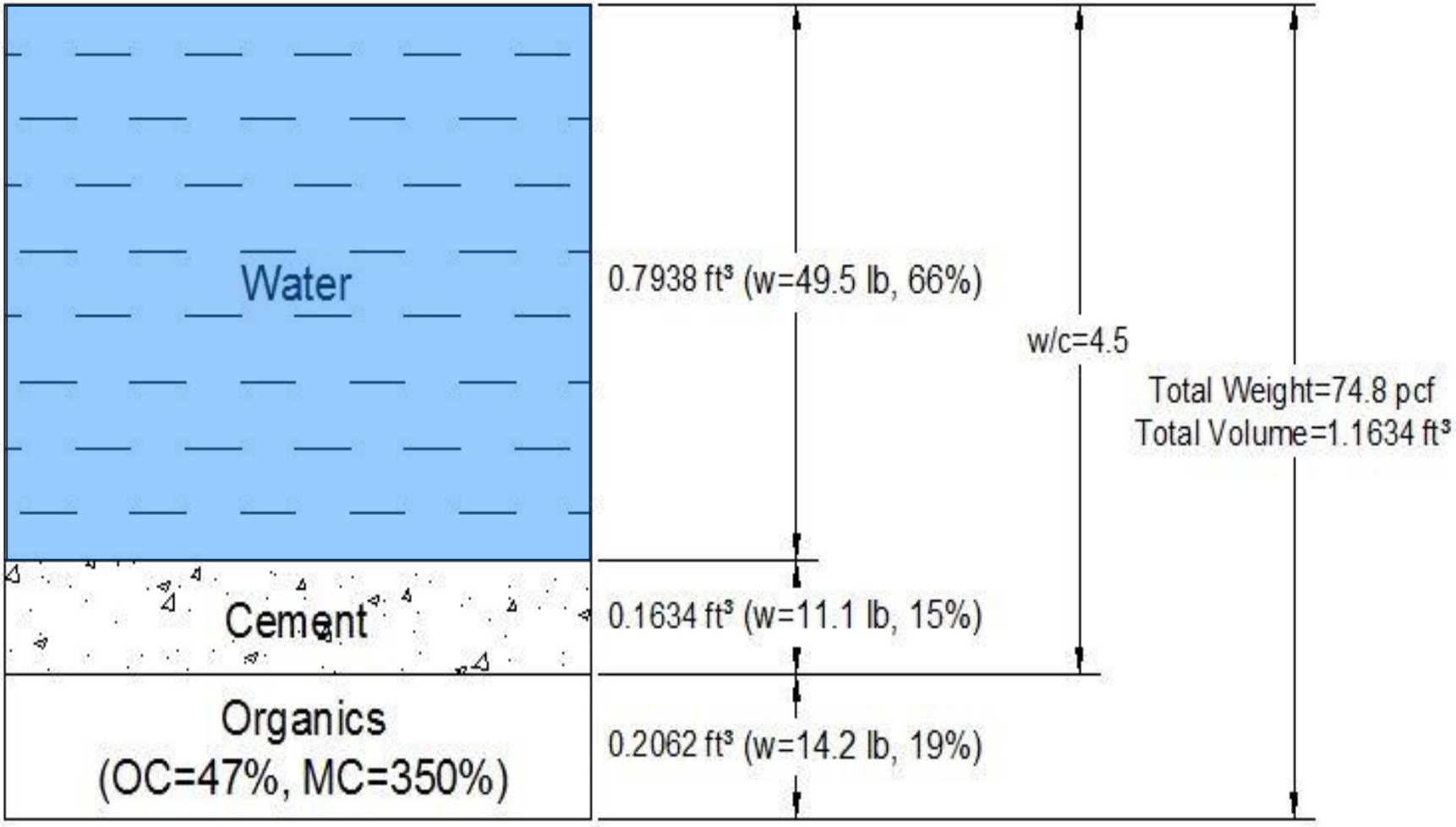
Volume Diagram (concrete w/c 0.4 – 4000psi)

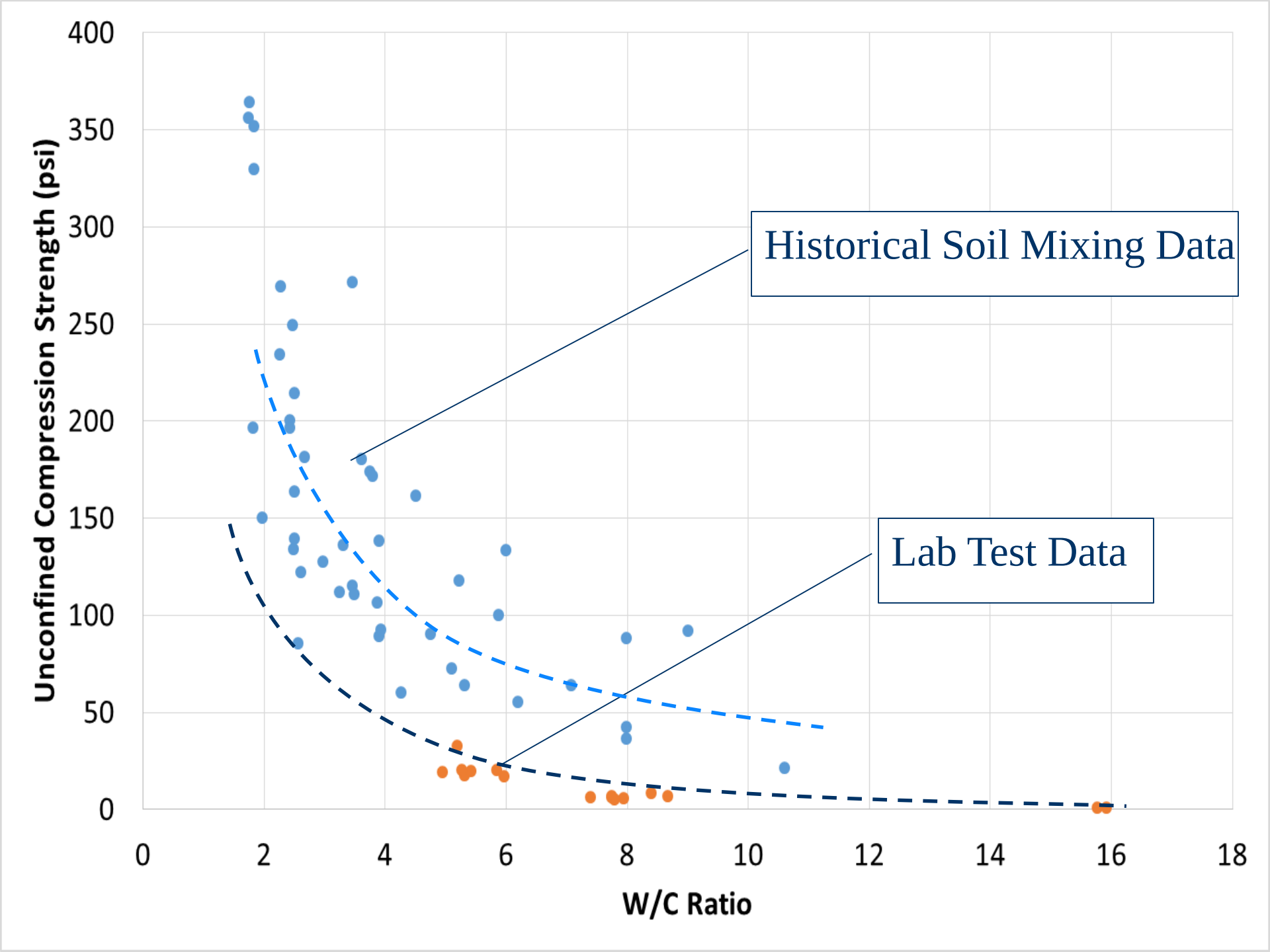


Volume Diagram (loose sand w/c 3.6 – 100psi)



Volume Diagram (organic soil w/c 4.5 – 20psi)




Unconfined Compression Strength (psi)
400
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
14
16
18
W/C Ratio
Historical Soil Mixing Data
Lab Test Data

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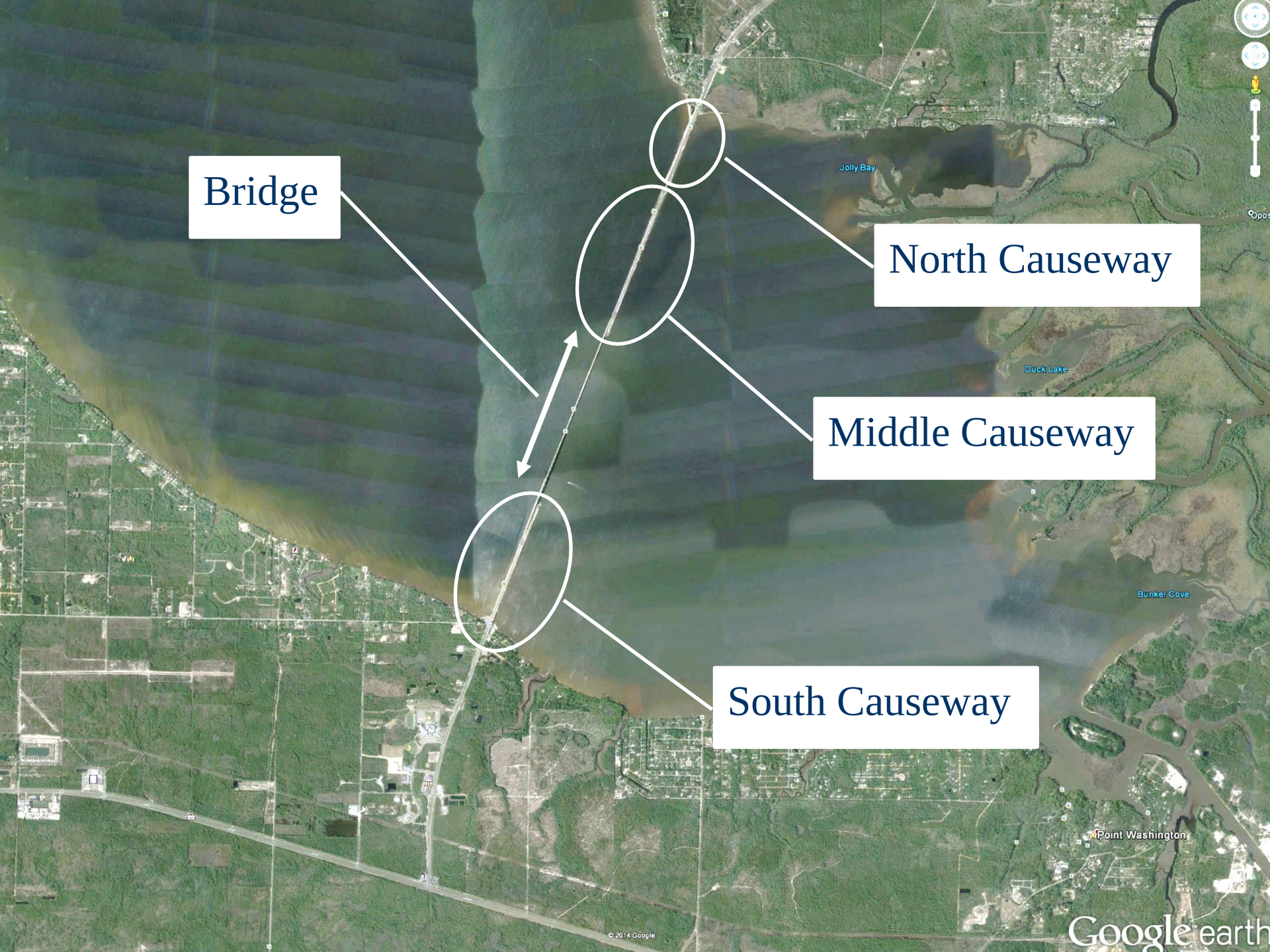
Case Histories

- District 1: SR 33 North of Polk City
- District 2: SR 100 in Putnam County
  The Rail and Trail Bike Path
- District 5: SR 46 in Sanford
- District 6: US-1 Jewfish Creek
- Turnpike: Milepost 284.7 in Lake County
- US331: Choctawhatchee Bay Causeway

US331: Choctawhatchee Bay Causeway

- ~16,000ft bay water crossing
- ~8000ft is filled causeway (late 1930's)
- Very loose fill and natural soils have settled and continue to cause maintenance problems
- Soils: sand, silt, clay and organic material
- Combination of deep and shallow soil mixing used to stabilize causeway portions


Bridge
North Causeway
Middle Causeway
South Causeway
Jolly Bay
Duck Lake
Bunker Cove
Point Washington
© 2014 Google
Google earth

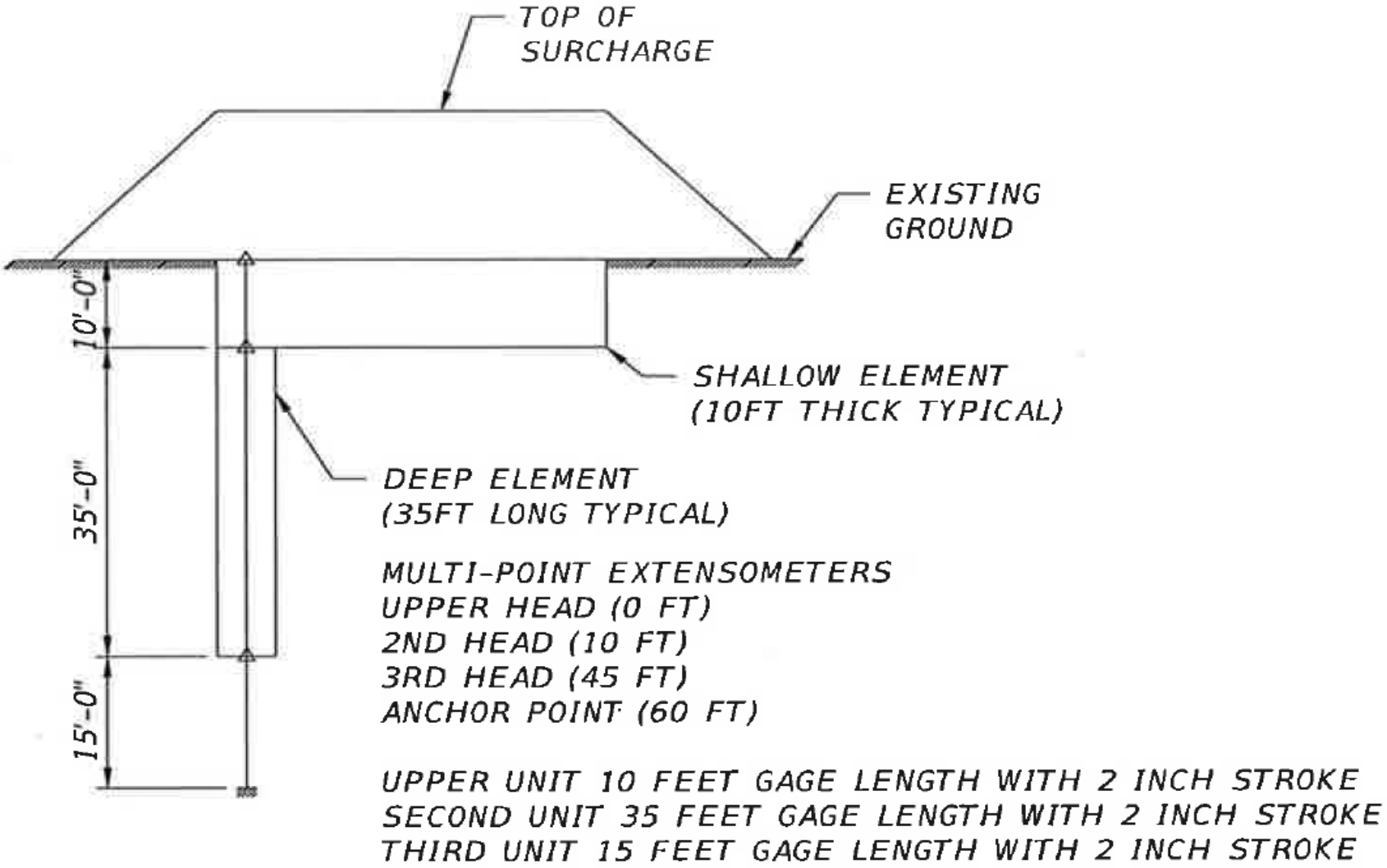
Test Program

- Bench scale tests
- Full scale demonstration elements
- Surcharge test section (19ft embankment)
- Instrumentation
  - Pore pressure transducers
  - Vibrating wire extensometers
  - Settlement plates

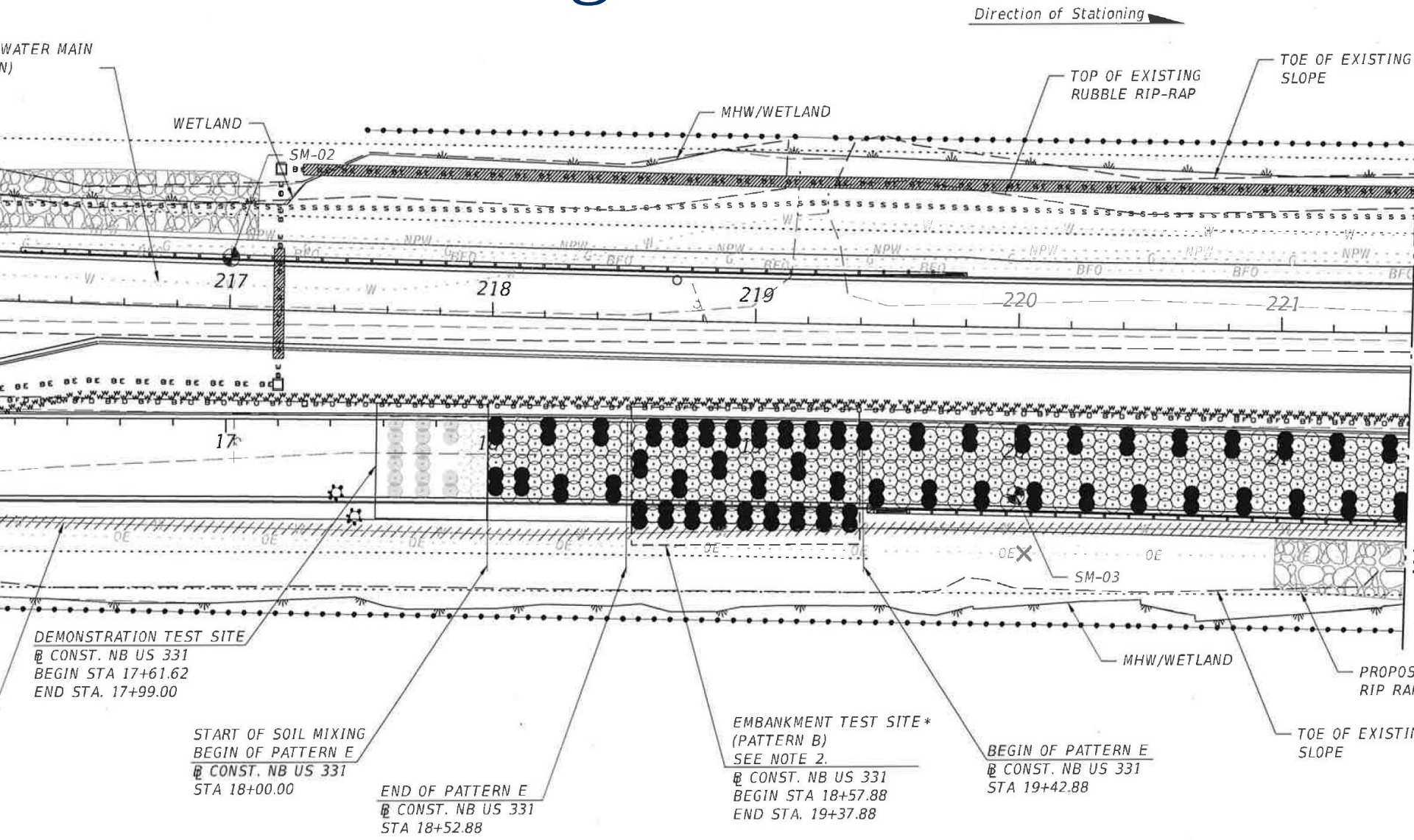
Design and QA/QC

- Req'd strength 75 – 150psi
- Depth of treatment
  - 0 – 10ft full coverage (transfer platform)
  - 10 – 45ft isolated deep columns
- Bench scale set cement content at ~10-17pcf
- Field demonstration set mixing effort by number of blade revolutions ~350-500
- Settlement control verified by surcharge test

Surcharge Test Section



Surcharge Test Section



Installation of Elements

Automated Measurement Systems

soilmec

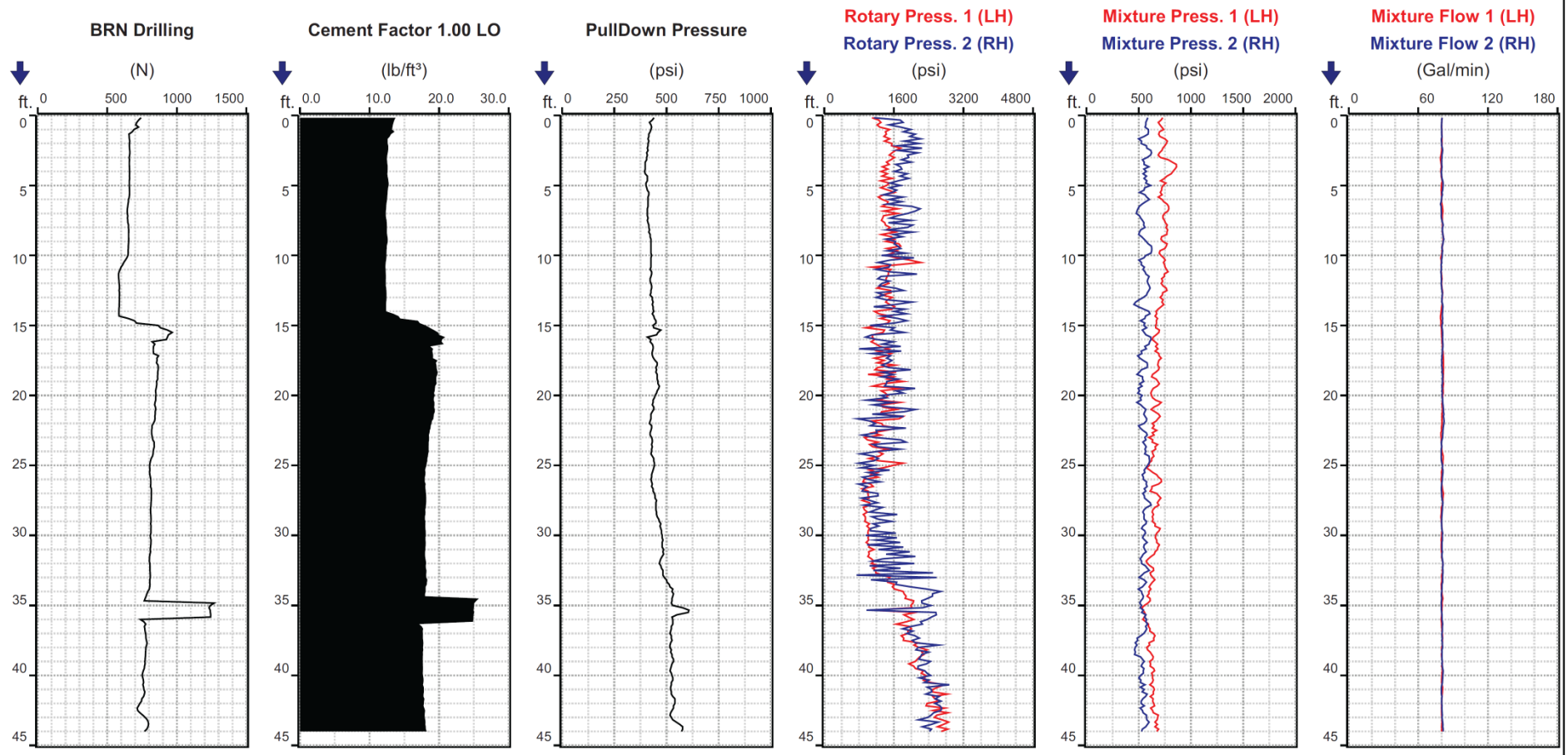
Site:	SR83	Site Code:	2013-03
Pile:	NSAC041	Serial Number:	SR90-M3400

Drilling Phase			Withdrawal Phase		
Start:	4/15/2014 7:49:49 AM		Start:	4/15/2014 8:23:28 AM	
End:	4/15/2014 8:23:05 AM		End:	4/15/2014 8:30:37 AM	
Pause time:	00:00		Pause time:	00:00	
Duration:	33:16		Duration:	07:08	
Design Depth:	44.07	ft.	Start withdrawal depth:	44.17	ft.
Depth Reached:	44.07	ft.			
Total Volume (L):	363.46	ft³	Total Volume (L):	26.42	ft³
Total Volume (R):	363.61	ft³	Total Volume (R):	26.11	ft³
Fluids Used	Cement Grout				

Tool Diameter	69	in.
Number of Blades:	8	
Mast Tilt (X):	0.20	°
Mast Tilt (Y):	-0.17	°

Specific weight of cement:	196.65	lbs/ft³
Ratio Water / Cement:	1.00	

Zone	Depth	N. Retreat.	Cement Factor
1	From 0.0 to 15.0ft.	1	12.0 lbs/ft³
2	From 15.0 to 44.0ft.	1	17.6 lbs/ft³



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Pause time:	0:00:00	Pause time:	0:00:00
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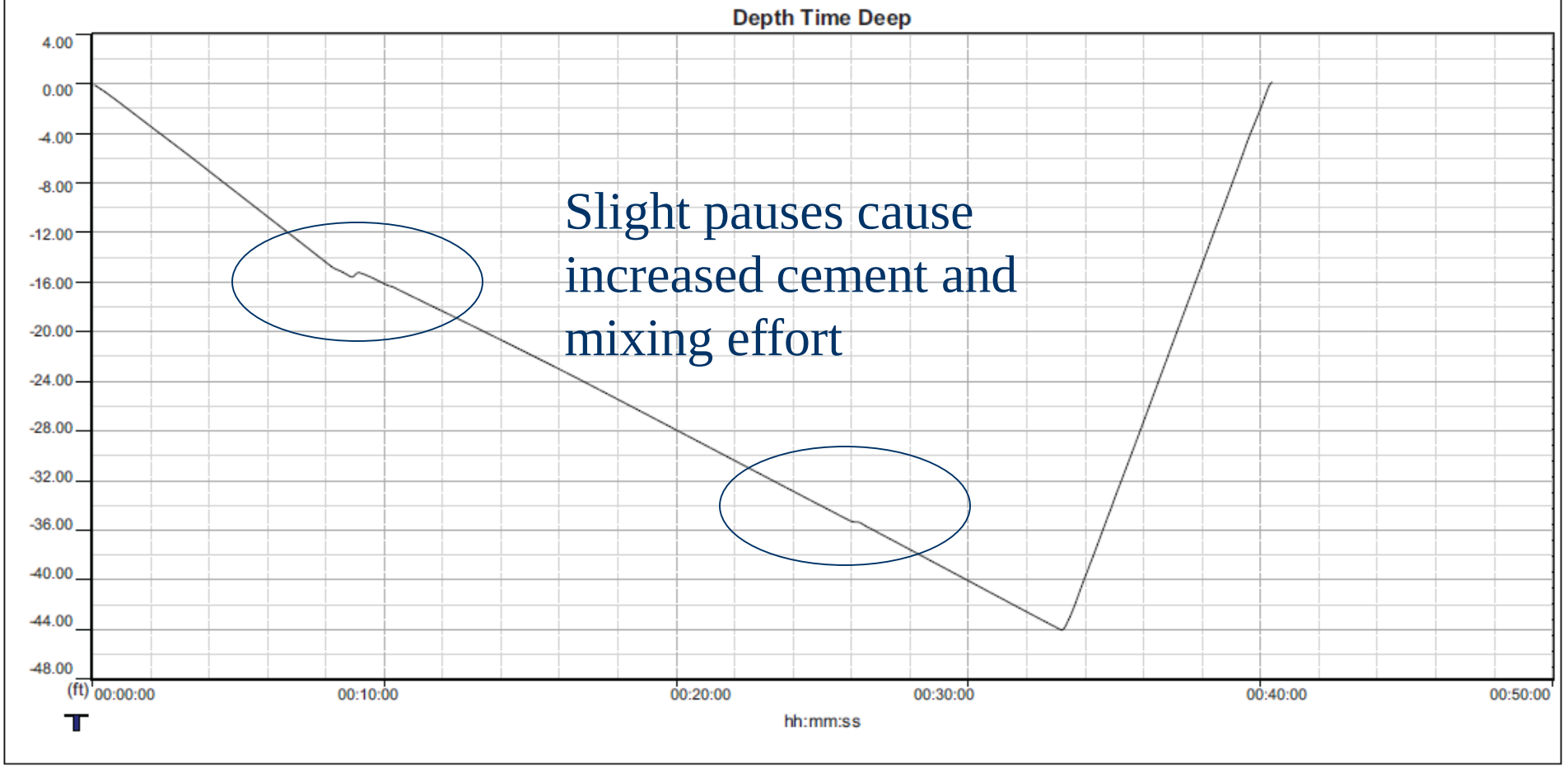
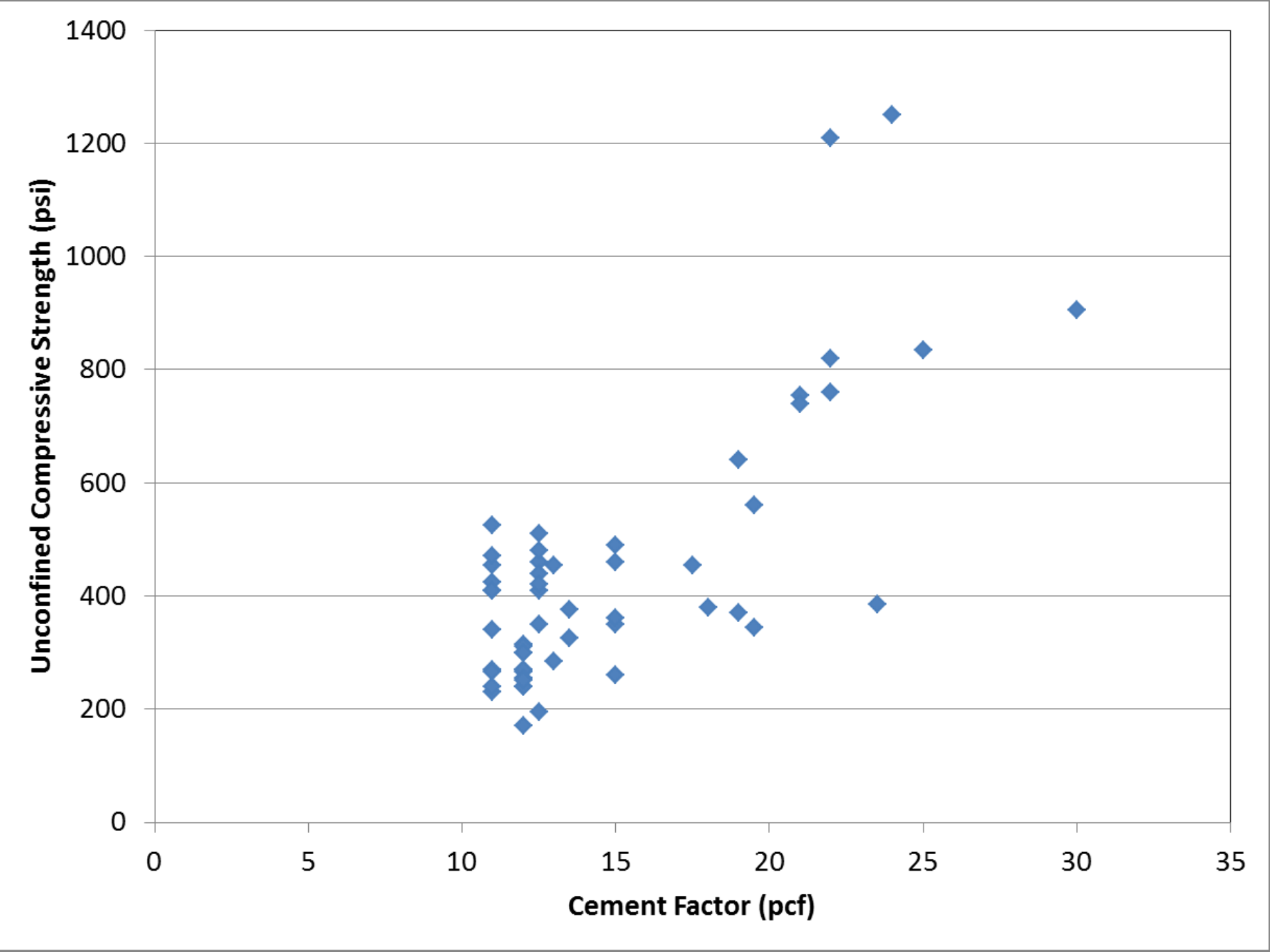
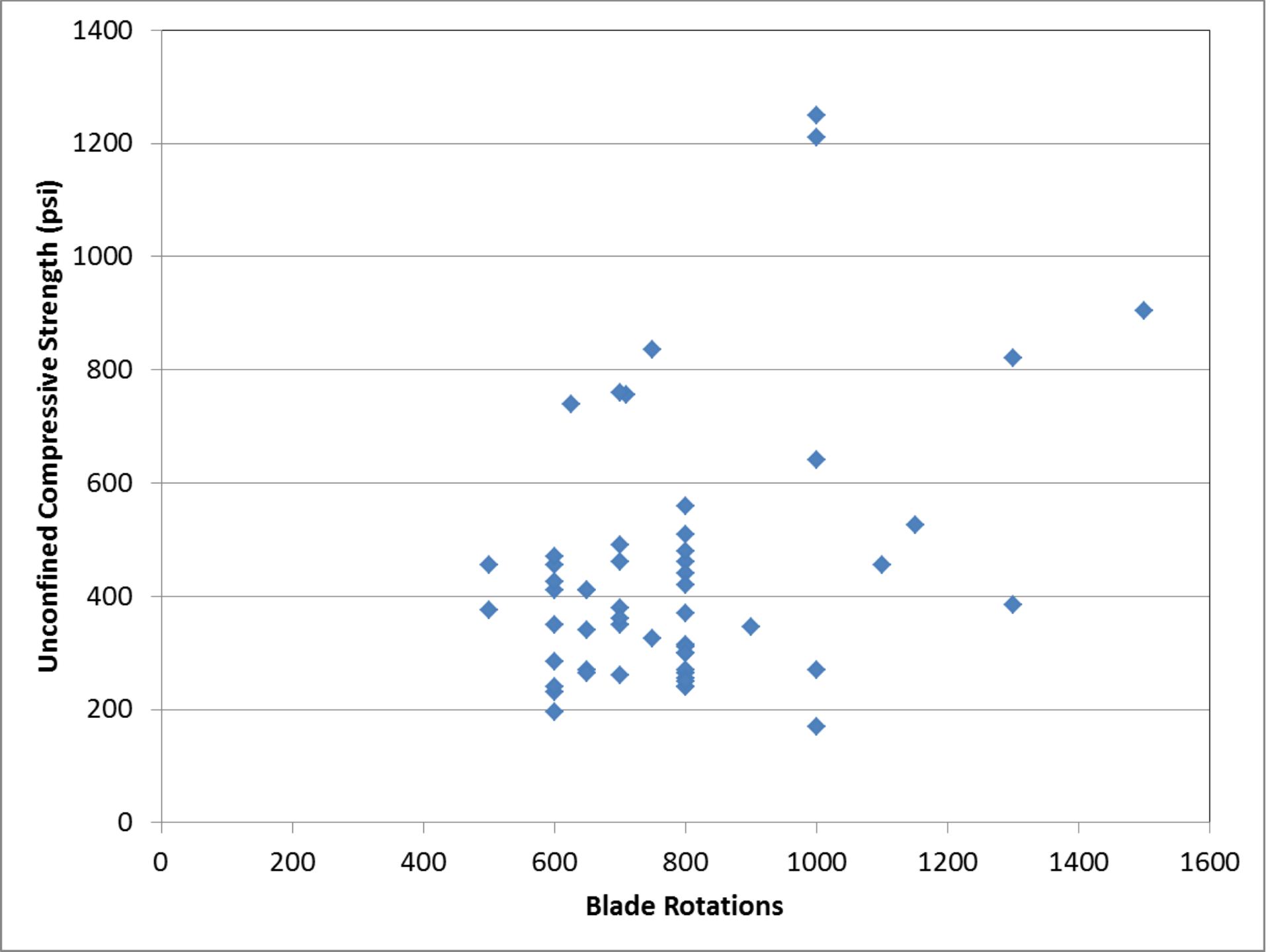
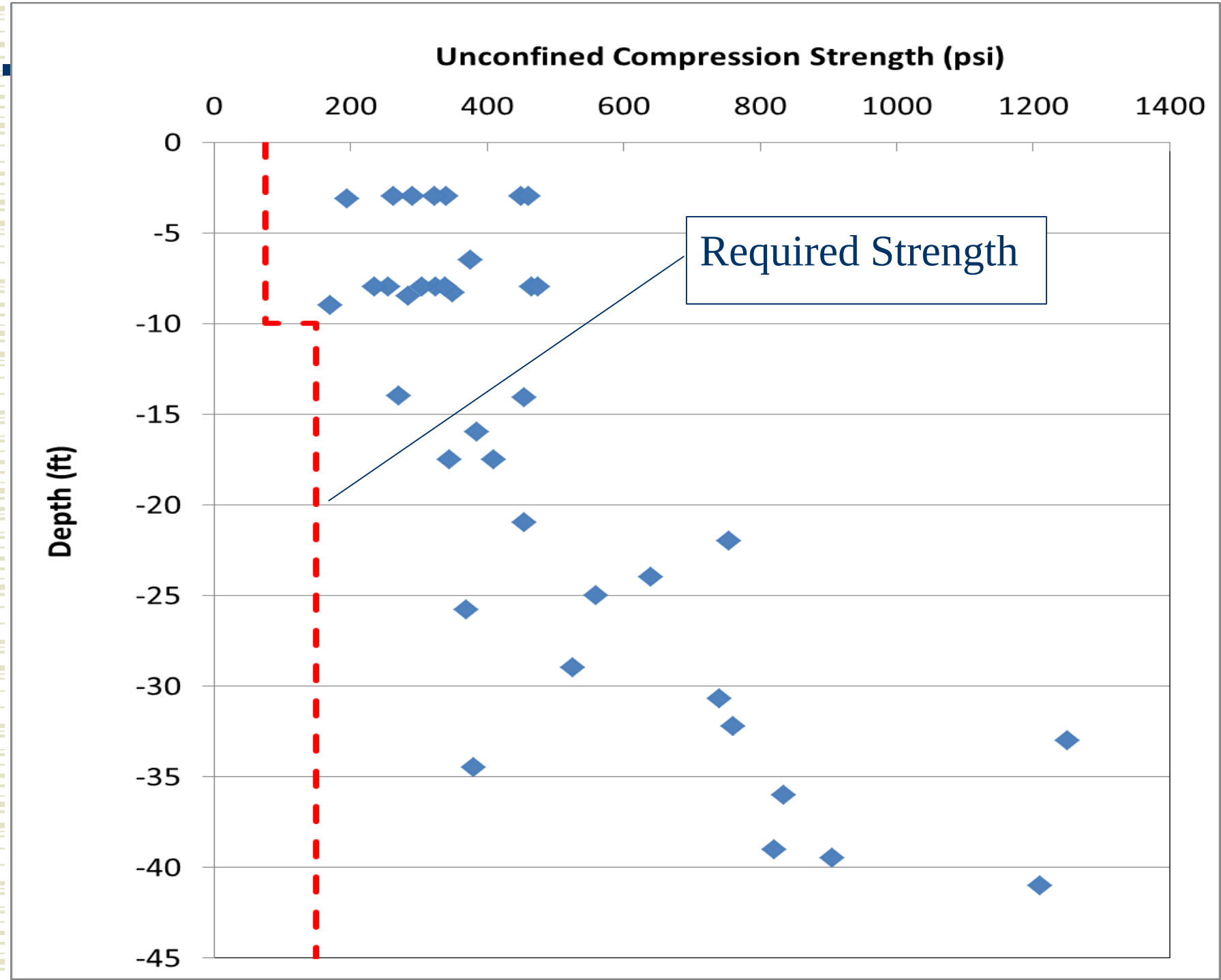
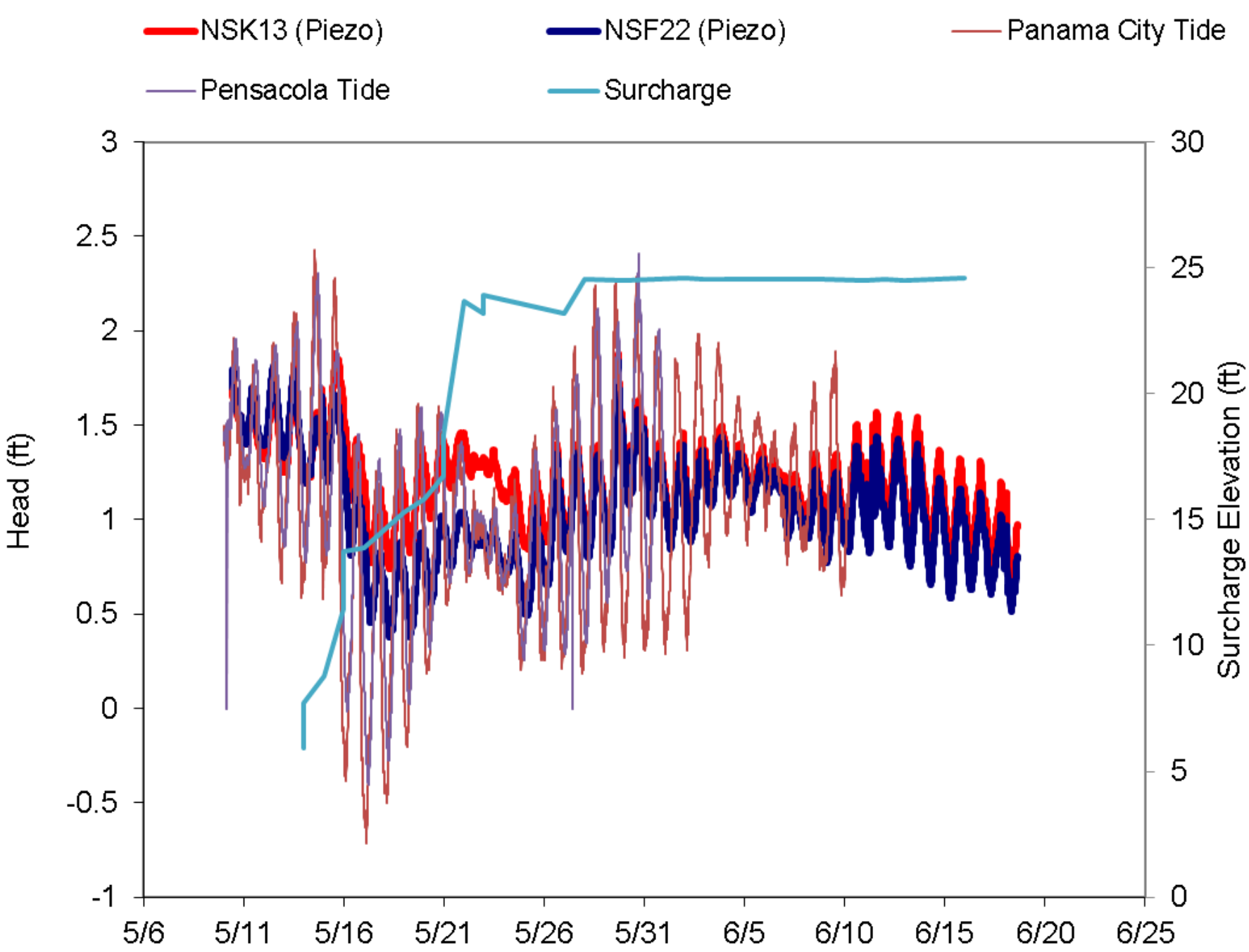
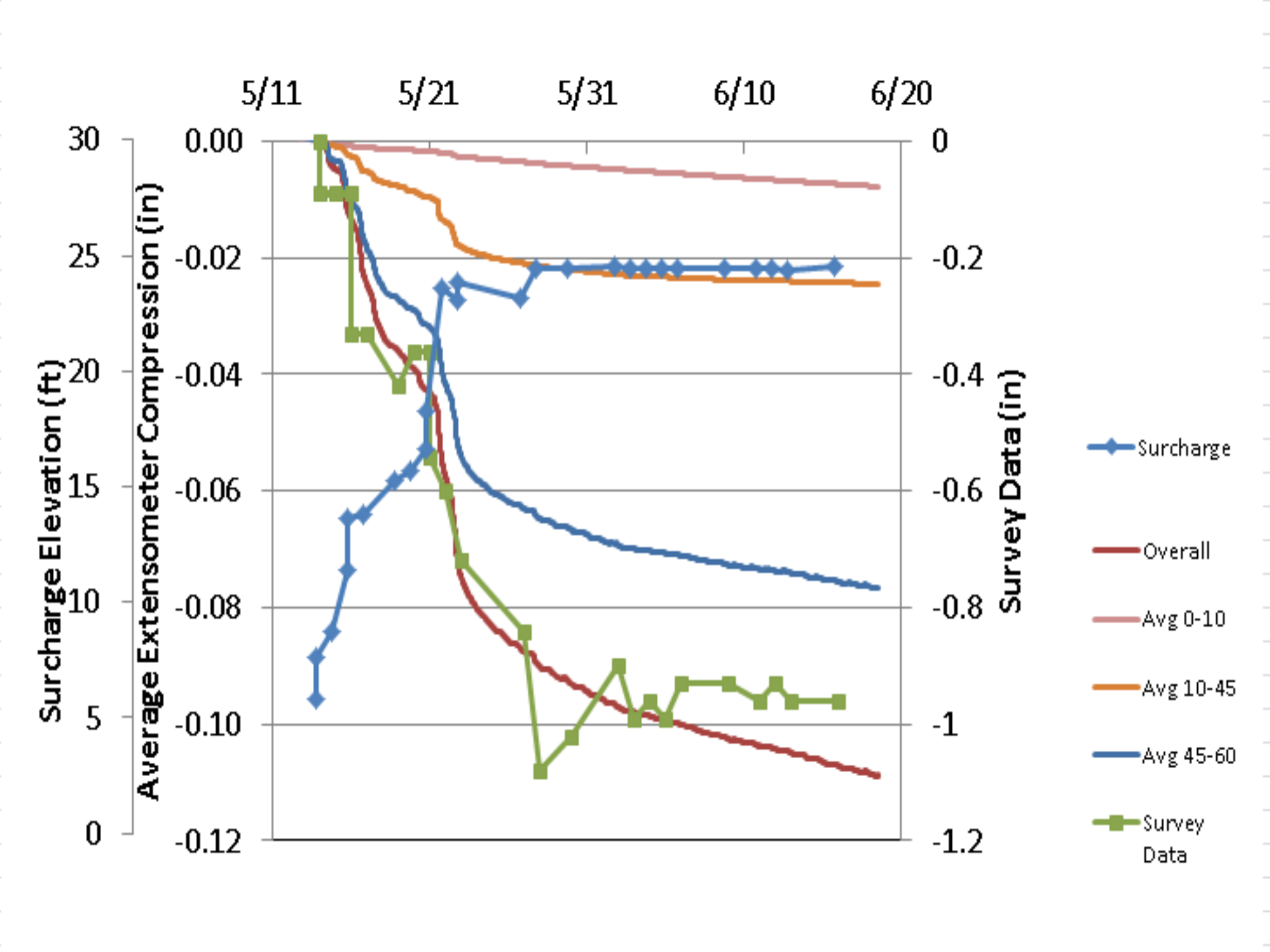



Unconfined Compressive Strength (psi)
1400
1200
1000
800
600
400
200
0
0
5
10
15
20
25
30
35
Cement Factor (pcf)


Unconfined Compressive Strength (psi)
1400
1200
1000
800
600
400
200
0
0
200
400
600
800
1000
1200
1400
1600
Blade Rotations


Unconfined Compression Strength (psi)
0
200
400
600
800
1000
1200
1400
Depth (ft)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
Required Strength

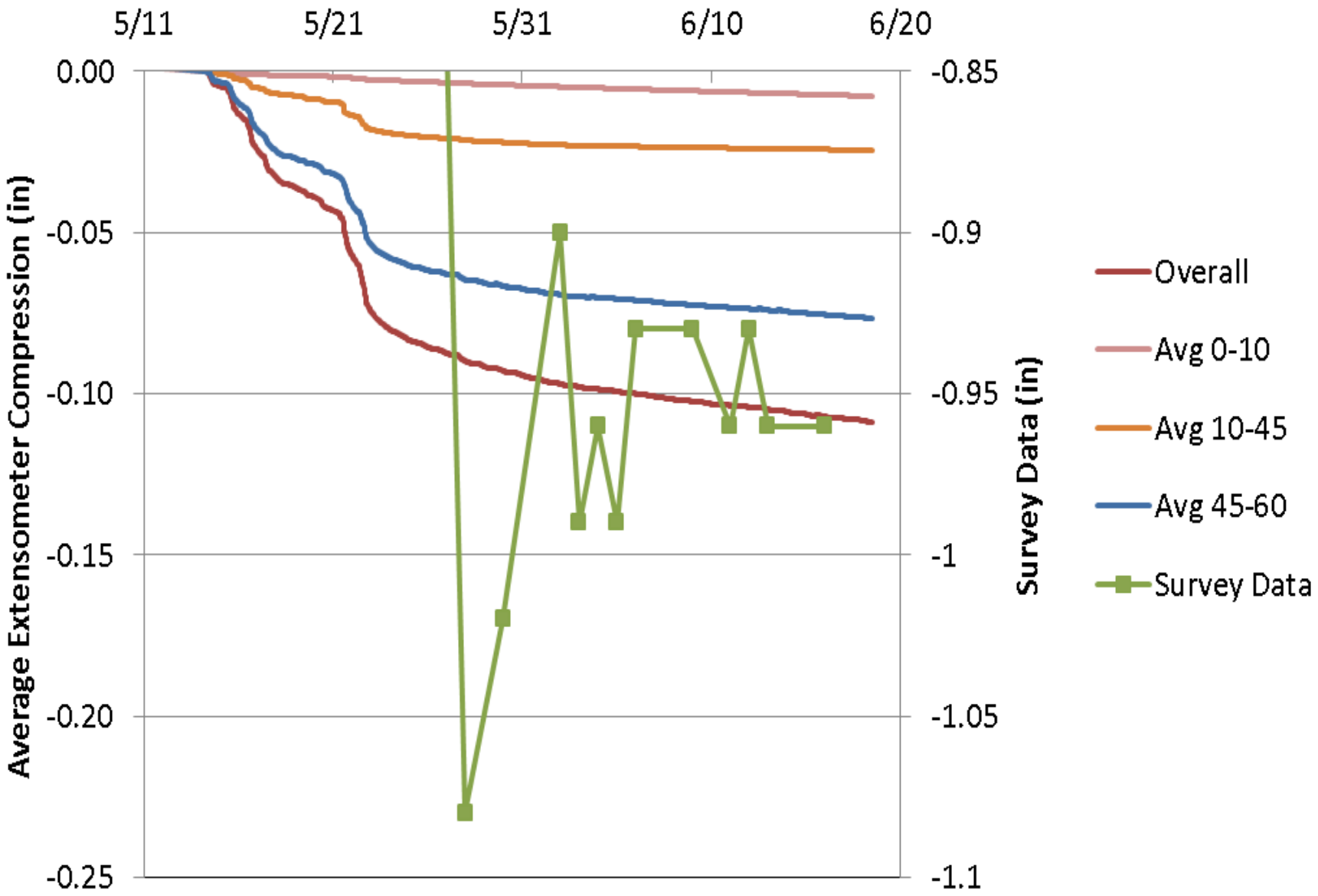

NSK13 (Piezo)
NSF22 (Piezo)
Panama City Tide
Pensacola Tide
Surcharge
Head (ft)
Surcharge Elevation (ft)
3
2.5
2
1.5
1
0.5
0
-0.5
-1
30
25
20
15
10
5
0
5/6
5/11
5/16
5/21
5/26
5/31
6/5
6/10
6/15
6/20
6/25


5/11
5/21
5/31
6/10
6/20
Surcharge Elevation (ft)
30
25
20
15
10
5
0
Average Extensometer Compression (in)
0.00
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
Survey Data (in)
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
Surcharge
Overall
Avg 0-10
Avg 10-45
Avg 45-60
Survey Data


4 15-17 EXT.#6L JV

Inclinometer Evaluation

Rod ID	Top of Settlement Rod Lateral Offset (ft)		Vertical error (in)
	Survey	Inclinometer	
NSM13	0.58	0.56	0.14
NSF20	2.32	2.10	1.06
NSI21	1.36	1.40	0.61
NSC25	2.41	3.00	3.32


5/11
5/21
5/31
6/10
6/20
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.85
-0.9
-0.95
-1
-1.05
-1.1
Average Extensometer Compression (in)
Survey Data (in)
Overall
Avg 0-10
Avg 10-45
Avg 45-60
Survey Data

Tracking Quality

- On-board computer systems may malfunction and could be “manipulated”
- Should verify via manual readings
  - Daily cement usage
  - Location of elements
  - Watching depth of rig
- Coring and UC tests are good where possible
- Weaker soil mix designs may not be able to retrieve cores (need alternate method)

Interim Conclusions

- While cement content and w/c ratio are key components to strength, organic soils will still require more cement
- Long term settlement surveys shows no discernible movements (some distress between treated and untreated regions of Jewfish Creek site)

Interim Conclusions

- Post treatment performance evaluation should be considered during design
  - strong enough to core or use alternate method
  - will geo-fabric hamper sampling
- Automated field QC should be supplemented with manual QA logs

Questions?