Liquefaction Bio-Mediation: An Industry Perspective

Sohell Kamalzare
PhD, PE, Project Manager
WHAT WE DO

Shoring
- Soldier Pile
- Soil Nail
- Secant Pile
- Sheet Pile
- Soil Mix

Block 5 – San Francisco
WHAT WE DO

Ground Improvement

- Stone Columns
- Rigid Inclusions
- Soil Mixing
- Jet Grouting
- Compaction Grouting
- Permeation Grouting

LNG Tank – Tacoma, WA
WHAT WE DO

Piles

• DRILLED SHAFTS (CIDH)
  • Open Hole
  • Slurry Displacement
  • Fully Cased
• Auger Cast
• Auger Displacement
• Micro
• Driven

Cle Elum Dam, WA
OUR LOCATIONS

OAKLAND, CA
480 Roland Way, Suite 200
Oakland, CA 94621
Tel: (510) 636-2100
Fax: (510) 568-9316

LOS ANGELES, CA
1100 Wilshire Blvd, Suite 400
Los Angeles, CA 90017
Tel: (909) 390-0268
Fax: (909) 605-7629

SAN DIEGO, CA
3434 Grove Street
Lemon Grove, CA 91945
Tel: (858) 530-9165
Fax: (858) 530-9171

KENT, WA
9012 S 208th Street
Kent, WA 98031
Tel: (425) 988-2150
Fax: (425) 988-2151

PORTLAND, OR
1239 NE 92nd Avenue
Portland, OR 97220
Tel: (503) 455-8550
Fax: (503) 647-1968
• Feasibility and commercial applicability of bio-mediation
  • Scenario 1: treatment under an existing structure
    • Cost Comparison with Microfine Grouting
    • Opportunities/Challenges
  • Scenario 2: treatment for a new structure – green field site
    • Cost Comparison with Cement Deep Soil Mixing (CDSM)
    • Opportunities/Challenges

• Conclusions and remarks
Treatment Under Existing Transformer Pad
**Scenario 1 - Assumptions**

- **Project Scope:**
  - Substation transformer pad
  - Shallow mat foundations
  - Plan dimensions 40-ft x 80-ft

- **Soil Profile:**
  - Existing building over loose sandy ground

- **Targeted Treatment:**
  - Below water table at top 25-ft

**Scenario 1 - Assumptions**

- Loose SAND
  - $k_h = 0.05$ cm/s
  - Porosity = 39%
Scenario 1 – Bio-Mediation

- Construct injection and extraction wells along the long side of pad
- Apply hydraulic gradient
  - Soil structure should not fracture
- Nutrient concentration should allow full site coverage before reactions slow down the seepage
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Scenario 1 – Bio-Mediation

- **Construction:**
  - 17 wells injection and extraction
  - Nutrient Injection: 190,000 gal
  - Calcium Nitrate and Calcium Acetate $0.92 /gal
  - Price = $240,000
Scenario 1 – Permeation Grouting

- Battered drilling and permeation grouting
- Using micro-fine Portland cement
Scenario 1 – Permeation Grouting

- **Construction:**
  - Drilling: 2400-ft x $25 per ft
  - Grout: 190,000 gal
    - Micro-fine cement: $2.7/gal
  - Price: $600,000
Scenario 1 - Summary

- **Feasibility for existing structures**
  - Conventional ground improvement techniques are very limited and expensive in sands and essentially non-existent in silts.
  - Bio-mediation appears to have economical viability
  - Ease of re-injection of wells over time if necessary.

- **Technical challenges**
  - Reliable assessment of horizontal permeability and its variation with nutrient injection/micro-reaction
  - Proportioning nutrients for proper reaction-travel through the profile
  - Confirming extent/consistency of desaturation.
  - Sustainability of desaturation.
Treatment for New Structure
Scenario 2 - Assumptions

Project Scope:
- Greenfield development
- Shallow foundations

Soil Profile:
- New building over soft silts

Targeted Treatment:
- Below water table to depth of 25-ft

PLANNED STRUCTURE

Soft SILT
- $k_h = 0.0005$ cm/s
- Porosity = 39%

40-ft

25-ft

5-ft
Scenario 2 – New Building

- Due to silty/low permeability nature of the site:
  - Ground cannot be densified
    - No stone columns
    - No grouted displacement column
    - No compaction grouting
  - Ground cannot be grouted
    - No permeation grouting with micro-fines and sodium silicates
  - Low permeability limits extent of efficient nutrient spread.
Scenario 2 – Bio-Mediation

• Construct wells across the site:
  • 32 injection wells
  • 45 extraction wells
  • Nutrient Injection: 180,000 gal
  • Price = $390,000
Scenario 2 – Bio-Mediation

- Construct wells across the site:
  - 32 injection wells
  - No extraction wells
  - Nutrient Injection: 180,000 gal
  - Price = $270,000
Scenario 2 – Deep Soil Mixing

Triple Auger Mixer

Cutter Head Mixer
Scenario 2 – Deep Soil Mixing
**Scenario 2 - Deep Soil Mixing**

- Construct soil-cement grids to enclose soft silts.

- Typically 40% area replacement ratio with 250 pci strength.

- **1,200 cy of soil-cement x $125/cy**
- **400 cy of spoils x $40/cy**

**Budget Price : $320,000**

After Nguyen et al. (2013)
Scenario 2 - Summary

- Feasibility for new structures
  - Conventional ground improvement techniques in fine silts are generally limited to deep-soil-cement mixing with a grid pattern
  - Bio-mediaption may have economical viability
  - Direct push methods and vacuum well points have potential to reduce time/cost

- Technical challenges
  - DSM provides increase in static bearing capacity. What does bio-remediation do to static capacity of the silts?
  - Confirming extent/consistency of desaturation.
  - Sustainability of desaturation
  - Difficult/impossible to re-inject once building constructed.
Bio Mediation for Liquefaction Mitigation

- Opportunities
  - Economically Viable for Existing Structures over Sands or Silts
  - Economically Possible for New Structures over Silts

- Challenges
  - Sustainability of desaturation
  - Extent of liquefaction mitigation for layered desaturation
  - Regulatory stance on injection/extraction points as wells with associated permits/reporting