

Liquefaction Mitigation in Silts using Microbially Induced Desaturation

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Research Team

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Partners

Industry / State Agencies:

- Condon-Johnson & Associates
- ConeTec
- Portland Bureau of Transportation
- Portland General Electric (PGE)
- Portland Water Bureau







Project Overview / Description

- Field trial of Microbial Induced Desaturation (MID) at Two (2) Sites in Portland, OR
- Nutrients (treatment substrates) are injected to the ground from a central well and extracted from perimeter wells
- Denitrification results in nitrogen and CO2 gas which desaturates the soil
- <u>Unsaturated soil is not liquefiable</u>)



SEM image of gas bubble remnant (O'Donnell 2015)



Project Scope / Timeline

- Field shaking with T-Rex at untreated site(July 2019)
- Apply ground treatment for 1 month (August 2019)
- Field shaking with T-Rex at treated site (September 2019)
- Long-term monitoring of treatment using crosshole p-wave velocities (next 3 to 5 years)





Seismicity (Portland, Oregon)

- Cascadia Subduction Zone
 - Magnitude 9, 100 km source-to-site-distance
- Shallow Crustal Faults (Portland Hills Fault)
 - Magnitude 6.8, <10 km
- PGA_M = 0.43 g for
 liquefaction analysis
 based on ASCE 7



Source: DOGAMI



Liquefaction Hazard in Portland

• Two sites selected for this study



Harborton site location





- Located in the area of Oregon's Critical Energy Infrastructure (CEI) hub
- ~90% of Oregon's fuel is handled through CEI (Oregon Solution, CUPA)



Harborton: subsurface conditions



Dredged river fill (< 100 years) over young, loose alluvial river deposits
 Water level: about 7.5 feet bgs





East extraction 12.5' to 14'

South extraction 12.5' to 14'

Sunderland: site location



Sunderland site (managed by Portland Bureau of Transportation, PBOT) is close to Portland International Airport



Sunderland: subsurface conditions



Columbia river floodplain deposits of interbedded silts and clays
 Water level: about 3.5 feet bgs





South extraction 16.5' to 18'

Injection 6.5' to 8'



Ground Treatment Method

- Microbial Induced Desaturation (MID)
- Desaturation \rightarrow little pp during cyclic loading \rightarrow mitigate effective stress loss
- Suitable for fine-grain soils (e.g. low-plasticity silts)
- Suitable for existing structures





Ground Treatment Method

- Nutrients are calcium nitrate (fertilizer) and calcium acetate (food grade), byproducts (nitrogen gas and carbon dioxide) are environmentally benign
- Small amount of nutrients are required for desaturation
 - ✓ 10 grams of CA and 10 grams of CN per liter of water







Ground Treatment Method

- Previous tests
 - Lab scale tests and centrifuge tests showed effectiveness
 - Field experience in Japan showed that the effect lasts for decades





Day 7



Day 17

Field tests are ongoing (Toronto ON, Richmond BC, and Portland)

> Pilot site Toronto Courtesy of Leon van Paassen





Sunderland: instrumentation & data collection

TREX sensor array:

- Measure V_p and V_s with crosshole and downhole seismic tests
- Measure cyclic-induced excess pore pressure generation before and after treatment
- CTD-divers:
 - Record volumes of injected and extracted water (CTD-divers)
 - Measure salinity (via Electrical Conductivity) of injected and extracted water (CTD-divers)
- TEROS-12 in-situ sensors:
 - Measure salinity (via EC) and temperature of groundwater in the monitoring well





Test area setup

Sunderland





TEROS sensor data transmitter

INJ

Test area setup

3.5 m

Sunderland



Crosshole sensor array

18



Test area setupHarborton (PGE)



Test area setupHarborton (PGE)

CALCIUM

Extraction tank (1000 gal)

- TEROS sensor data transmitter

EXT

INJ

Mixing tote (275 gal)



Volume of injected treatment





Injection flow rates

Injection Flow Rate





Salinity vs. time (CTD divers)

Submerged in injection and extraction tanks



Portland State

Salinity vs. time (TEROS-12 sensors)







TREX sensor array

P-wave and S-wave velocity crosshole measurements



TREX sensor array preliminary pre-treatment results



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Summary of results (so far)

- > Targeted soil stratigraphy is being treated with MID
 - Salinity sensors show injected solution through soil
 - V_p measurements indicate desaturation through the treated layers
- Some preferential paths between injection and extraction wells
- TREX testing prior to treatment provides a baseline of seismic-induced excess pore pressure generation



What's next?

- Post-treatment round of TREX testing will quantify reduction in seismicinduced excess pore pressure generation
- Cyclic lab testing
 - Characterize excess pore pressure generation vs. shear strain curve to strains larger than those induced during TREX testing
 - Further characterize cyclic behavior of Portland-area soils
- Long-term monitoring at Sunderland
 - V_p/V_s cross hole seismic measurements
 - Effectiveness of treatment over time
- > CPT profile in treated area

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