PERMEABLE LOW DENSITY CELLULAR CONCRETE (PLDCC): SUMMARY OF BASIC RESEARCH FOR CHARACTERIZATION AND PERFORMANCE

AERIX INDUSTRIES WEBINAR SERIES
2/6/19

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Webinar outline

- 5 min - Welcome and logistics
- 10 min – Background on PLDCC
- 20 min - Summary of PLDCC characterization research
- 10 min - Discussion of opportunities
- 10 min - Wrap up

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Low-Density Cellular Concrete (LDCC) is defined by ACI 523 as...

- Concrete made with hydraulic cement, water and preformed foam to produce a hardened material with an oven dry density of 50 pounds (22.7 kg) per cubic foot or less.
- Preformed foam is created by diluting a liquid foam concentrate with water in predetermined proportions and passing this mixture through a foam generator.

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Permeable & Non-Permeable LDCC

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Permeable vs. Non-Permeable

- Bubble Chemistry is different
  - In non-permeable we need to maintain the bubble structure
  - With Permeable we need to coalesce the bubble structure

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Project Spotlight-Louis Armstrong International Airport-New Orleans

- $826 million terminal expansion timed to open for New Orleans' 300th anniversary in May 2018
- Sight contained a highly plastic clay with high water table
- A solution was needed to provide good soil support with minimal fill weight and good drainage
- AQUAERiX Permeable Low Density Cellular Concrete (PLDCC) was utilized

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Site conditions

- Lighting vault replacement

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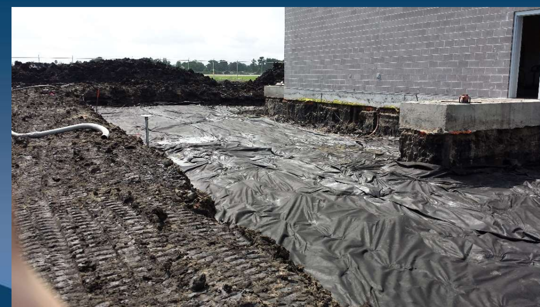
Site conditions



Non-woven geotextile

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Construction – Two, 2ft lifts: 3,000CY in 4 days

- 750 CY/day

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Construction – Two, 2ft lifts: 3,000CY in 4 days

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Research Study Objectives

- To provide basic characterization of PLDCC to support geotechnical and materials-based engineering designs and specifically investigate across a range of densities:
  - Strength and freeze-thaw durability
  - Permeability and sedimentation/clogging
  - Thermal conductivity
  - Pollutant removal capacity

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PLDCC Mixtures and Samples

- AQUAERiX 50:1 water:concentrate by volume
  - Foam supplied at 2.0-2.1pcf
- Neat cement slurry using Type I/II at w/c of 0.50
- BASF Glenium 7500 high range water reducer dosed at 3 oz/cwt

- Samples produced at 25pcf, 30pcf, and 35 pcf wet density
  - All samples cured sealed in molds 25 days, then stripped and dried (50%RH) 3 days before testing

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Compressive Strength and Durability

- Strength tested per ASTM C495
- Freeze-thaw testing performed, 0, 3, 50 cycles (-10° F 24 hrs, 73° F 24 hrs)
  - Dry
  - Moist (ASTM D560 felt towel)
  - Wet (weighted and submerged)

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Shear Strength Testing

- Iowa 406-C guillotine split load frame
- 400-500psi/min

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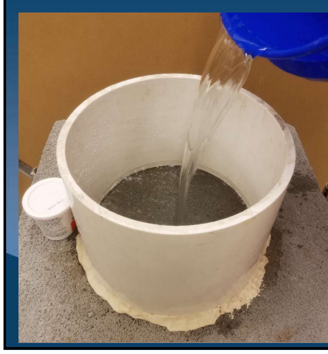
Infiltration Testing (ASTM C1701)



- 12 in. ring
- 1 gallon prewet
- 1 or 5 gallon test
- Head kept 10-15mm (~1/2in.)

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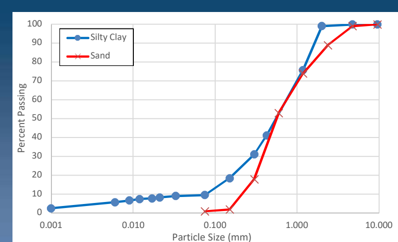
Soil Gradations for clogging (300mg/l)



Loaded at 32 in./hr until infiltration fell below 10 in./hr or stabilized

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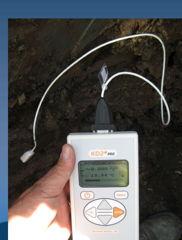
Thermal Resistivity

- ASTM D5334
- Three samples at each density
- Tested dry



Conductivity/resistivity testing on soil (Bentham)

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Basic Characterization Results

Density	Dry UW, pcf (kg/m^3)	Voids (%)	Permeability, in/s (cm/s)	C1701 Infiltration, in/s (cm/s)	Resistivity (°C cm/W)
25 pcf (400 kg/m^3)	13.4 (215)	89.6	0.08 (0.20)	0.19 (0.47)	1086
30 pcf (480 kg/m^3)	16.5 (265)	87.1	0.04 (0.09)	0.04 (0.10)	748
35 pcf (560 kg/m^3)	18.9 (305)	85.9	0.02 (0.05)	0.007 (0.019)	658

- Dry density about half of wet
- Voids tested using boil method (ASTM C642) for saturation portion of (ASTM C1754)

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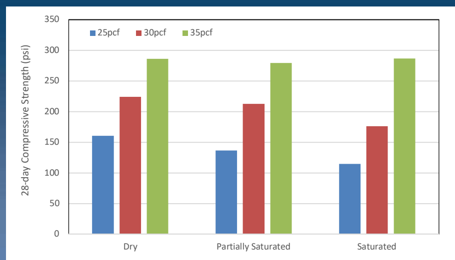
Results – Compressive Strength



0 freeze-thaw cycles

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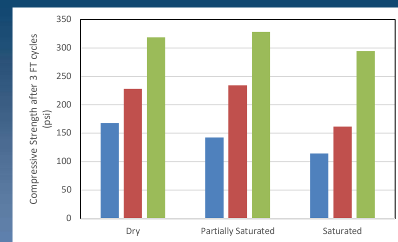
Results – Compressive Strength



3 freeze-thaw cycles

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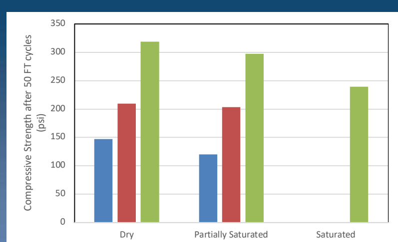
Results – Compressive Strength



50 freeze-thaw cycles

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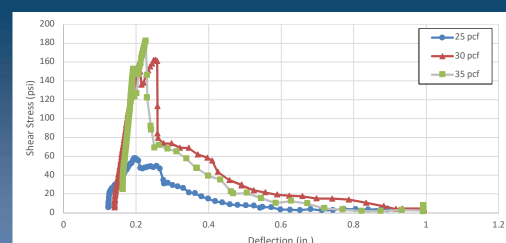
Results – Shear Strength



Modulus and strength increased with density

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Strength Performance Summary

Density	Condition	Compr. Str. Avg, psi (MPa)	Shear Str. Avg., psi (MPa)	Shear Modulus,psi/in. (Mpa/cm)/R^2
25pcf (400kg/m^3)	Dry	160 (1.1)	58 (0.4)	1501 (4.1)/0.75
	Partially Saturated	137 (1.2)		
	Saturated	115 (0.8)		
30pcf (480kg/m^3)	Dry	224 (1.5)	112 (0.8)	2343 (6.4)/0.99
	Partially Saturated	213 (1.5)		
	Saturated	176 (1.2)		
35pcf (560kg/m^3)	Dry	286 (2.0)	159 (1.1)	4093 (11.1)/0.98
	Partially Saturated	280 (1.9)		
	Saturated	287 (2.0)		

- Using traditional guidance for CLSM, only 25pcf hand excavatable. Because of the bubble structure, 30 and 35pcf used here would be as well.

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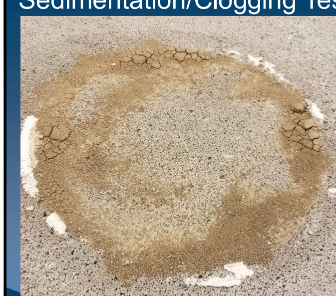
Sedimentation/Clogging Testing Results



25 pcf sample after 13 years of loading of the silty loam

(White ring is leftover plumber's putty from sealing the ring)

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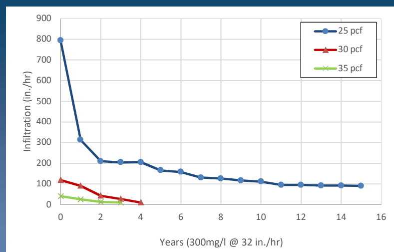
Sedimentation/Clogging Testing Results



Sand soil performance

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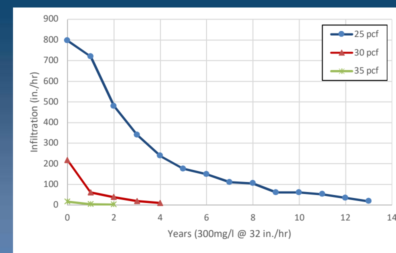
Sedimentation/Clogging Testing Results



Silty clay soil performance

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Opportunities – Changing Gears to Pollutant Removal

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Sources of Heavy Metal Contamination

- Mining
- Smelting
- Metallurgical Industries
- Corrosion
- Waste Disposal
- Fossil Fuel Combustion
- Agriculture and Forestry

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Heavy Metal Contamination

2015 Gold King Mine Spill

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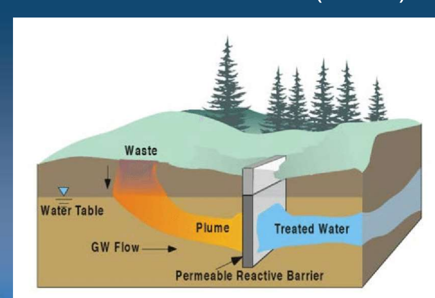
Permeable Reactive Barriers (PRBs)



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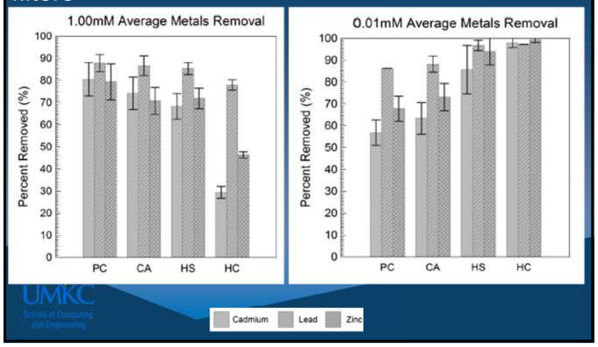
Heavy metal removal through cement-based filters



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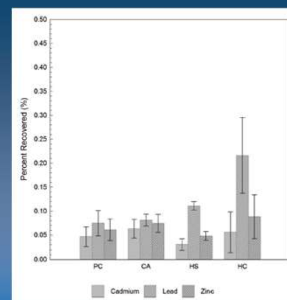
And They Stay Put-DI water flush results



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Real water through AQUERiX

Water Sample	Aluminum ug/l	Boron ug/l	Calcium ug/l	Chromium ug/l	Magnesium ug/l	Manganese ug/l	Chloride mg/l	Fluoride mg/l	Sulfate mg/l	Nitrate mg/l
DI water	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
AQ4 with DI water	414	ND	204000	15.5	ND	ND	1	ND	6.7	ND
CCB pond water	ND	22400	480000	ND	237000	9.8	418	5.5	2300	-
AQ4 with CCB pond water	ND	13600	825000	231	62	36.5	480	0.78	2050	0.71

Boron – 39% removal
Magnesium – 99.9% removal
Fluoride – 86% removal

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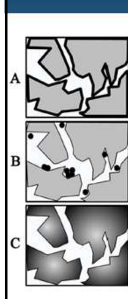
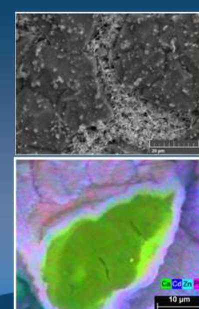
So Where are They Going?



A) Adsorption

B) Precipitation/Co-precipitation

C) Diffusion



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Summary

- Strength, permeation, thermal conductivity, and elastic modulus all correlate directly to density.
- For the lower density samples (25, 30 pcf) strength decreased with increased saturation
- The highest two densities were susceptible to clogging from either silty clay or sand with clogging occurring after simulated 2-4 years. The lowest density, highest permeability, samples clogged after 13 years for the silty clay soil and did not clogged after a simulated 15 years of sand (geotextile is recommended)

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Summary

- When freeze-thaw testing was performed in the damp condition according to ASTM D560 *Standard Test Methods for Freezing and Thawing Compacted Soil-Cement Mixtures,* all densities had excellent performance through 50 cycles which is 4 times the test length used for comparable soil-cement. Under fully-saturated freeze-thaw cycling only the 35 pcf (560 kg/m^3) samples were able to be tested after 50 cycles.

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Summary

- PLDCC was able to provide significant pollutant removal capacity for a variety of heavy metals
- Further modification and optimization of cement chemistry possible for removal of other targeted ions
- Metal recovery and beneficiation possible during secondary smelting because of the similarity between PLDCC and limestone chemistry

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