Ground improvement support using Confined aggregate piers in soft soil

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OUTLINE

• Ground improvement historical perspective
• Confined aggregate piers
• Embankment support project
• Design solution
• Verification Program

Crosby Creek Replacement Bridge
“Ground Improvement” means many things to many people:

- Over-excavation / replacement techniques (Egyptians > 2000 years ago).
- Earth reinforcement (with reeds) and tamping with stones (Chinese > 1000 years ago).
- Dewatering
- Grouting...compaction grouting, permeation grouting, jet grouting......
- Blending soil with admixtures
- The list goes on.....
Historical Perspective

Early forms of aggregate reinforcement commenced in the 1930’s

- Vibroflotation developed by J. Keller in Germany in the 1930’s for compacting sand.
- Some soils didn’t compact easily – so open cavities backfilled with gravel = stone columns
- Rammed Aggregate Pier developed in the 1980s.
More Ground Improvement:

- Prefabricated Vertical Drains (PVDs) “wick drains” invented by W. Kjellman at SGI in the 1940’s.
- Soil Mixing developed by U.S. firm Intrusion Prepakt in 1950’s with most of subsequent development in Sweden and Japan.
Historical Perspective

Other Ground Improvement Systems developed over the years, mostly in Europe:

- Rammed Aggregate Piers
- Rapid Impact Compaction
- Controlled Modulus Columns (Rigid Inclusions)
- Vibro Concrete Columns (Rigid Inclusions)
- ...and more...
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What are confined aggregate piers?

- Consist of closed-ended HDPE confining sleeve
- Installed through very soft clay and organic soil
- Backfilled and compacted with sand or gravel
- “Hybrid” rigid inclusion solution
Confined Aggregate Piers

- Confining sleeve provides bulging resistance in very soft soil
- Sleeve length typ. 10-15 ft long
- Traditional aggregate pier above very soft layer
Confined Aggregate Piers

Confined aggregate pier schematic

Shell provides confinement in soils with low shear strength

20- to 24-inch diameter
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MTO Highway 15 Crosby Creek Bridge Replacement

- Location: Seeley’s Bay, Ontario, Canada
- Roadway widening: 2 lanes to 4 lanes
- 75 ft long replacement bridge and approach embankments required
Generalized soil conditions

- 7 ft of stiff to very stiff clayey silt to clay
- 10 ft of **soft to very soft sensitive** clayey silt to clay
- Over glacial till and bedrock
PROJECT BACKGROUND

- Poor soil conditions
- Initial approach embankment settlements estimates 3 to 6 inches
- Global stability FS < 1.3
- Environment concerns impacting existing creek

Crosby Creek
MTO Highway 15 Crosby Creek Bridge Replacement

- 2H:1V side slopes up to 12 ft high
- Min FS for Slope Stability = 1.3
- Performance based specification
- Stricter tolerance near abutments

<table>
<thead>
<tr>
<th>Distance from Abutment (ft)</th>
<th>Maximum Total and Differential Settlement (in)</th>
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<tbody>
<tr>
<td>0 – 50</td>
<td>1.0</td>
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<tr>
<td>50 – 150</td>
<td>2.0</td>
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<tr>
<td>150 – 250</td>
<td>4.0</td>
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<tr>
<td>&gt; 250</td>
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Proposed Remediation Method Options

- Over-excavate sensitive soil
- Lightweight fill
- Surcharge with wick drains
- Aggregate piers
Geopier® Ground Improvement Solution

- Confined aggregate piers near abutments
- Densified aggregate piers beyond 50 ft from abutment
- Avoid shored excavations and active dewatering
- Expedite settlement time and construction schedule
Settlement Approach

- Estimate compressibility of
  - Confined elements
  - Unconfined elements
- Estimate composite compressibility
- Use Hooke’s law
- Perform individual modulus tests to verify

\[ \delta = \frac{q \cdot I_\sigma \cdot H_{uz}}{E_{comp}} \]
Predicted settlement
Global Stability

- Ignore the confining sleeve (conservative)
- Static global stability $FS = 1.6$ (1.3 Required)
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PERFORMANCE VERIFICATION

Verification Test Program

• Measure settlements (short term and long term)
• Measure lateral deformation
• Rate of excess pore water pressure dissipation
• Actual ground improvement performance vs. predicted performance
PERFORMANCE VERIFICATION

Verification Test Program

Modulus Load Test

Modulus Test Results
PERFORMANCE VERIFICATION

Geopier® Ground Improvement Solution

- Two (2) Standpipe Piezometers - BLUE
- Eight (8) Settlement Plates - GREEN
- Two (2) Slope Inclinometers - RED
- Nine (9) Vibrating Wire Piezometers - BLUE
- Eighteen (18) Surface Settlement Markers - ORANGE

Post-Installation Test Plan
PERFORMANCE VERIFICATION

Settlement from fill placement and after paving

Settlement Plate Deflection
Settlement 6 months after paving

End Pavement (Less than ½ in)
SUMMARY

- Installed from above the water level
- Avoided shored excavations and active dewatering
- Expedited construction schedule
- MTO extremely pleased with performance
- On-going monitoring
Thank you for your time and consideration!
Questions?