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Effects of Electromagnetic Stimulation on Soil's Hydraulic Conductivity

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Abstract

Our research involves the identification of the different effects that electromagnetic (EM) stimulation has on varying soil properties; properties such as hydraulic conductivity. This work could prove to be of importance in furthering our understanding of the effects of EM stimulation with regard to the hydraulic conductivity of soil. A positive correlation between EM stimulation and an increase in hydraulic conductivity could have broad applications for environmental contaminant mitigation in soils and for various geotechnical construction applications such as minimizing soil setup during pile driving operations. EM waves can be used to enhance soil and groundwater remediation in a way that no heat is generated, yet the desired mechanisms in soil are stimulated. Our approach in this project involved the construction of a customized permeameter that enabled us to measure the change in hydraulic conductivity given a tuned EM wave from an antenna. An EM wave with a fixed frequency and varying power output was sent through the permeameter while the hydraulic conductivity was measured in real time. Tests performed for the research project were successful in showing a correlation between hydraulic conductivity and EM stimulation.

Disciplines

Civil Engineering

Effects of Electromagnetic Stimulation on Soil's Hydraulic Conductivity

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Project Abstract

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Research Basis

The dipole properties of water enable EM waves to affect it in ways that were previously thought impossible. Individual water molecules can be aligned using an electrostatic source and droplets of water can even be levitated by magnetic fields. It has been shown that when stimulated by an electric field matching the water molecule's resonant frequency, vibrations and flow within a water droplet can be induced by both direct and alternating currents. We conducted tests to see whether we can stimulate the water molecules to individually oscillate and therefore induce a net increase in the movement and flow of water through a porous medium thereby increasing the hydraulic conductivity of the medium. Hydraulic conductivity is a measure of how rapidly water flows through a porous material. It can be calculated using the equations shown below both of which are derived from Darcy's Law with respect to the type of test that is being conducted. Equation 1 is used for constant head tests while equation 2 is used for falling head tests.

$$K = \frac{VL}{AtH}$$

$$V = \frac{\Delta m}{\rho_{H2O}}; \rho_{H2O} \propto T \qquad (1)$$

$$K = \left(\frac{L}{AH}\right)\left(\frac{\Delta m}{t\rho_{H2O}}\right)$$

$$K = \left(\frac{d_t^2 L}{d_c^2 t}\right) Ln\left(\frac{h_i}{h_f}\right) \qquad (2)$$

K: Hydraulic Conductivity
H: Hydraulic Head
A: Soil Sample Cross Sectional Area
L: Length of Soil Sample
t: Water Collection Duration
V: Volume of Water Collected
Δm: Change in Collection Container Mass
ρH2O: Water Density at Specific Temperature
T: Water Temperature

dt: Falling Head Tube Diameter
dc: Soil Sample Diameter
hi: Initial Falling Head Tube Height
hf: Final Falling Head Tube Height

Experimental Apparatus:

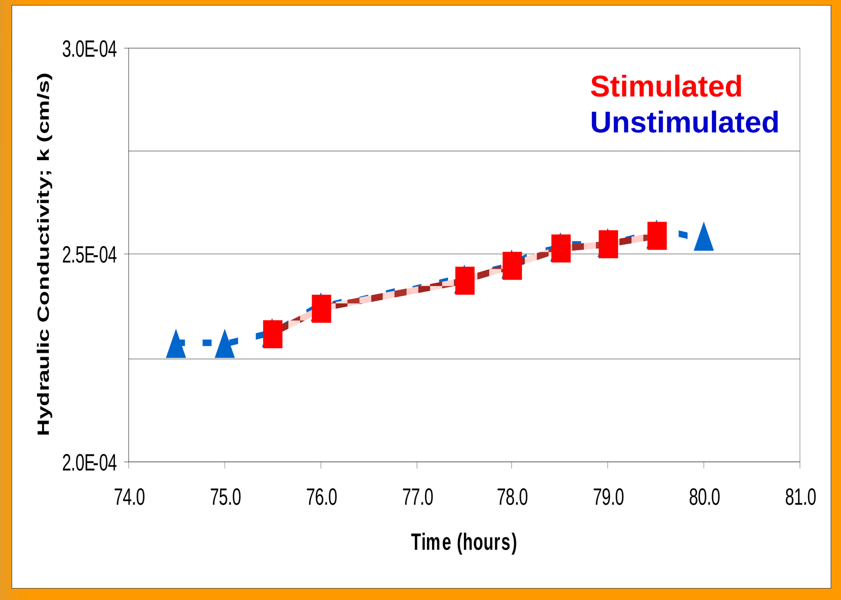
Constant Head and Falling Head Permeameters

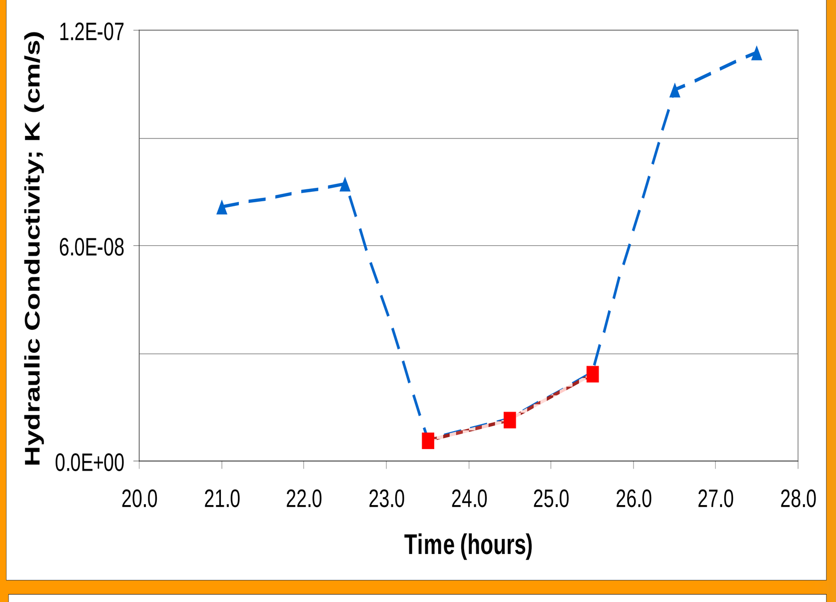
Constant head permeameters are used for non-cohesive soils such as sand while falling head permeameters are used for cohesive soils like clay. Flow through the saturated samples were allowed to stabilize at a consistent value prior to EM stimulated testing. Constant head tests were conducted via mass based collection and measurements of outflow with respect to time with constant values for *L*, *A*, and *H* and incremental measurements taken for *Δm*, *t*, and *ρH2O*. Falling head tests were done with constant values for *L*, *dc*, and *dt* while incremental measurements were taken for *hi*, *hf*, and *t*.

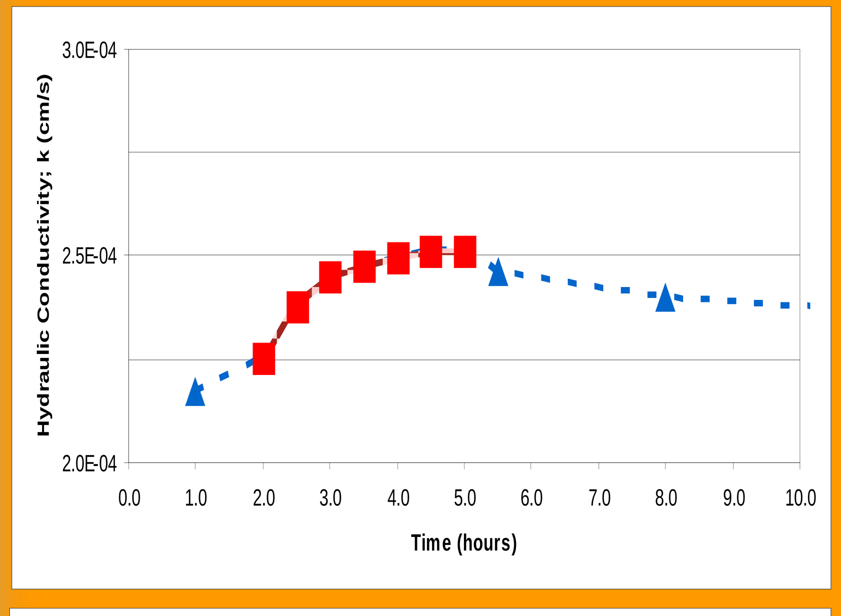
The EM wave through a coaxial cable was generated via an Agilent E4400B signal generator and an Amplifier Research electrical amplifier. The electrical impedance of the soil within the permeameter was first matched using an Agilent N9320A network analyzer to ensure maximum power output through the amplifier prior to signal generation.

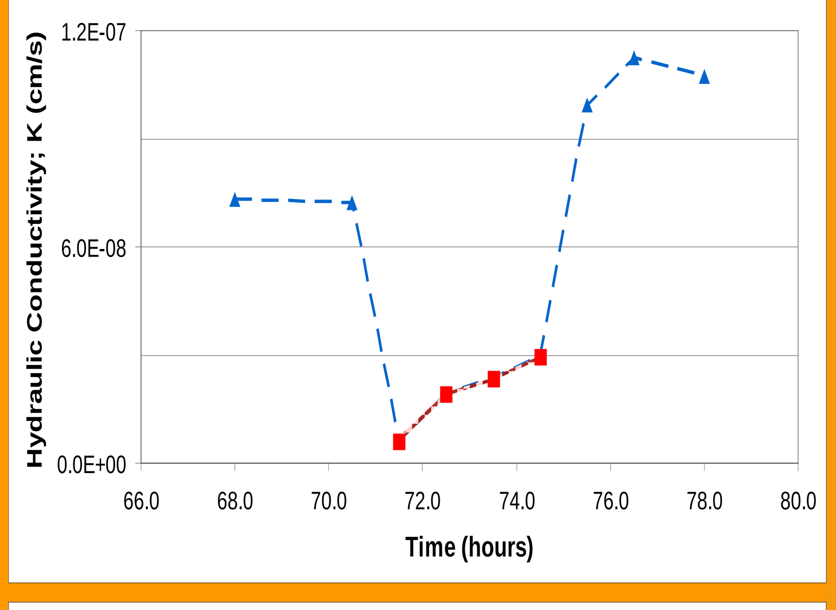
Sample Test Results

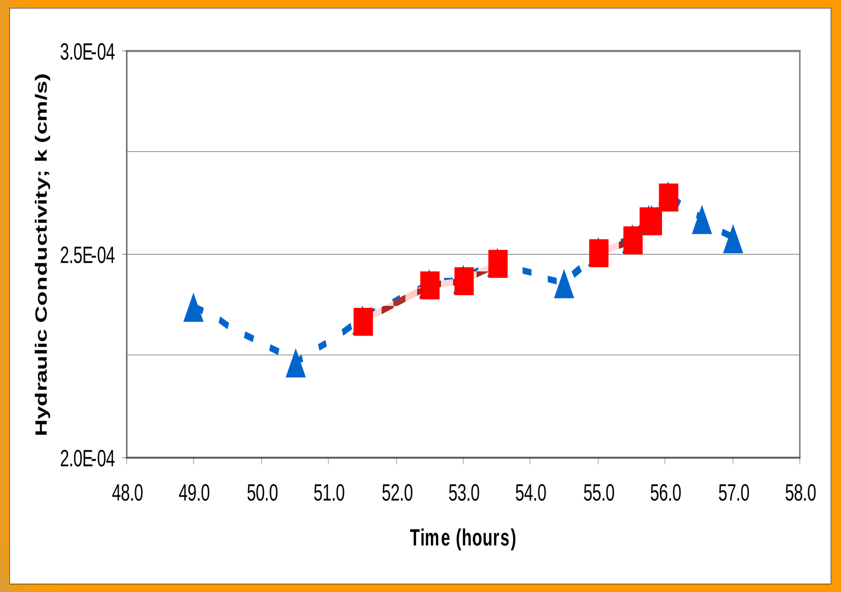
Sand | **Clay**

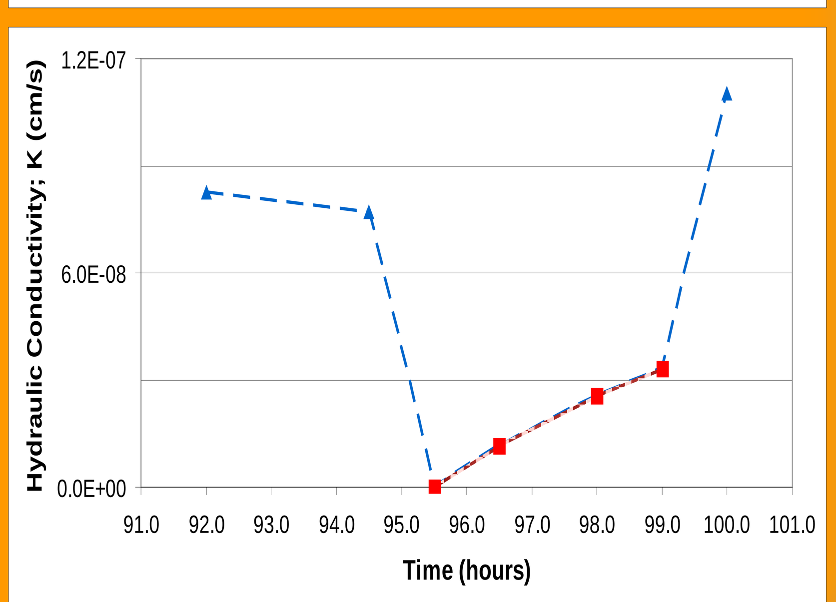




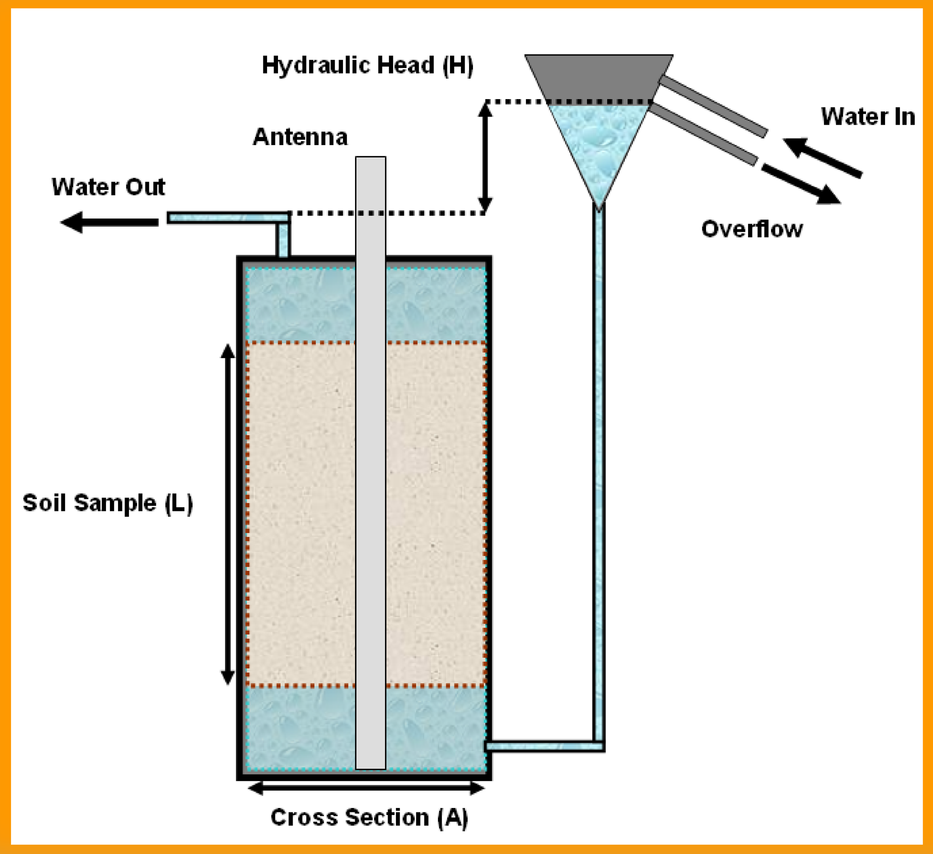




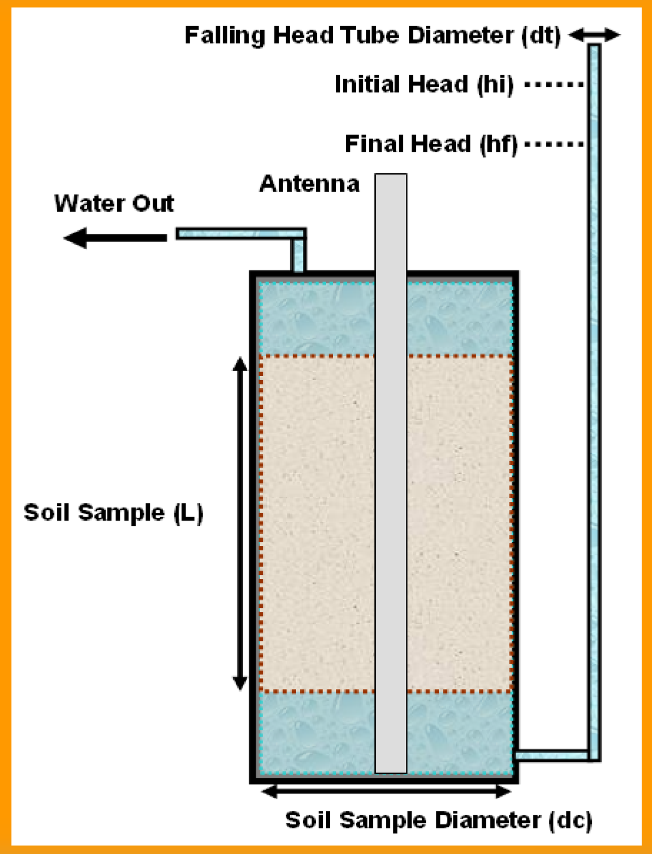




Constant Head Permeameter



Falling Head Permeameter



Research Results

A positive correlation between EM stimulation and an increase in hydraulic conductivity (K) in sand was observed during the research testing phase through a noticeable and consistent increase in the hydraulic conductivity of the soil sample. Multiple stimulation tests were conducted and it was found that a specific configuration that pushes roughly between 30-50W of power through the permeameter yields the most optimal results as shown below. The test results for sand show an upward trend in the K values after stimulation was initiated. The bottom most graph for sand was used to more concretely validate the effect of EM stimulation on the K value increase by stopping stimulation midway through the test and restarting it. This resulted in a sudden decrease in the observed K value while stimulation was halted and a continued upward trend once stimulation was resumed which clearly shows that the observed increases are primarily due to the EM stimulation.

Power (W)	Percent Increase in Hydraulic Conductivity
15	0
28	6
50	14

Test results from the falling head tests on clay yielded very different results. As shown on the graphs to the left, EM stimulation caused a sharp decrease in the K value of the clay sample. In some tests, K through the clay was effectively reduced to zero for a short amount of time immediately after EM stimulation was initiated. The termination of EM stimulation also caused a sudden increase past K's average pre-stimulation value. Some degree of relaxation is evident from the graphs and suggests that the hydraulic conductivity might be regained after a certain amount of time despite the EM stimulation. Further testing is currently being conducted to determine the cause of this phenomenon.

Our team plans on conducting additional tests using varying combinations of soil samples and EM wave parameters such as frequency and power output to more concretely determine the nature of the effects that EM waves have on hydraulic conductivity and other soil properties.

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