Outline

- What is Microbial Induced Calcite Precipitation (MICP)?
- Project Team
- Field Study Overview
- Results
Microbial Induced Calcite Precipitation

Motivation
- Multi-billion dollar ground improvement industry
- Possible applications include strength & stiffness increase, liquefaction control, permeability reduction, erosion control, dust suppression, . . .

Technology
- Bacteria consume urea (nutrient) and produce ammonia and carbon (carbonate and bicarbonate) as by-products
- pH goes up and calcite (calcium carbonate) precipitates on sand grains
- Precipitation on grains results in
  - “Binding” of grain to grain contacts → stiffness & strength increase
  - Increased solid mass → reduction in pore size and permeability
- For above to happen, may need to add bacteria, urea, and calcium if not already present in groundwater
MICP Soil Improvement For Mining

- Erosion control
- Low permeability barrier
- Co-precipitation or sequestration of heavy metals
- Reduce oxygen flux
- Slope Stabilization
- Berm/Tailings
University of California Davis
- Jason DeJong – Geotechnical Professor / Principal Investigator
- Mike Gomez – Geotechnical Doctoral Student / Field Implementation & Data Processing

Geosyntec - Oakland
- Brian Martinez – Technology Expert / Field Trial Design & Implementation
- Chris Hunt – Geotechnical Engineer / Applications Focus

Geosyntec – Guelph and Waterloo
- Dave Major – Project Director / Microbiologist
- Len deVlaming – Project Manager / Application System Design

SIREM (a Geosyntec Company)
- Sandra Dworatzek – Bacterial culture production

Cameco Corporation
- Dana Fenske – Geo-Environmental Engineer / Client Lead
Project Motivation

- Loose, poorly graded sands eroded by wind, rainfall, and snowmelt
- Stabilization needed for erosion control to promote long term closure and revegetation, reduce water use for dust control, and maintain site roads and slopes
Test Plot Setup

Before Setup

After Setup
Test Plots

- **Heel Plot**
  - Leftovers from 2, 3, 4

- **Plot 1**
  - No treatment

- **Plot 2**
  - High treatment

- **Plot 3**
  - Medium treatment

- **Plot 4**
  - Low treatment

- **Mixing Totes**

- **Water Tanks**
Ingredients

Urea  Calcium Chloride  Bacterial Solution  Nutrient Broth
Treatment Approach

**Treatment Cycle**
- Five 4-day cycles, 20 days total
- Day 1 = Bacterial amendment with nutrients
- Days 2, 3 and 4 = Nutrient amendment only

**Variables**
- Plot 1 = Water only
- Plots 2, 3 and 4 = Varying nutrient (urea + calcium chloride) quantities
First Evidence of Crust Development
Water Jetting

Plot 1 - Untreated

Plot 4 - Light Treatment
Hard Crust Development

Heel Plot Excavation

Dried Sample from Heel Plot
Measurements

Dynamic Cone Penetrometer (DCP)

Sample Collection

Calcite Measurement
Plot 1 = Control; Plot 2 = Heavy Treatment; Plot 3 = Medium Treatment; Plot 4 = Light Treatment
Plot 1 & 2 DCP Results – Raw Data

Plot 1

Plot 2

Plot 1 = Control; Plot 2 = Heavy Treatment; Plot 3 = Medium Treatment; Plot 4 = Light Treatment
Plot 1 = Control; Plot 2 = Heavy Treatment; Plot 3 = Medium Treatment; Plot 4 = Light Treatment
Plot 4 DCP Results – Average Blows/cm

Plot 1 = Control; Plot 2 = Heavy Treatment; Plot 3 = Medium Treatment; Plot 4 = Light Treatment
Plot 4 DCP Results after 44 Days

Day 0
Blows/cm

Day 20
Blows/cm

Day 64
Blows/cm

Depth (cm)

40
35
30
25
20
15
10
5
0

0 1 2 3 4

0 1 2 3 4

0 1 2 3 4

45 J - Day 0
6.5 J - Day 0

10

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Plot 1 to 4 DCP Results – Crust Formation

- **Free-Fall Distance** is the distance the DCP cone tip sank under self-weight.
- Smaller distance means more resistance = crust.

Plot 1 = Control; Plot 2 = Heavy Treatment; Plot 3 = Medium Treatment; Plot 4 = Light Treatment
Plot 1 & 2 Calcite Content – Raw Data

Plot 1 = Control; Plot 2 = Heavy Treatment; Plot 3 = Medium Treatment; Plot 4 = Light Treatment
Plot 3 & 4 Calcite Content – Raw Data

Plot 1 = Control; Plot 2 = Heavy Treatment; Plot 3 = Medium Treatment; Plot 4 = Light Treatment
Plot 3 & 4 Calcite Content – Average

Plot 1 = Control; Plot 2 = Heavy Treatment; Plot 3 = Medium Treatment; Plot 4 = Light Treatment
- Plots 3 and 4: Strong ureolytic potential (significant bacterial activity)
- Plot 2 shows low ureolytic potential
- Plot 1 results questionable

Plot 1 = Control; Plot 2 = Heavy Treatment; Plot 3 = Medium Treatment; Plot 4 = Light Treatment
MICP improved erosion resistance and suppressed dust from mine site soils
- Up to 28 cm in observed improvement
- Up to 4 cm of sandstone-like crust
- Load bearing under human and animal weight
- Resistant to erosion under water jetting

Monitoring captured spatial and temporal improvement
- DCP free fall and blow count measurements
- Calcite measurements

Biological activity was confirmed
- Ureolytic Potential Tests
Video
Water Jetting
A few things we know

- Treatment was not optimized – the lightest treatment worked best
- Results will depend on site materials and depth of treatment required
- As a short term erosion control solution, may not be cost competitive yet
- As a long term ground modification approach, it can be very cost competitive
- Evaluation is needed on fate of ammonia byproduct