In Situ Soil Stabilization

Using Biocementation to Stabilize unconsolidated soils

Solution Provider
Environmental Asset Management

Leading in soil and groundwater remediation
Unconsolidated loose soils often have poor physical properties:

- Low natural slope angle
- Low load-bearing capacity
- Prone to subsidence / settlement
- Prone to erosion
- Prone to liquefaction

Niigata, Japan, 1964
San Fernando earthquake, 1971.

Cassidy, J.F and others, Canada’s Earthquakes: ‘The Good, the Bad, and the Ugly’: Geoscience Canada, Volume 37 Number 1
CLASSIC SOLUTIONS

• Dewatering to improve settlement
• Surcharge for prolonged time to limit residual settlement
• Physical mixing with bonding agents
• Civil engineering solutions
  – Deep foundations
  – Sheet piling
  – Concrete piling
IN SITU BIOCEMENTATION

Increase bonding of soil particles:
- Utilizing soil natural biological characteristics;
- stimulating micro-organisms to catalyze chemical reactions;
- precipitation of calcium carbonate (CaCO$_3$) to bind soil particles

<table>
<thead>
<tr>
<th>Conversion type</th>
<th>Catabolic reaction per mole CaCO$_3$</th>
<th>By products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urea hydrolysis</td>
<td>1 CO(NH$_2$)$_2$ + 2 H$_2$O + 1 Ca(Cl)$_2$ $\rightarrow$ 1 CaCO$_3$ + 2 NH$_4$Cl</td>
<td>Ammonium chloride</td>
</tr>
<tr>
<td>Nitrate reduction with Calcium</td>
<td>0.385 Ca(C$_2$H$_3$O$_2$)$_2$ + 0.615 Ca(NO$_3$)$_2$ $\rightarrow$ 1 CaCO$_3$ + 0.615 N$_2$ + 0.539 CO$_2$ + 1.159 H$_2$O</td>
<td>none</td>
</tr>
<tr>
<td>Sulphate reduction</td>
<td>1 Ca(C$_2$H$_3$O$_2$)$_2$ + 2 CaSO$_4$ $\rightarrow$ 3 CaCO$_3$ + 1 CO$_2$ + 1 H$_2$O + 2 H$_2$S</td>
<td>Hydrogen sulfide</td>
</tr>
</tbody>
</table>

From: Qualitative comparison of the suitability for bio grouting of several theoretical heterotrophic conversions using calcium acetate as organic substrate and several electron acceptors compared with urea hydrolysis (Van Paassen et al/ Ecological Engineering 36 (2010) 168 – 175.).
Process is lab-proven and field-demonstrated:

- Bio-consolidation controlled from 5kPa UCS (improved slope stability, less erodible) to high strength, 30MPa UCS (concrete: 20 - 70 Mpa)) by adapting the concentration and the number of treatments applied.

- Application uses standard in situ remediation technologies
BIOCEMENTATION

Steps:
1. Analyze soils for suitability (pH, macro parameters, contaminants, toxicity) (optionally: do lab test)
2. Enrich local naturally occurring bacteria
3. Apply cultivated bacteria & amendments in treatment zone
4. Process takes between 1 week & 3 months
Biostabilization Applications

- reinforce embankments
- prevent liquefaction and its damage
- reduce building settlement and increase bearing capacity for foundations
- stabilize the soil prior to trenching or underground construction (eliminate over-excavation)
- increase resistance to erosive forces of water flow (piping or surface erosion)
Biostabilization Applications

- provide additional stability needed to stabilize slopes
- reduce sand production in oil or water wells (sand control)
- create barriers that treat/clean groundwater as it flows
- immobilize materials in the soil and prevent contamination of aquifers
- create subsurface facilities for storage of liquefied natural gas or CO₂
- stabilization of gravels formation
Examples

Theory:

Slope stability:
Example calculation for project: a cohesion of \(~16 \text{ kPa}\) is sufficient to provide stability against (static) failure for a 4 m high, 1 in 2 slope in extremely loose sand. This is a low strength application.

Erosion resistance:
< 5kPa required (low strength application)

Maximum strength achievable:
30,000 kPa UCS (concrete: 20,000 - 70,000 kPa)

Example of application
Sea protection dam
Underlaying aquifer prone to liquefaction in case of earthquake

Example of application
Road bank along drainage canal
Road surface

Solution Provider
Environmental Asset Management
Thank you for Your Attention

Solution Provider
Environmental Asset Management
Leading in soil and groundwater remediation

Groundwater Technology
Sheffieldstraat 13
3047 AN Rotterdam
Netherlands

E-mail: yve@gtbv.nl info@gtbelgium.be
Web: www.gtbv.nl www.gtbelgium.be

Tel: +3110 238 2850
Incident response: +3110 238 2868
Cell: +3165 391 6526