Foundation Solutions for New Tanks

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

Factor of safety: 1.39
Side force Inclination: -11.01 degrees
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

Figure 6. Unit cell model geometry.

Table 3. Graphical presentation of anticipated settlement distribution.

Figure 4. Anticipated settlement distribution calculated with Plaxis and compared to Bousinesq distribution on homogenous linear elastic material.
Important!

Δσ to 2B
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Vibro-Replacement or Stone Columns: reinforce the ground with aggregate

Vibro Systems

1. Vibrocompaction
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
3. VibroPiers / Aggregate Piers
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
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
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
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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

<table>
<thead>
<tr>
<th>GI Method</th>
<th>Soft Soils, Compressible Soils, Organic Soils</th>
<th>Mixed Soils or Undocumented Fills</th>
<th>Liquefiable Soils or Clean Sands</th>
<th>Sandy Soils</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wick Drains</td>
<td>Excellent - Requires Preload - May require staged loading</td>
<td>Good - May require extra measures to install - Requires Preload - May require staged loading</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Earthquake Drains</td>
<td>N/A</td>
<td>N/A</td>
<td>Good</td>
<td>N/A</td>
</tr>
<tr>
<td>Stone Columns or Aggregate Piers</td>
<td>Good - Sufficient settlement reduction may not be achievable</td>
<td>Very Good</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Rigid Inclusions</td>
<td>Very Good</td>
<td>Very Good</td>
<td>N/A</td>
<td>Good</td>
</tr>
<tr>
<td>Soil Mixing - Columns</td>
<td>Excellent</td>
<td>Very Good</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Soil Mixing - Mass</td>
<td>Excellent</td>
<td>Good to N/A - Depending on soil type</td>
<td>Excellent</td>
<td>Good</td>
</tr>
</tbody>
</table>
Thank You!!  Questions?

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