Ground Improvement Support of MSE Wall in Sugar Land, Texas
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Presentation Outline
- Hayward Baker Overview
- Project Background
- Site Conditions
- Geotechnical Solution
- Other Transportation Ground Improvement Projects

Hayward Baker – A Keller Company
- Keller Group is Hayward Baker’s parent company, headquartered in London
  - Publicly owned and traded on the London Stock Exchange
  - Offices in over 40 countries on 6 continents
- The world’s leader in geotechnical solutions

Geotechnical Construction Challenges
- Bulkhead Support
- Deep Foundations
- Earth Retention/Shoring
- Foundation Rehabilitation
- Ground Improvement
- Groundwater Control
- Heave
- Railroad Subgrade Stabilization
- Seismic/Liquefaction Mitigation
- Sinkhole/Karst Mitigation
- Slope Stabilization
- Tunneling Stabilization
- Underpinning
- Void Filling

Geotechnical Construction Techniques

University Boulevard
- Sugar Land, TX
  - Population increase of ~45% from 1990 to 2000
  - City established Major Roadway Plan in 1994
  - Identified a need for another major North/South corridor
- University Boulevard
  - South segment completed in 2003
  - North extension
    - Phase I completed in 2014
    - Phase II to be completed in 2018
University Boulevard North Extension

- Stability & Settlement Criteria
  - Minimum factor of safety against global stability failure: 1.3 (per TxDOT requirements)
  - Minimum allowable bearing capacity: 4,900 psf (based on wall height of 25')
  - Post-construction differential settlement of \( \leq 1.2'' \) (btw. approach embankment & bridge)

University Boulevard – Soil Conditions

- High modulus grout columns typically installed through weak, highly compressible soils to reduce settlement and increase bearing capacity
  - Soils typically too soft / loose for conventional stone columns / Aggregate Pier construction
  - Often referred to as Controlled Stiffness Columns (CSC) or Controlled Modulus Columns©
  - Material is typically a pea gravel concrete or sanded grout
  - 2,000 to 3,000 psi typical
  - Usually used in conjunction with a load transfer platform (LTP)
  - No direct contact with foundations
  - Typical diameters 12'' to 18'' (320 to 450 mm)
  - Typically unreinforced

Benefits

- Rigid Inclusions utilize a cementitious material that can transfer loads through weak strata to a firm layer below
- Load can be partly carried by soil
- Unless soft / loose soils extend to the ground surface
- The use of shallow spread foundations vs pile caps
- Saves money on time and material after HBI leaves the project site
- HBI handles the cutoff, typical shallow foundation preparation by others
- Can be installed in a variety of ways
  - Displacement technique
  - Little to no spoil

Common Rigid Inclusion project characteristics

- A relatively thick zone of very soft / loose soil that generally precludes the use of stone columns / aggregate piers
  - Or deep soft soils that may make stone columns economically unattractive
- A dense or hard “bottom” within ~100 feet from the work surface
  - Deeper RIs can be constructed with large specialty drill rigs
- Tight settlement tolerances particularly with large area loading
- Project schedule constraints (surcharge / wait for settlement to occur isn’t an option)
- Contaminated soils
- Often a value-engineered (VE) Alternate to deep foundation specified projects
Rigid Inclusion system installation overview

1. Working platform preparation and control
2. RIs are installed using displacement or replacement
3. RI heads are lowered (as needed)
4. Load transfer platform (LTP) is installed per design

Rigid Inclusion design

- Design of Rigid Inclusion ground improvement systems include the following considerations:
  - structural capacity of the rigid inclusion element
  - geotechnical capacity of the rigid inclusion element
  - load transfer platform mechanics
  - overall system settlement

Rigid Inclusion and adjacent soil interaction

Rigid Inclusion design – iterative process

- The amount of negative and positive skin friction is a function of the load transfer platform, RI spacing and geometry, and soil stratigraphy and engineering properties.
- Due to the complex interaction between the soil and the RI, conventional pile foundation bearing capacity calculations are not applicable.

Finite element – axisymmetric/ unit cell model

- Behavior of a single RI that is part of an infinite grid of RIs
- Load-displacement
  - Designer must account for the relative movement between the RI tip and the adjacent soil and the relative movement between the RI head and the LTP

Finite Element – Total System Model

- Used to evaluate global stability and lateral loading on RIs due to unbalanced loads.
Load Transfer Platform
- A load transfer platform (LTP) is used to transfer load from the structure to the Rigid Inclusions and to minimize ‘dimpling’ or excessive bending stresses in a slab or foundation.
- LTPs often consist of 1 to 5 feet of well compacted granular soil and may include 1 to 3 layers of embedded geogrid or steel mesh (under embankments / tanks).

University Boulevard
- Quick (vibratory) installation through soft soils into granular bearing layer
- LTP-columns transfer loading below soft soils (no pile cap)
- Utilize embankment fill & geotextile-reinforced cement stabilized sand as LTP
- Efficient design using numerical modeling for settlement estimates

University Boulevard RI Design

Typical RI equipment (Vibratory Method)

HBI Data Acquisition System (DAQ)
- Real-time monitoring, recording, and display of all parameters during RI construction process
  - On-screen depth, strokes, pen, rate, crowd pressure/torque, actual vs. target grout quantities, grout pressure, inclination, etc.
  - All data is transmitted in near real-time to an online central database via cell modem for PM and designer review
University Boulevard

- Rigid Inclusion depth varied between 25 and 50 feet
- A total of 1775 Rigid Inclusions were installed
  - Amounting to more than 11 miles of Rigid Inclusions
- RI construction (including LTP placement) completed in about 8 weeks
  - More than 750 linear feet of embankment treated
- Scheduled to open for traffic in 2018

Other Ground Improvement Embankment Projects

Other Ground Improvement Embankment Projects

Ohio River Bridges

- Stone Columns, Grouted Stone Columns, and Rigid Inclusions for global stability and settlement control of 43 embankments/MSE walls.
- HBI scope includes instrumentation and monitoring of 6 production embankment sections and a test embankment prior to production work

Other Ground Improvement Embankment Projects

Ohio River Bridges (continued)

- Ground Improvement Criteria
  - Pavement installation cannot proceed until settlement is less than ¼” for 3 consecutive weeks
  - Maximum long-term settlement at MSE walls < 1”
  - Angular distortion of paved areas < 1:500
  - Areas deficient for global/external stability – meet KYTC/AASHTO minimum requirements

Other Ground Improvement Embankment Projects

Ohio River Bridges (continued)

Test Embankment

The more geotechnical data there is, the more accurate geotechnical predictions will be!
Thank You!
Any Questions!