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Geotechnical Construction



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Foundation Solutions for New Tanks

NISTM – 6th Annual International Aboveground Storage Tank Conference and Trade Show – September 19, 2013

**HAYWARD
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TANK SERVICES DIVISION



NISTM

National Institute for Storage Tank Management

Presentation Outline

- Some Definitions to set the stage
- Design Considerations for Supporting Tanks
- Ground Improvement Tank Support Methods
 - Stone Columns
 - Soil Mixing
 - Wick Drains
 - Other Improvement
- Conclusions

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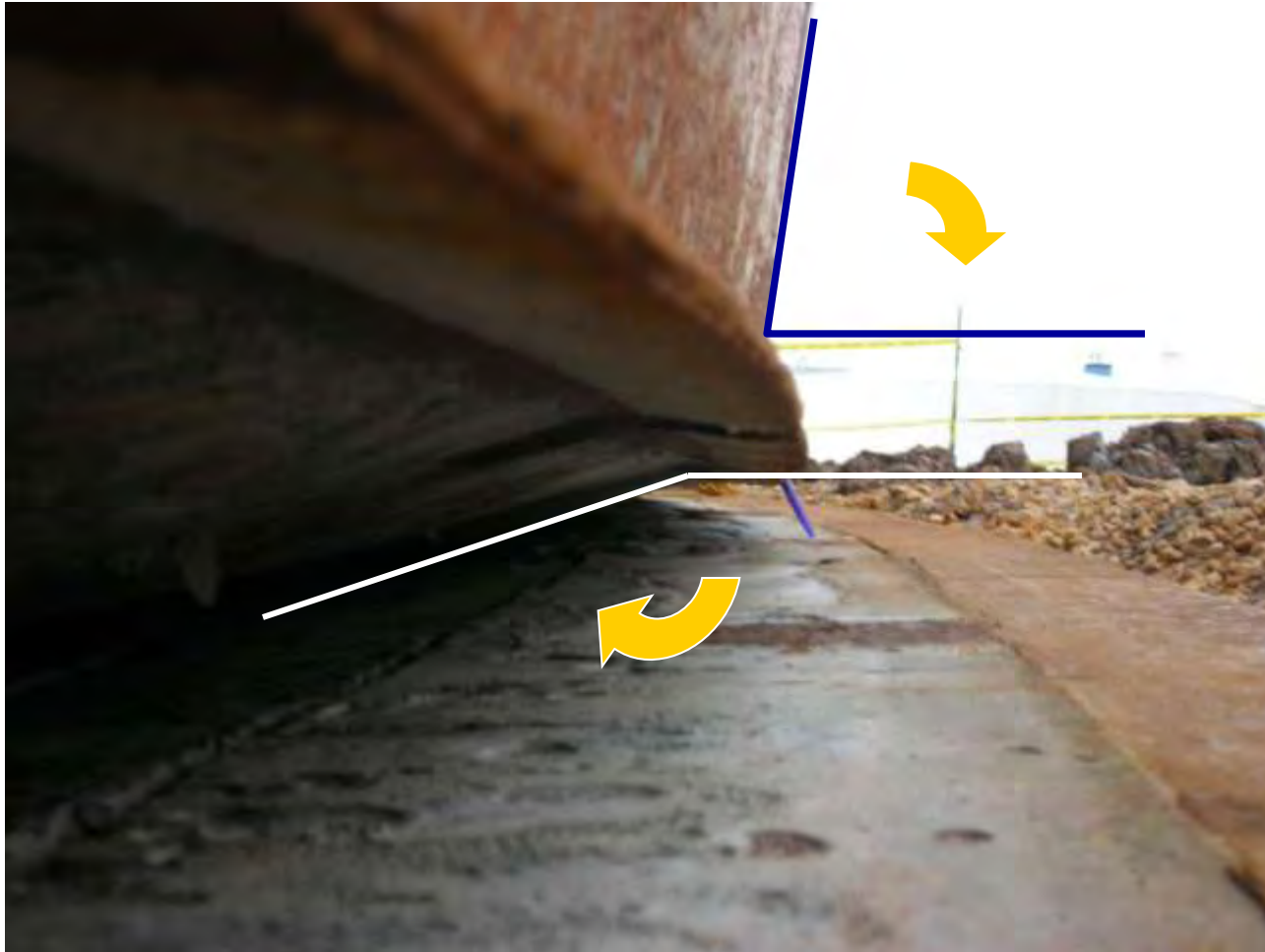
Above Ground Storage Tanks are not built on the best sites, so they offer foundation challenges

- Soft Compressible Soils
 - The load is always there
 - Differential Settlements offer maintenance challenges
 - Edge stability can lead to catastrophic consequences
- Mixed bearing soils and placed fills
- Foundations available
 - On grade
 - Ring beam
 - Piled slab
 - **Improved Ground**

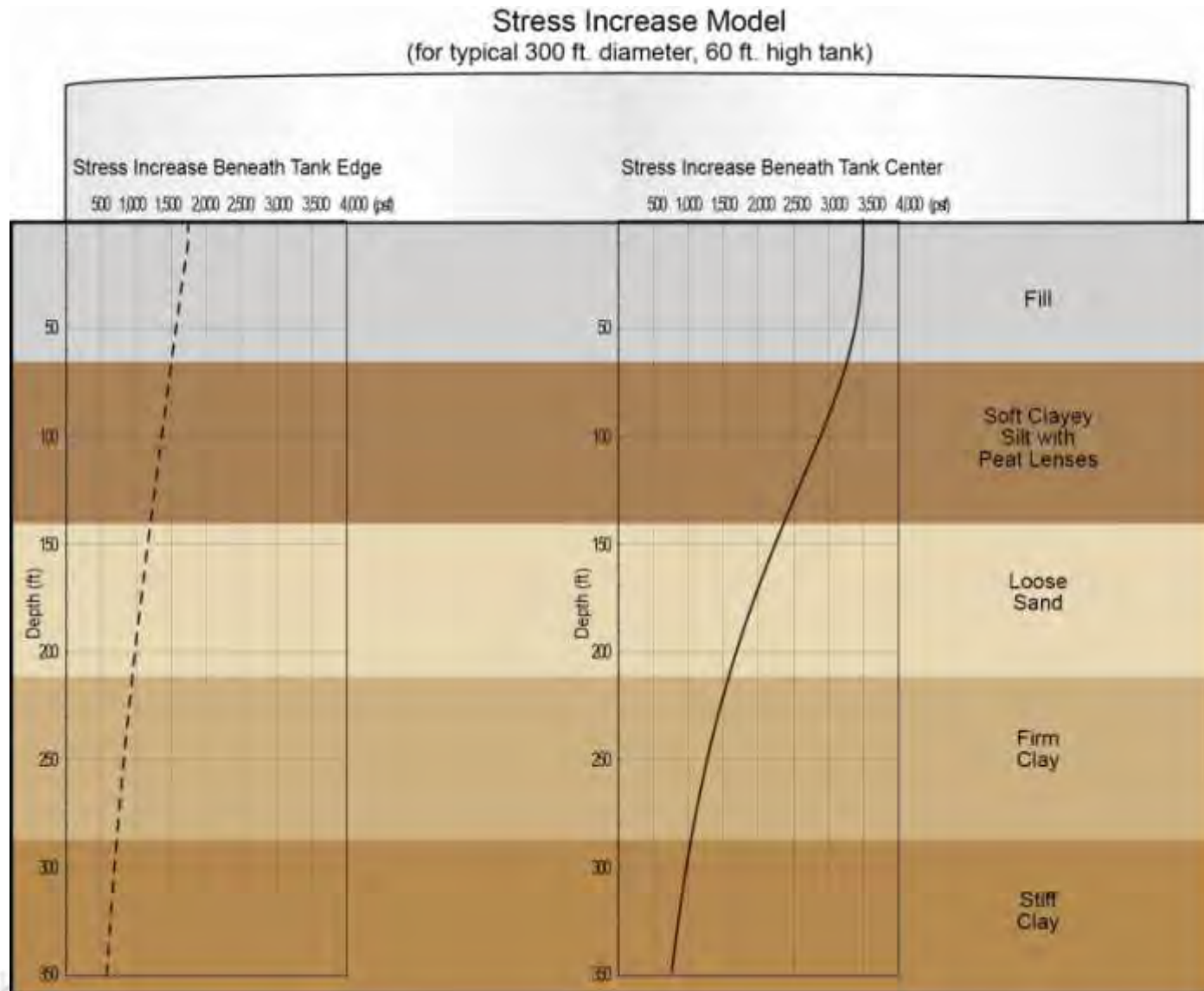
Soft soil beneath the tank can consolidate with time rendering the tank useless



Lack of sufficient edge stability can create floor plate failure or buckling of shell



What does the Load Distribution under a tank look like?



What types of Ground Improvement methods are tank friendly?

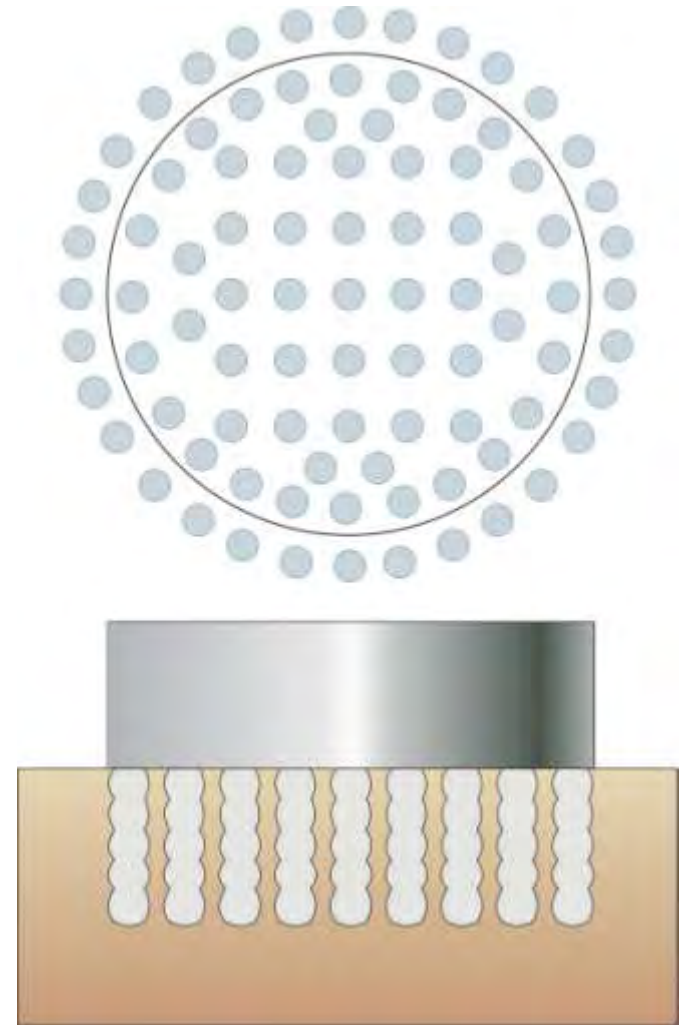
- Stone Columns
 - Vibro Piers
 - Aggregate Piers
 - Geo Piers
- Wick Drains – Vertical Drains (PVDs)
 - Need surcharge + time
 - Using the tank for surcharge is risky
- Displacement Piles – CMCs, DeWall Piles, CSCs
- Rigid Inclusions
- Deep Dynamic Compaction
- Soil Mixing – Wet and Dry Methods

Why does Ground Improvement make sense for Tanks?

- Offers faster site turnover
- Predictable long term performance
- ***Higher Tank Capacities***
- Controllable settlements
- Usually less expensive than traditional methods
- Flexible Designs
- Very good history in the USA as a widely accepted practice

Arrangement of Treatment

- Typically in a square pattern under the floor of the tank
- Replacement ratios from 10 to 50%
- Placement of elements directly beneath the shell
- Typically settlement criteria controls design



The Load Transfer Platform Must Provide Uniform Support of the Load from the Tank

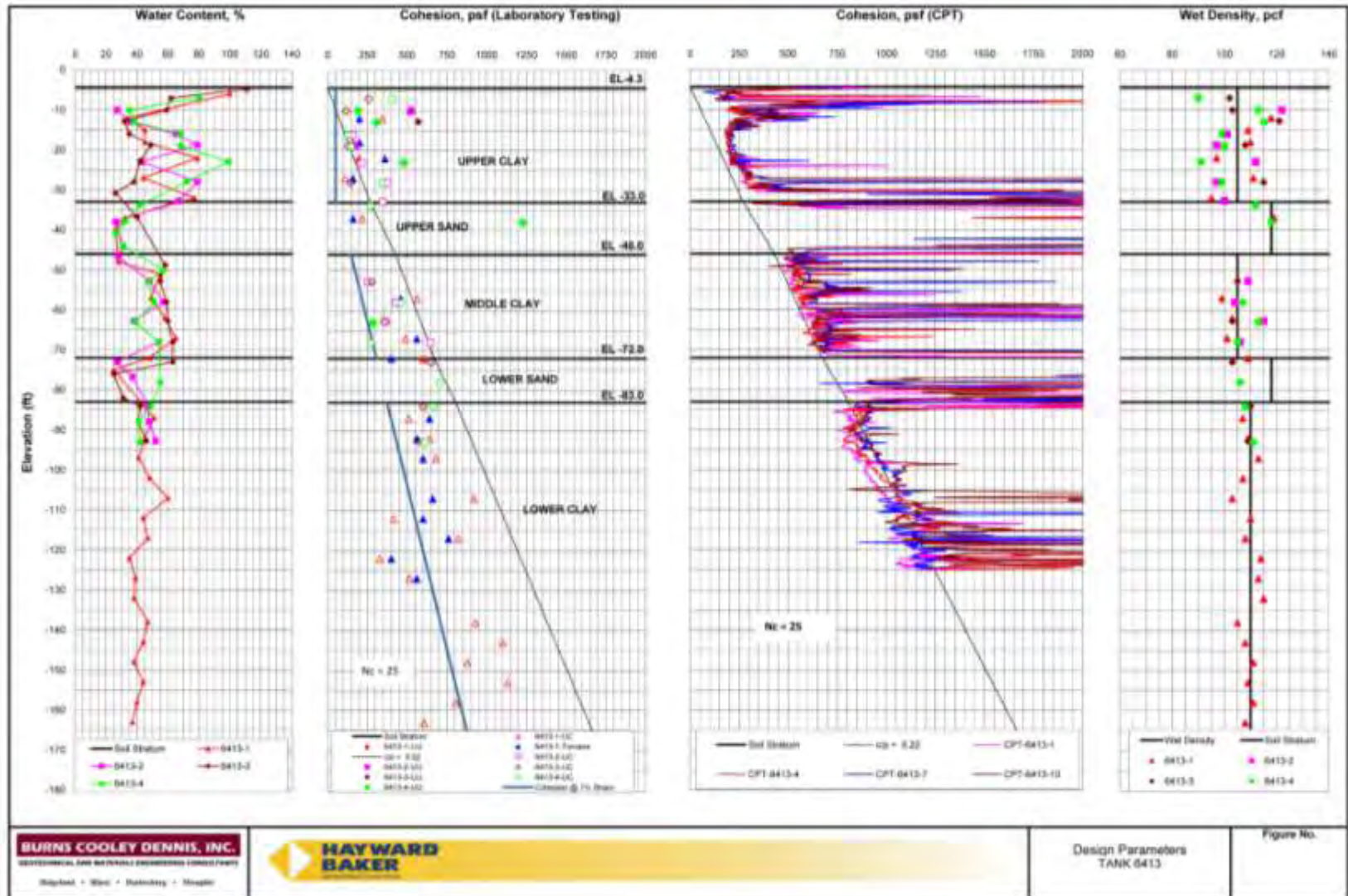
- Uses a semi rigid transfer platform
- Designed to limit dishing between GI elements
- Crushed rock is fantastic...but sand will do
- Layers of geogrid to increase efficiency



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Design soil parameters used in the Ground Improvement solution for support of the tank



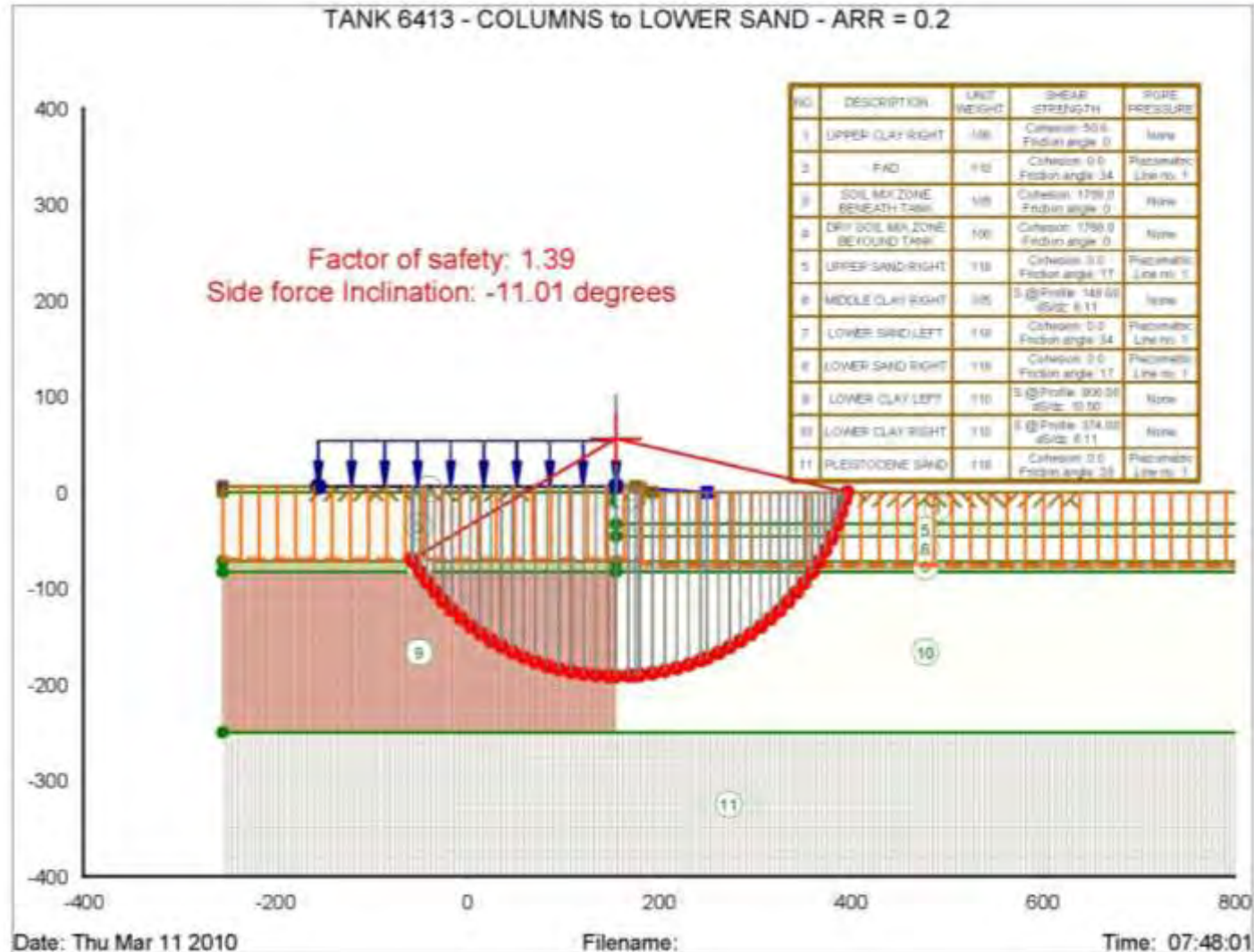
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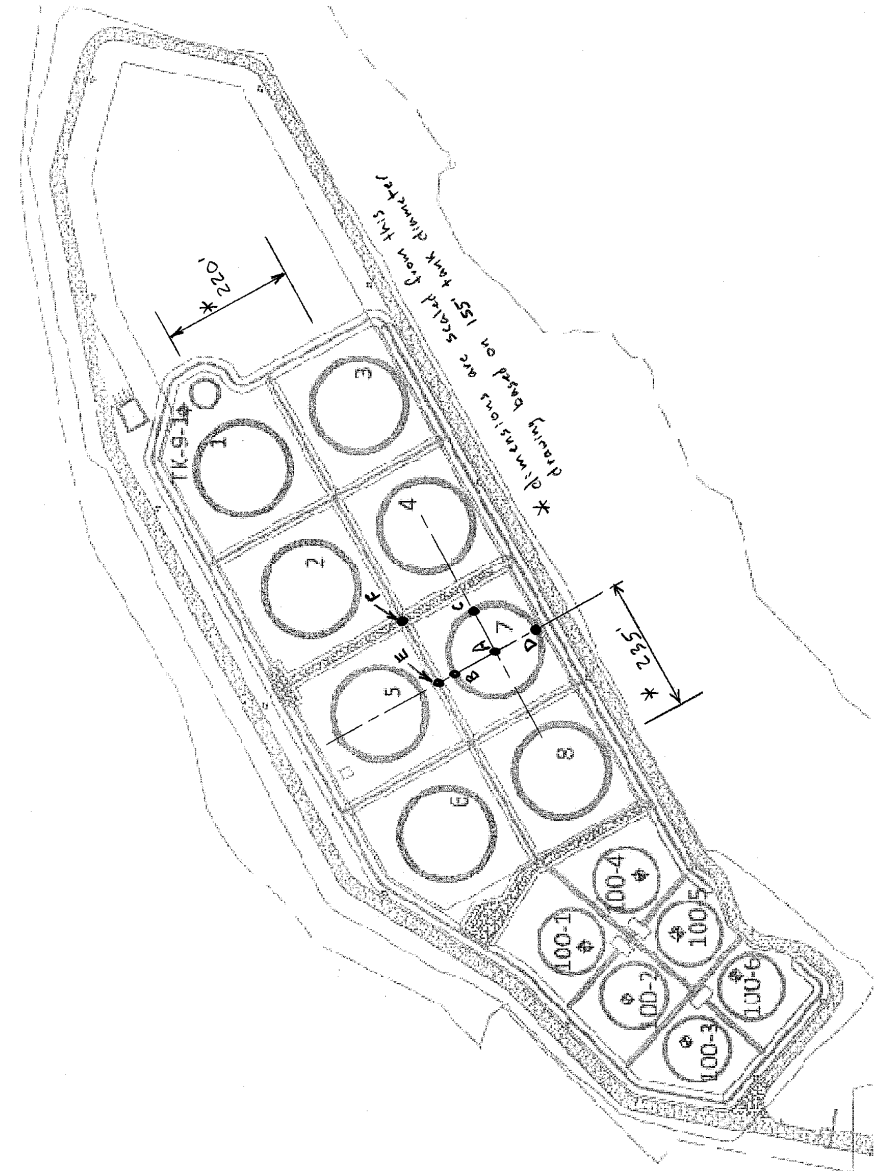
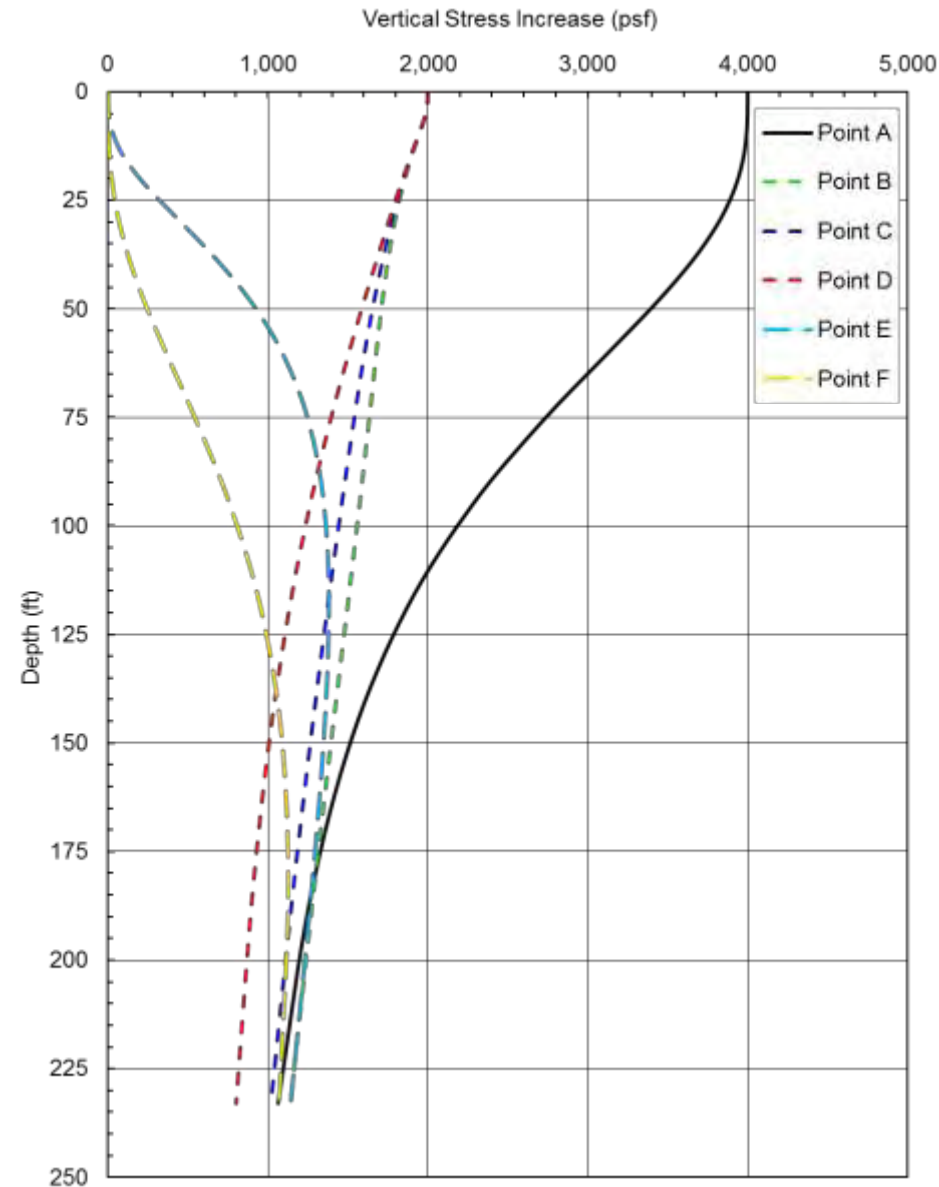
Design Parameters
 TANK 6413

Figure No.

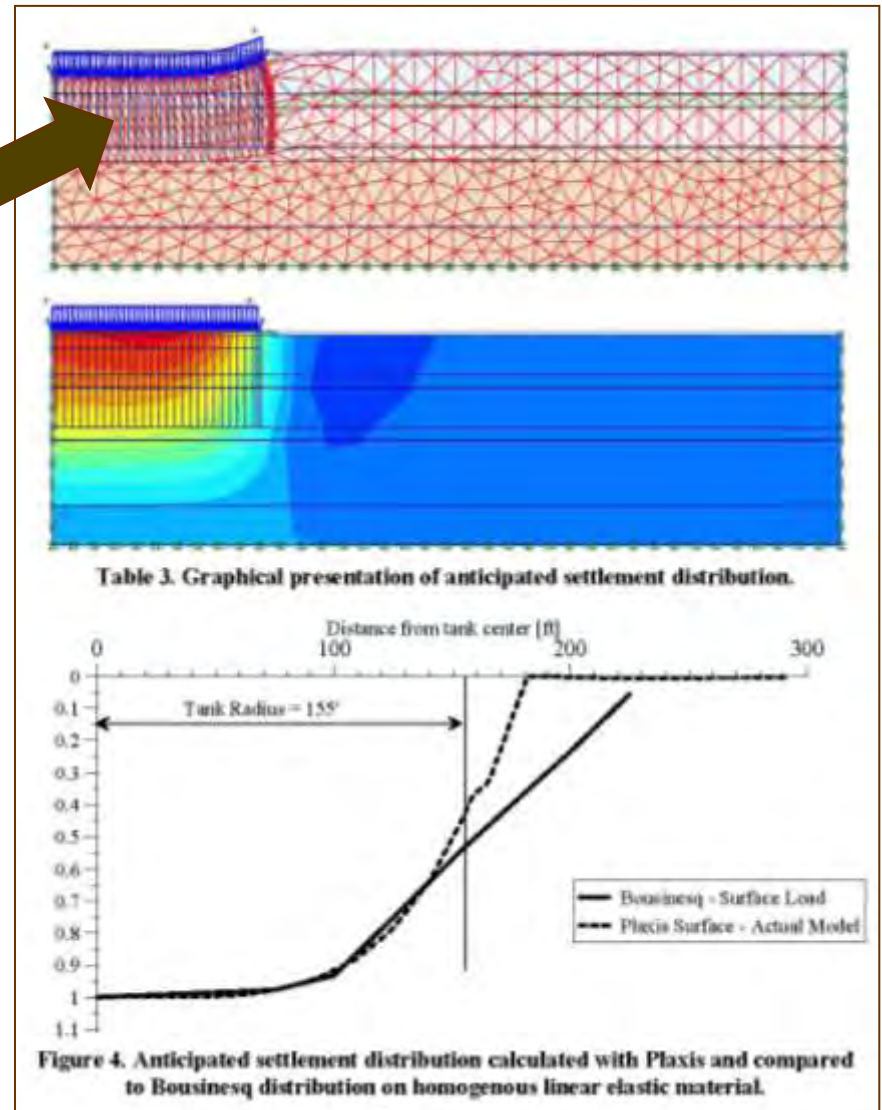
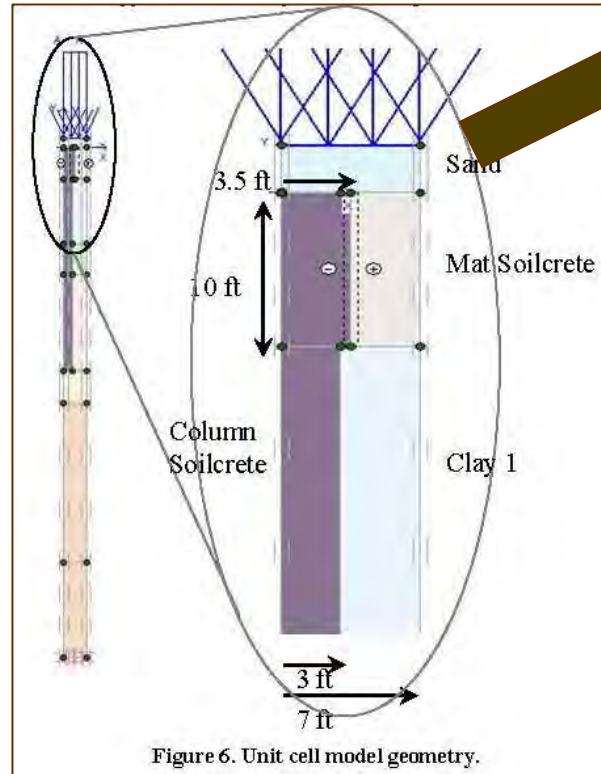
Stability check is crucial to the success of the tank foundation project



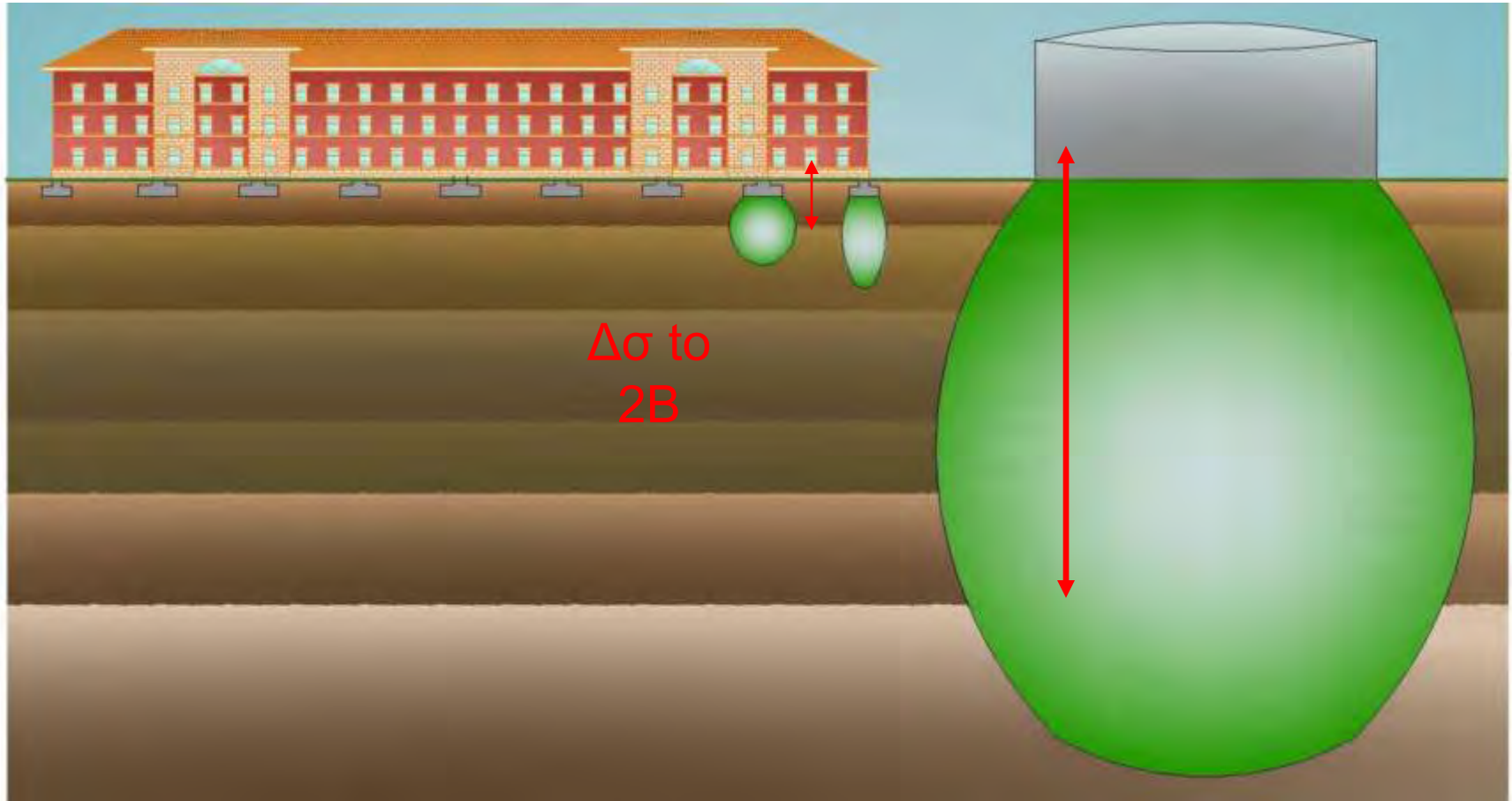
Stresses under the tank as well as overlapping stresses from other tanks must be checked



Numerical model setup to analyze the long term performance of the Soil Mix support system



Important!



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Vibro-Replacement or Stone Columns: reinforce the ground with aggregate

Vibro Systems

1 Vibrocompaction

3 VibroPiers / Aggregate Piers

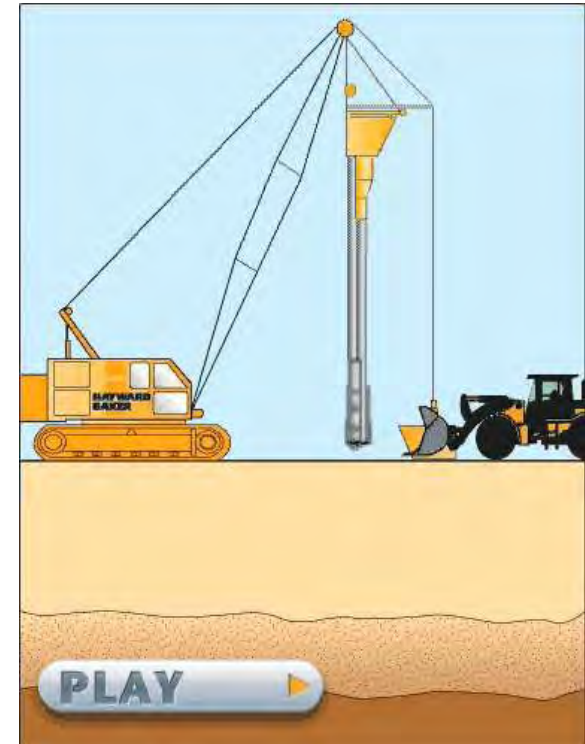
2 Vibro-Replacement Stone Columns

Performed in-situ up to 120 feet deep

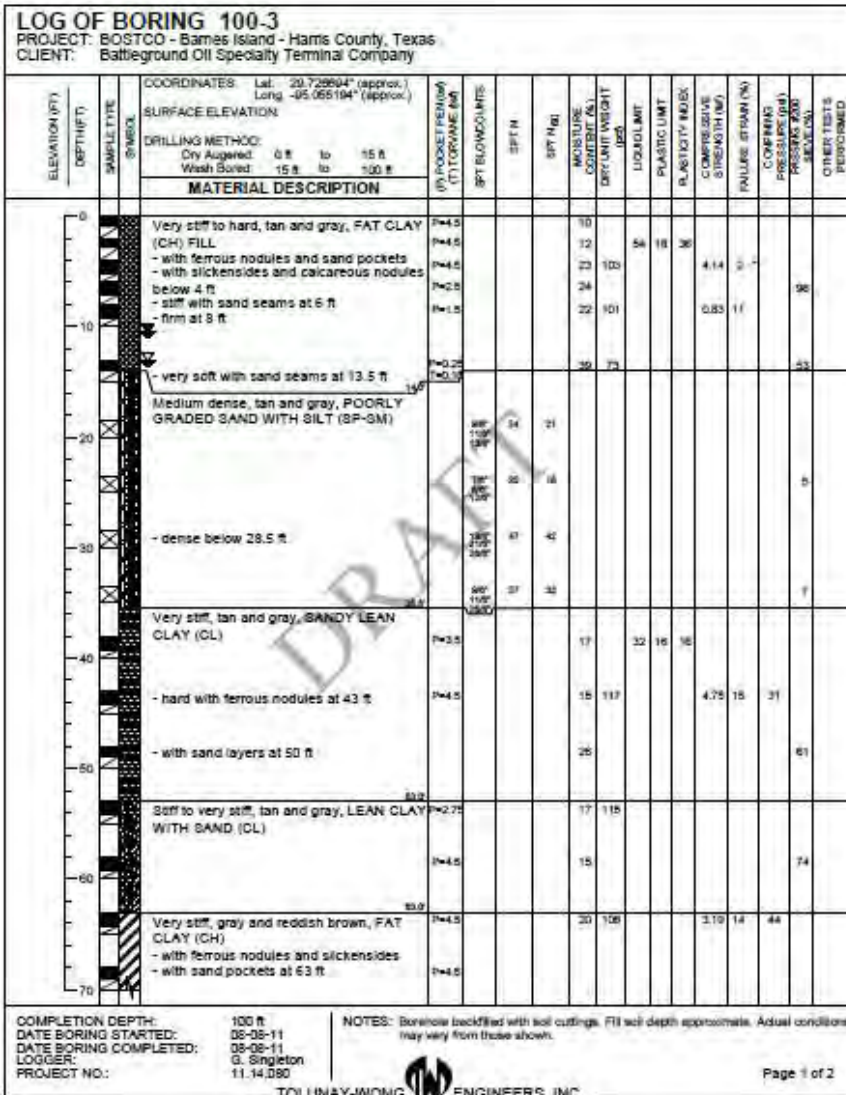
Effective above and below the water table

Performed using wet top-feed method or dry
bottom-feed method

Commonly used for seismic response
improvement



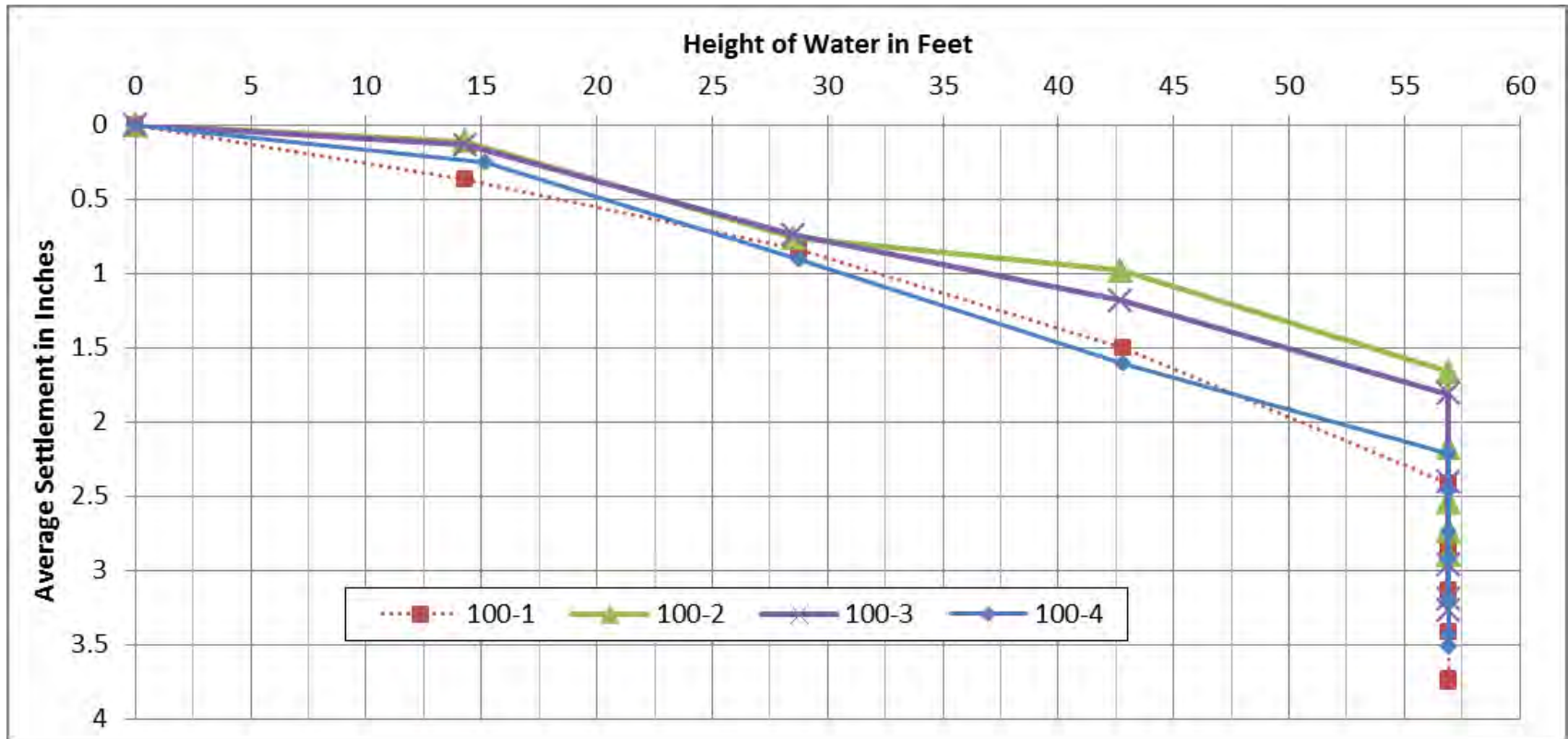
Typical Boring and design from the tank side of the project



- Stone Columns designed to carry 2/3 load from tank
- Treatment depths just into the dense sand
- Maximum center settlement – 4 inches
- Maximum perimeter settlement – 3 inches
- Satisfies all criteria



Hydrotest Data from Stone Column Supported tanks...the settlement has been designed



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Soil Mixing methods can use a Wet process when dryer stiffer soils need to be mixed



Wet mixing process combines the binders with water and the binder is injected as a slurry during the mixing

Top down soil mixing process

The use of higher strength material in the design is possible with the wet installation process

Dry Soil mixing methods are utilized in wetter softer soils or where REM is a problem

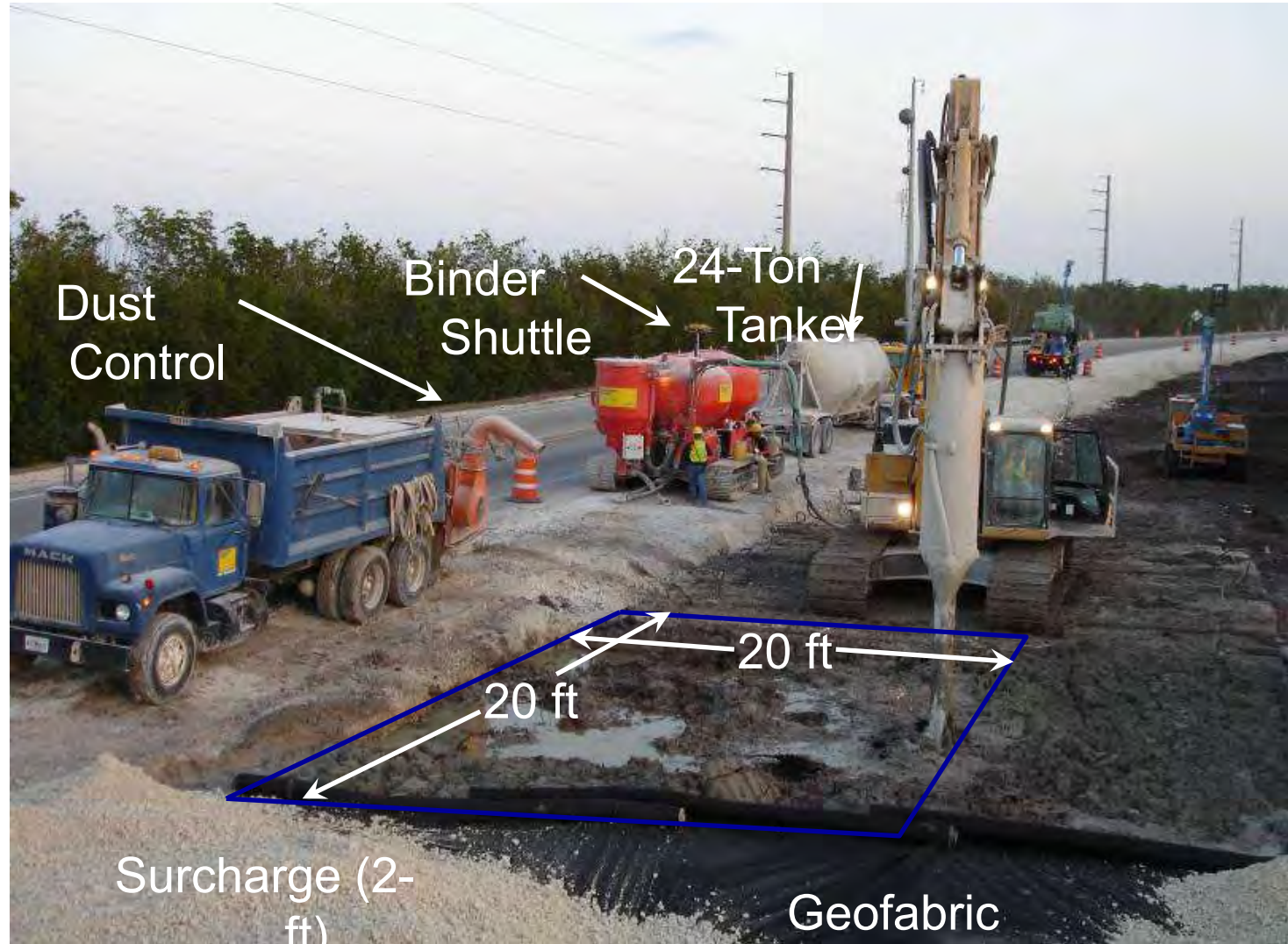


Dry binder materials are pneumatically injected into the soil during the dry mixing process

Bottom up method of soil mixing

There must be adequate soil moisture for the binders to fully hydrate often limiting design strengths

Dry or Wet Mixing can be used to treat 100% of the soil to form blocks



Dry Soil Mixing at Port Everglades to support tanks in organic soils



| GRAPHIC LOG | DESCRIPTION | DEPTH, ft | SAMPLES | | | | TESTS | | | |
|-------------|---|-----------|-------------|--------|------|--------------|------------------|------------------|-----------------|-------------------------|
| | | | USCS SYMBOL | NUMBER | TYPE | RECOVERY, in | SPT-N BLOWS / ft | WATER CONTENT, % | DRY UNIT WT,pcf | FINES CONTENT (-200), % |
| 2 | FILL - SAND with laterock, fine, tan | 0 | SP | 1 | HA | | | | | |
| 4 | SAND fine, tan | 4 | SP | 2 | HA | | | | | |
| | SILT with organics, trace sand, dark brown to black, very soft | 11 | ML | 3 | HA | | | | | |
| | | | ML | 4 | SS | WOH | | | | |
| | | | ML | 5 | SS | WOH | 99 | | | 6 |
| | LIMESTONE trace sand, trace silt, light tan, medium hard | 11 | | | | | | | | |
| | | | | 6 | SS | | 21 | | | |
| | | | | 7 | SS | | 22 | | | |
| | | | | 23 | | | | | | |
| | SAND trace limestone, trace silt, medium, light tan, loose | 26 | SP | 8 | SS | | 4 | | | |
| | SAND trace silt, fine, gray, medium dense to dense | 26 | | | | | | | | |
| | | | SP | 9 | SS | | 15 | | | |
| | | | SP | 10 | SS | | 21 | | | |
| | | | SP | 11 | SS | | 34 | | | |
| | | | SP | 12 | SS | | 31 | | | |
| | | | | 48 | | | | | | |
| | NO RECOVERY very hard/very dense BORING TERMINATED AT 50 FEET | 50 | | 13 | SS | | 50/1" | | | |

The Project was contracted as design-build and met the following criteria

- Design Strength
 - Allowable bearing capacity of 3,750 lbs/ft² for the in-situ soil mass
- Settlement
 - Planar tilting not to exceed 8 inches (100-ft diameter), 10 inches (125-ft diameter) across the diameter of the tank
 - Center-to-edge dishing not to exceed 5 inches (100-ft diameter), 6 inches (125-ft diameter)
 - Out of Plane Differential not to exceed 3/8 inch in an arc length of 30 feet

Dry mass mixing is working in block cell arrangement working from platform



Following Mass mixing, the tank foundation can be completed using ring beams

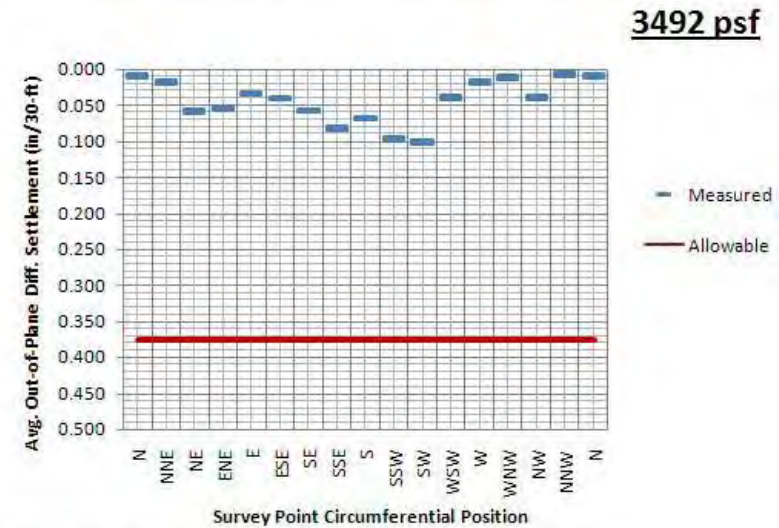
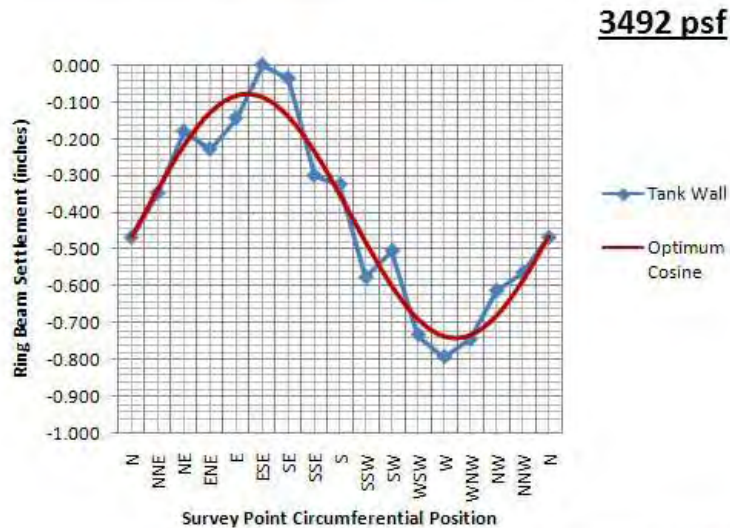
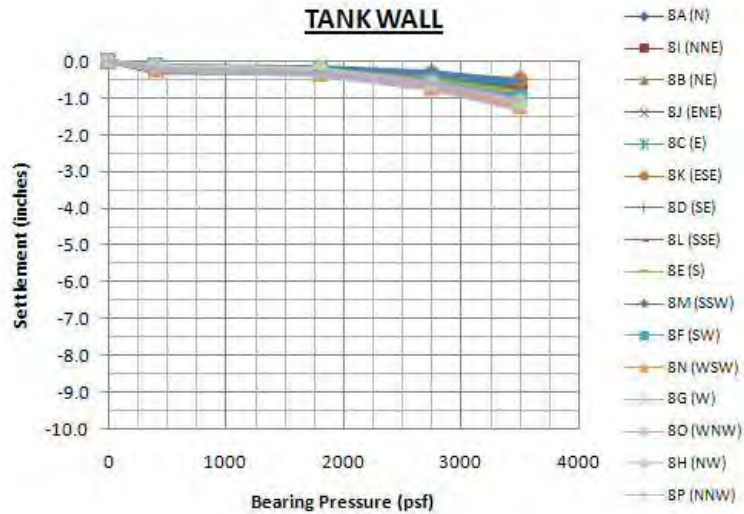


All tanks constructed on shallow foundations

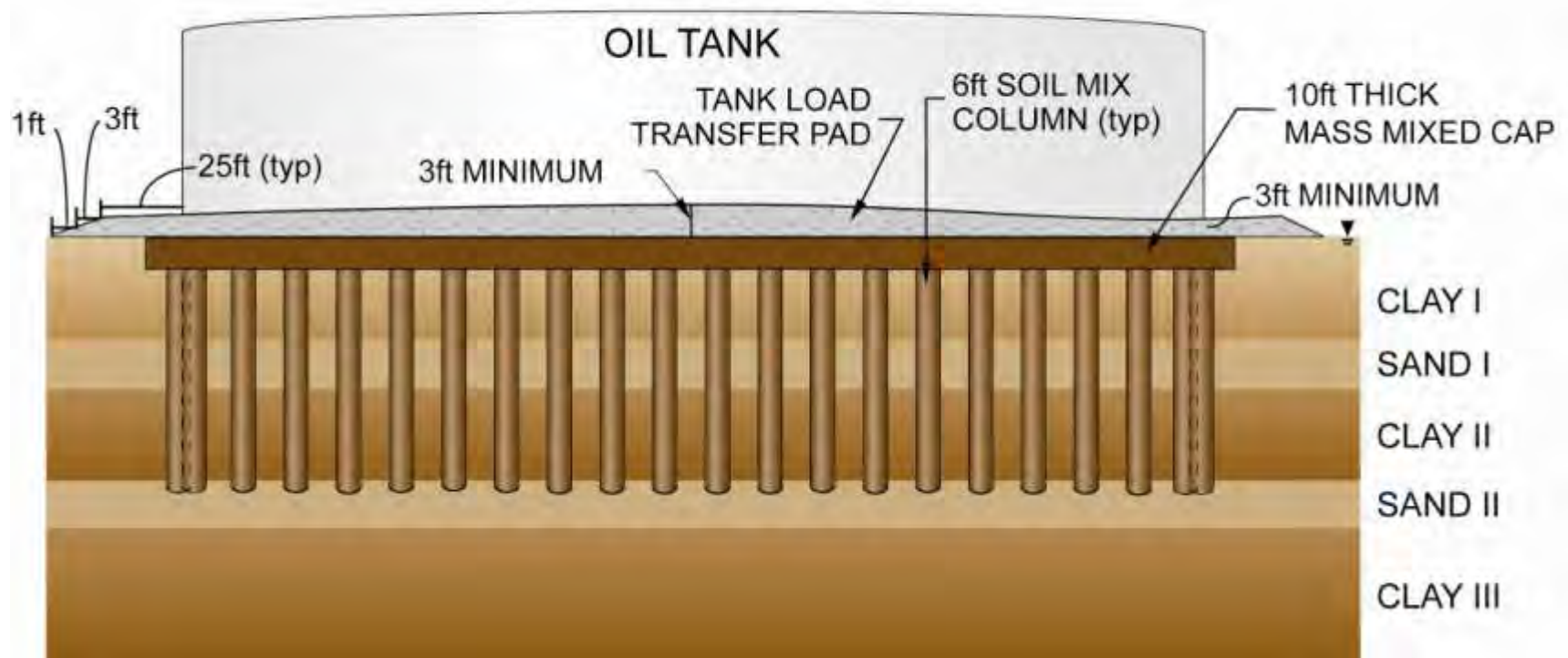
Foundation elements constructed to bear directly on soil mix / or compacted fill bearing on soil mix

No relieving platform is required

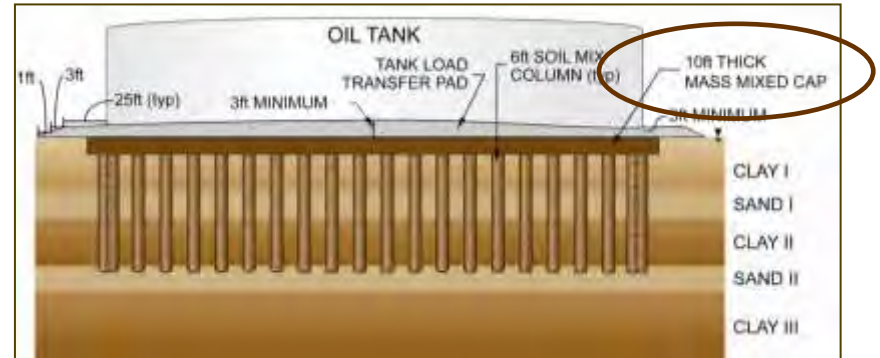
Following the work and after the tank is built the hydrotest is monitored from start to finish



Supporting tanks with Deep Mixed Columns and Mass Mixing can provide an economical solution



Construction of the Soilcrete Mat is the first step in the process



Mass Mix Cap is the first element to be installed. Design thickness of 10 feet.



Columns are installed through the soilcrete mat to complete the foundation system



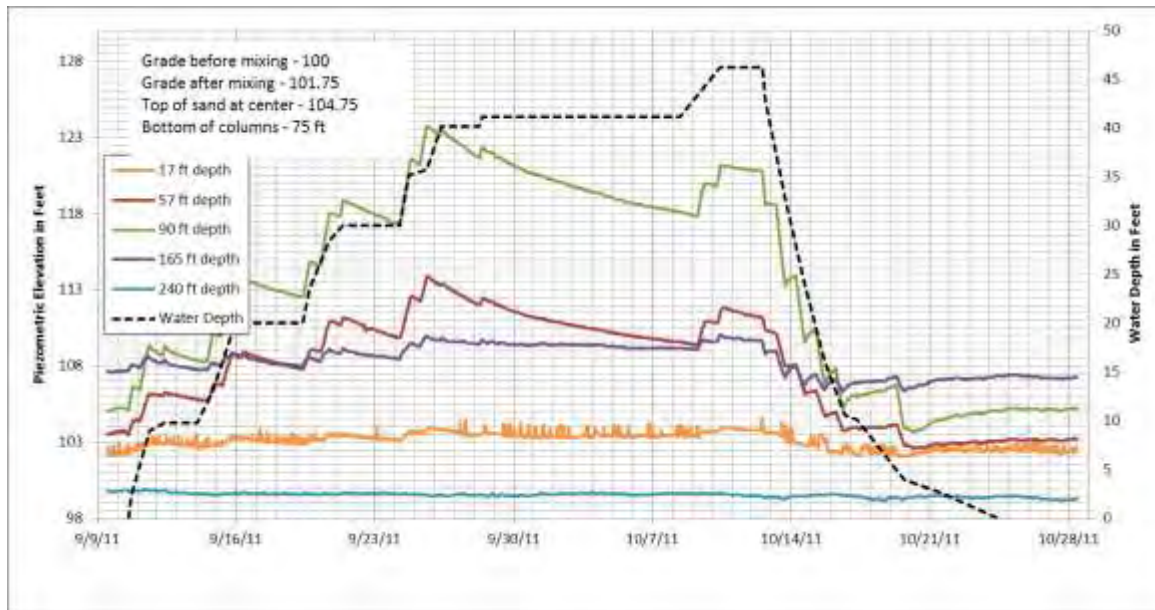
Columns installed in a single pass depth of 75 feet



The three new tanks being constructed over the new structural support system using Soil Mixing

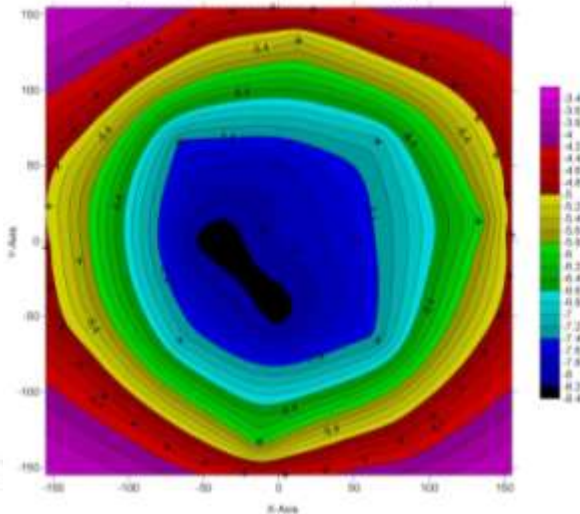


Monitoring the Tank to full height during hydrotest

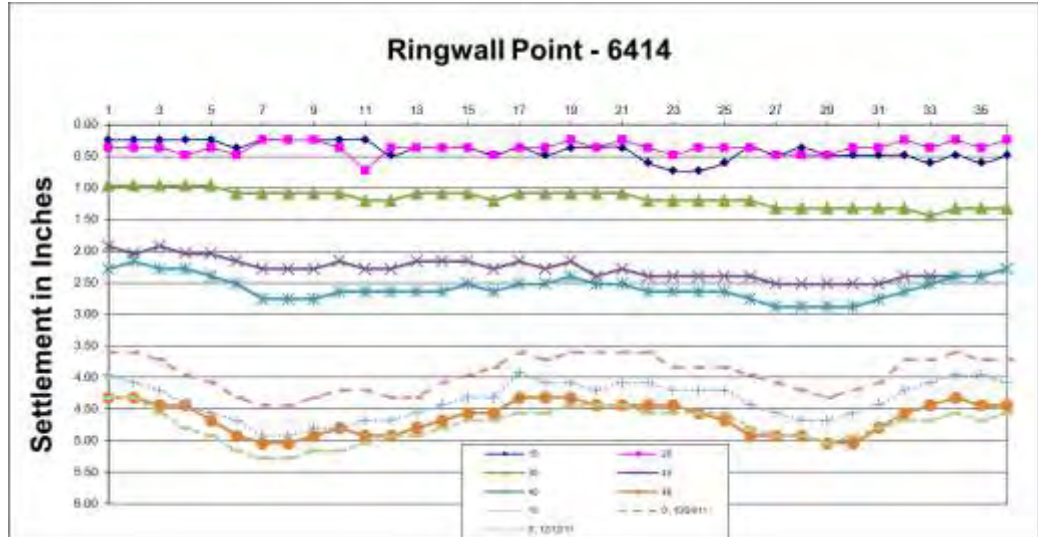


Final Hydrotest Height of 46' - 3"
 Ringwall Settlement well within API tolerances as well as floor settlement

Tank - 6414 Settlement (in) 10/10/2011
 Hydrotest Water Level 46.23' (ft)



Ringwall Point - 6414



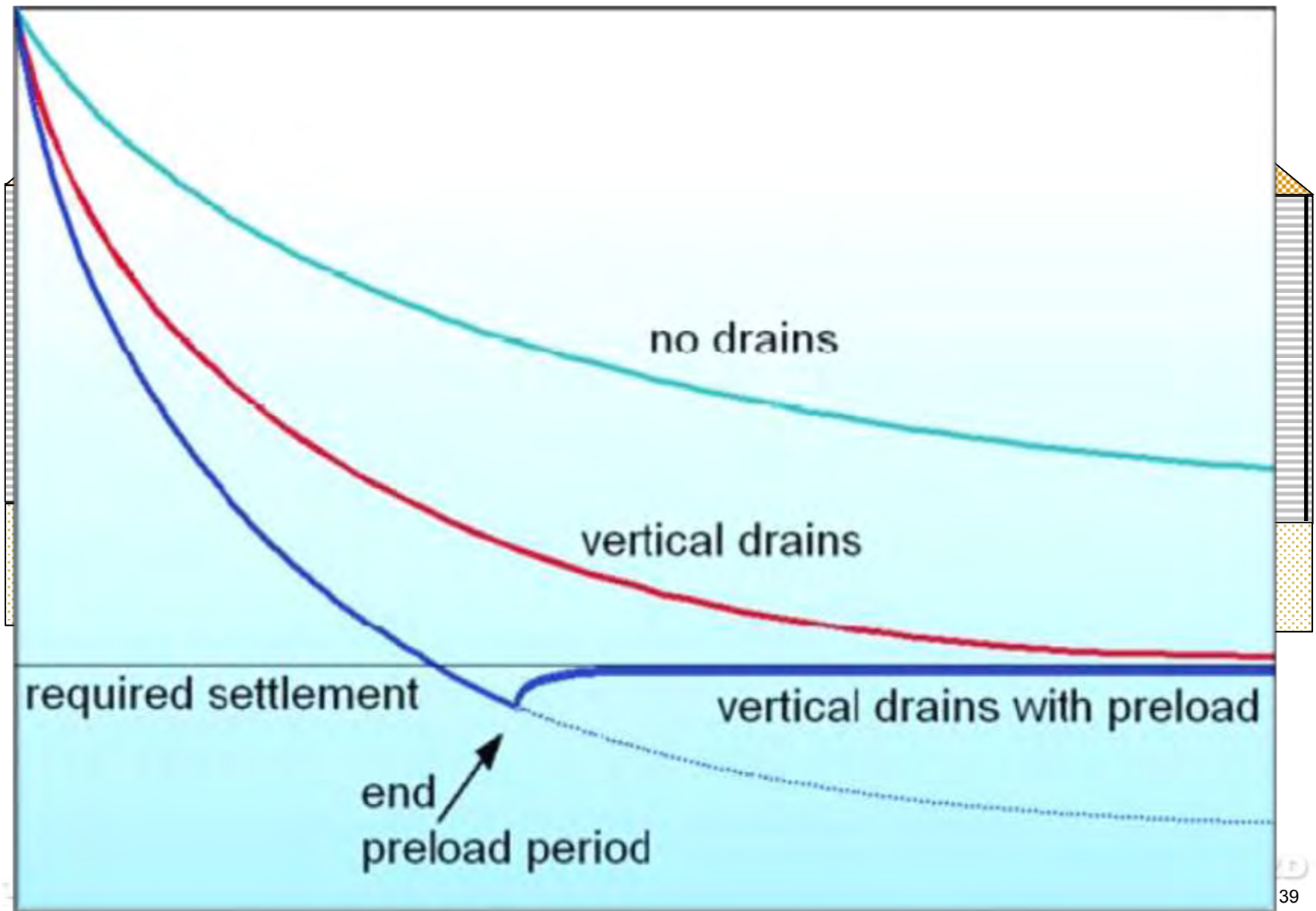
Lots of Happy Tanks!



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Wick Drains – The General Idea



How are wick drains installed and how do they work?



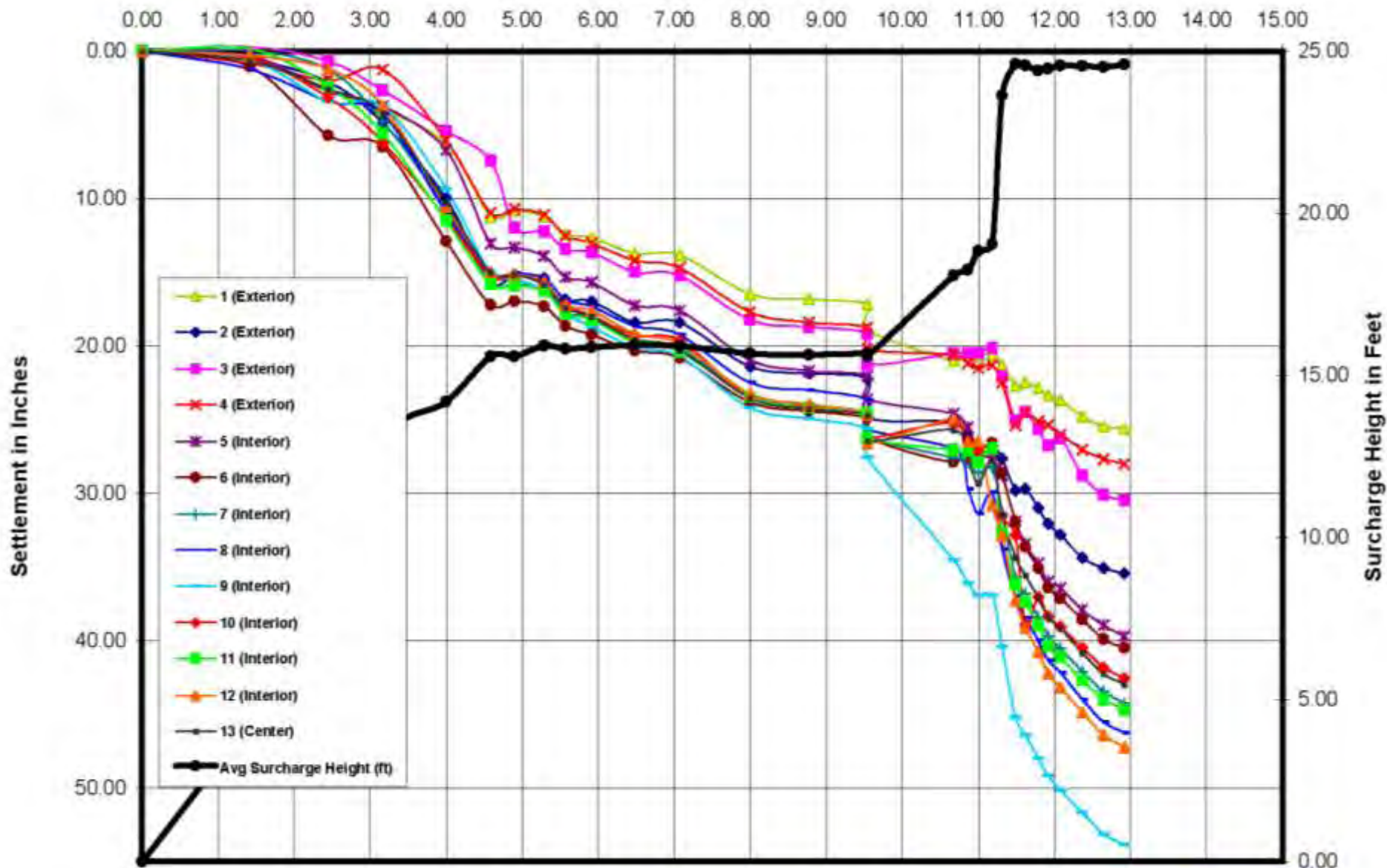
- The Drains can be installed to depths greater than 100 ft.
- Very fast installation speeds
- The water has to go somewhere on site!
- Needs surcharge







SQRT Settlement Since 10/14/03



Settlement Summary, Tank 6409



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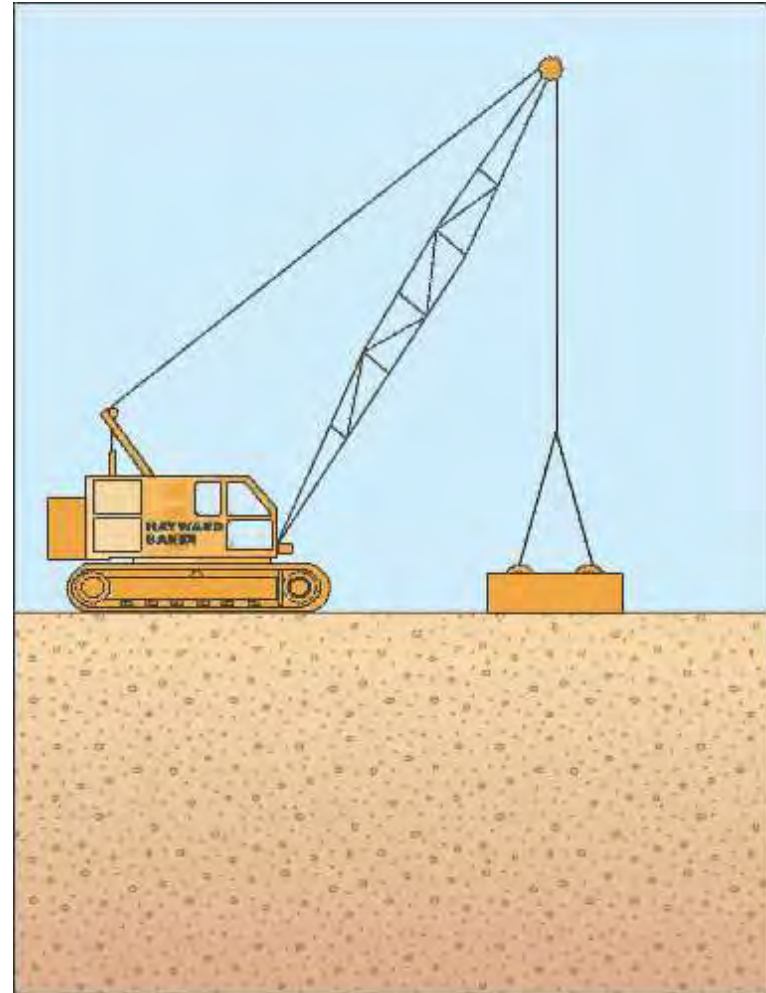
Dynamic Compaction (DDC)

Densification Technique

Improves the ground through repeated applications of a falling weight. The energy generated at impact densifies the ground.

Best in free-draining (“granular”) materials.

Treatment depth usually <30 ft.



Dynamic Compaction for Chemical Storage



Ground Modification for Asphalt Storage Tanks



Conclusions

| GI Method | Soft Soils, Compressible Soils, Organic Soils | Mixed Soils or Undocumented Fills | Liquefiable Soils or Clean Sands | Sandy Soils |
|----------------------------------|--|--|----------------------------------|-------------|
| Wick Drains | Excellent -Requires Preload -May require staged loading | Good -May require extra measures to install -Requires Preload -May require staged loading | N/A | N/A |
| Earthquake Drains | N/A | N/A | Good | N/A |
| Stone Columns or Aggregate Piers | Good -Sufficient settlement reduction may not be achievable | Very Good | Excellent | Excellent |
| Rigid Inclusions | Very Good | Very Good | N/A | Good |
| Soil Mixing - Columns | Excellent | Very Good | Excellent | Excellent |
| Soil Mixing - Mass | Excellent | Good to N/A -Depending on soil type | Excellent | Good |

Thank You!! *Questions?*



Dennis W. Boehm dwboehm@haywardbaker.com

Hayward Baker www.haywardbaker.com

509 North Sam Houston Parkway/Houston, Texas

281-668-1870