Development of a Smear Proof Horizontal and Vertical Permeability Probe

V.A.H.I.P.

(Vertical and Horizontal In-situ Permeameter)

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FDOT Geotechnical Research in Progress Report

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VAHIP Overview

- Under a previous FDOT sponsored project, the PI developed a probe capable of measuring both horizontal and vertical permeability
- Designed to be robust and quickly assembled/disassembled in the field
- Used with SPT/CPT rigs
- A flow meter was used with the probe to monitor the flow at the injection sites

Issues With Previous Design

- Probe became problematic in weak clay
- The soil would smear the side screens or enter the probe
- When pushed into uniform sand after the clay layer, permeability could not be determined

Old probe debris intrusion

Project Scope Task 1 - 3

- Project reinitiated to resolve smearing issues
- Task 1 – Design PVC prototype to investigate new options
- Task 2 – Once design was confirmed, construct new probe using stainless steel
- Task 3 – Perform small-scale testing for different sands (coarse, intermediate and very fine)

Project Scope Task 4 – 7

- Task 4 – Once the probe's operation was verified, it was to be tested in the field
- Task 5 – Investigate the effect of soil compaction on permeability
- Task 6 – Compare probe results to independent lab permeability measurements of materials used in small-scale testing
- Task 7 – Submit final report including all findings and constructed probes

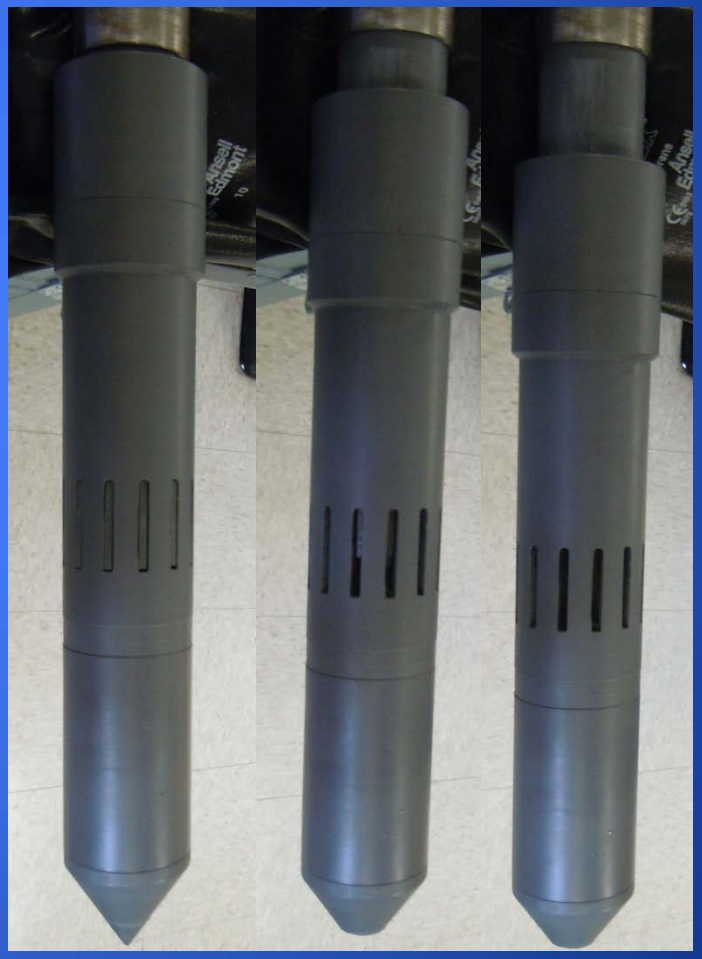
Last Year

- Presented new PVC prototype
- Discussed design for new pressurized water vessel
- Discussed new probe design with locking system
- Presented results from Lab permeability of soils
- Presented small-scale testing environment
- Discussed flushing technique to remove soils
- Presented JAVA analysis program

PVC Prototype Design Flaws

- No way to ensure probe is in proper stage under ground
- Friction reducer too small compared to AWJ rod diameters
- Smear proofing keys did not fully retract in horizontal position

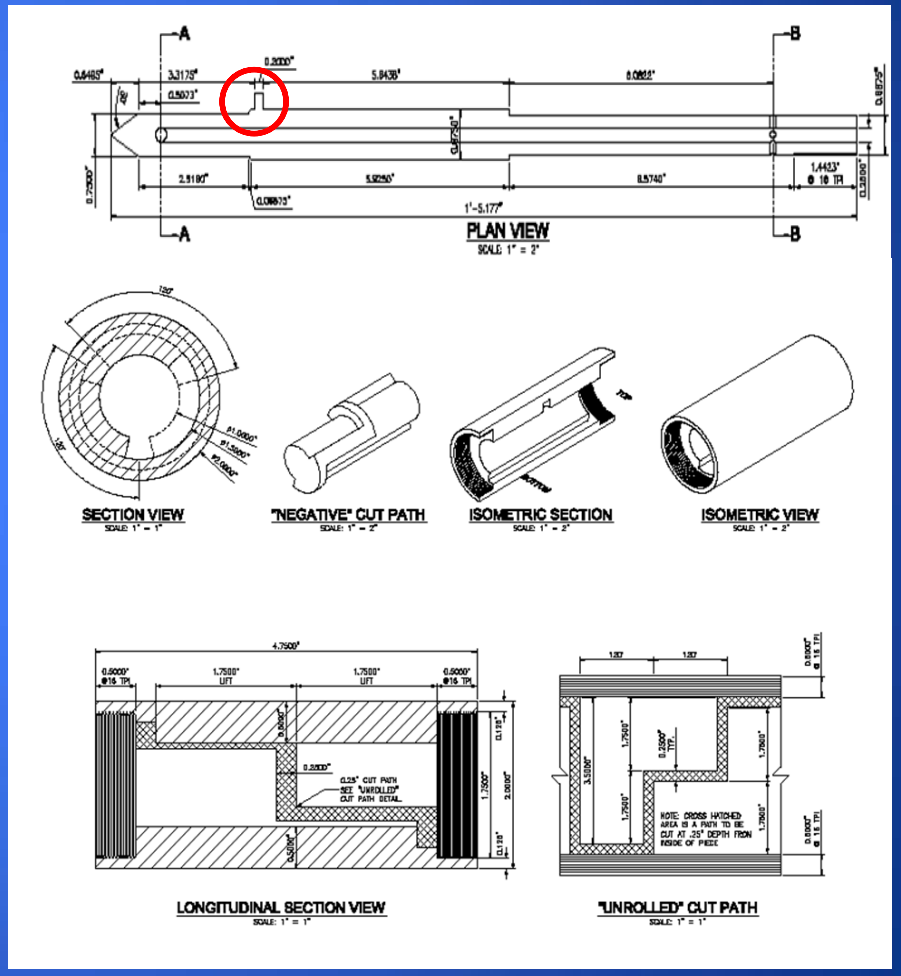
PVC Prototype - 3 stages of lift



Closed Horizontal Vertical

Tracking System

- Designed a pre-determined tracking system in the lower chamber
- Pin on the inner rod must follow the predetermined track
- New design allows inner rod axial rotation and vertical movement



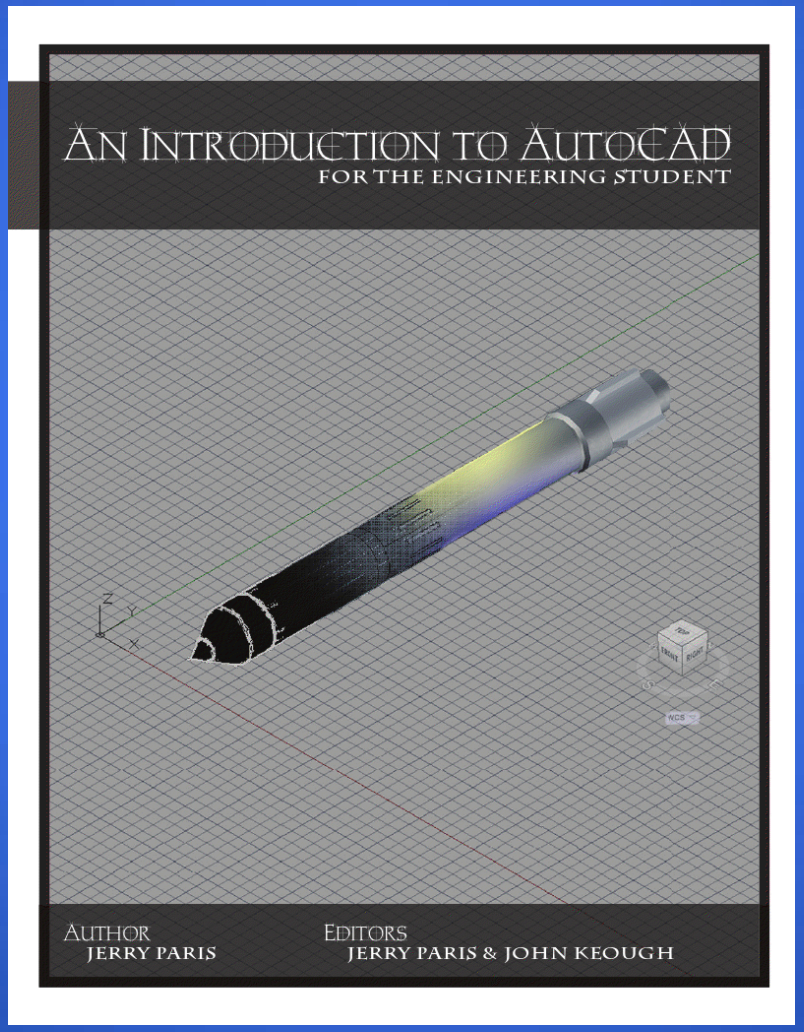
Pinned inner rod and tracking system plans

Design Properties of Steel Probe

- Constructed using 304 stainless steel
- 21” closed length
- 24” open length
- 2” O.D.
- 2 ¼” O.D. friction reducer with ¼” wings extending outward
- Approximately 16.5 lbs in weight
- 80+ hours of AutoCAD design work

Steel Probe

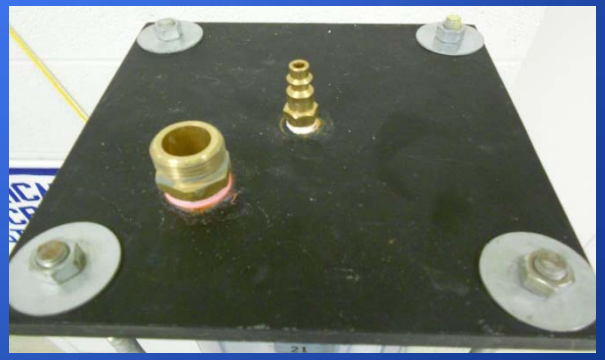
UF's New Autocad Manual



New Water Vessel

- Constructed using 6” clear schedule 40 PVC pipe, steel base plates and rods holding the system together
- Can store up to 3 gallons of water
- Removable cap for quick and easy filling
- Quick connect placed on top that allows the system to be pressurized
- Tripod provides stability and ease of monitoring
- Unit scale placed for easy monitoring of flow
- Quick connect placed on the base of the tank which allows the hose to be disconnected
- Water vessel can be easily removed from the tri-pod for transport

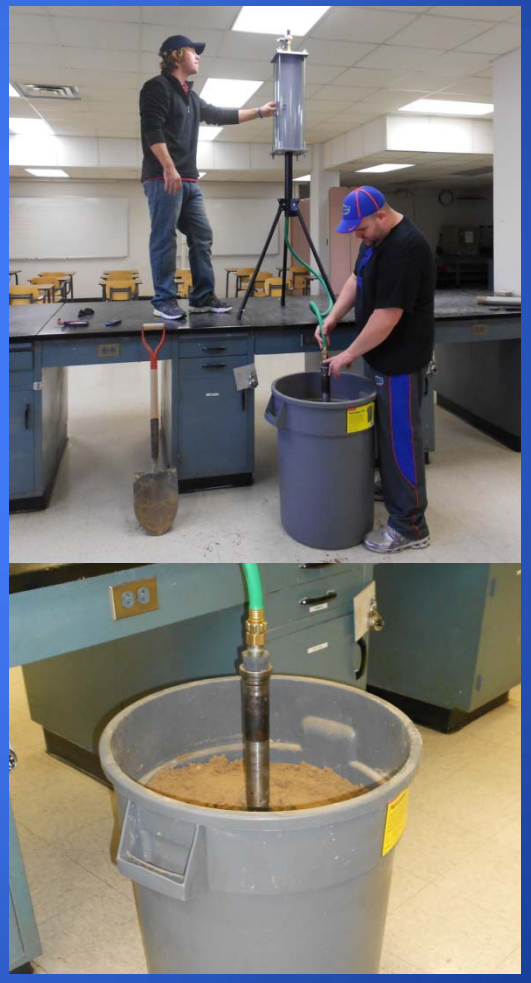
Tri-Pod and New Water Vessel



Top of Water Vessel

Small-scale Testing

- 55 gallon barrels filled with various soil types (coarse, intermediate, fine)
- Probe was placed and soil back filled
- Initial testing of mechanics and functionality
- Flow monitored but not recorded



Sand – Barrel Testing

1st SMO Visit – Test Pit

- First steel probe trial took place in the test pit
- A Hole was dug out and the probe placed at bottom
- Soil was then back filled and water introduced
- Design did not restrict initial flow
- Flow was unable to be monitored as the probe drained the water vessel before going into horizontal and vertical stages with only 5 feet of head being placed on the system

Steel Probe Redesign

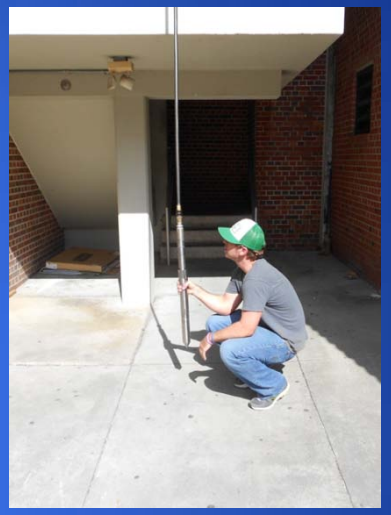
- 1st modification - repositioned inner rod flow ports - ineffective
  - Prevented premature leakage
  - Did not route water properly when changing from horizontal to vertical flow
- 2nd modification - shortened the inner rod and cone tip and placed o-rings on the inner rod - effective
  - Prevented premature leakage
  - Routed water properly

Probe Modifications

Modification Testing

- Hung 45’ hose off of 4th floor of Weil Hall
- Monitored probe for any leakage – no leaks
- Checked both stages of flow for proper routing of water - successful
- AWJ connection failed before probe over an extended time period

Hose hung off 4th floor



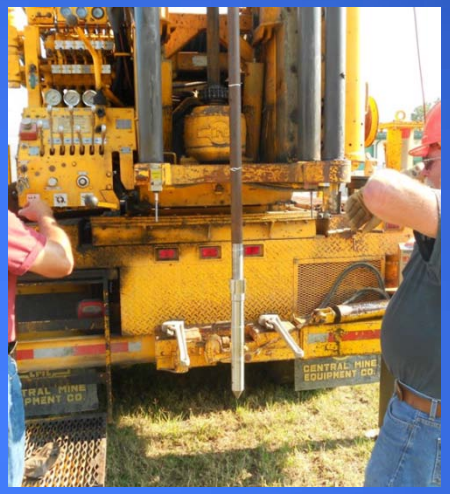
Monitoring leaks

Flow stage testing

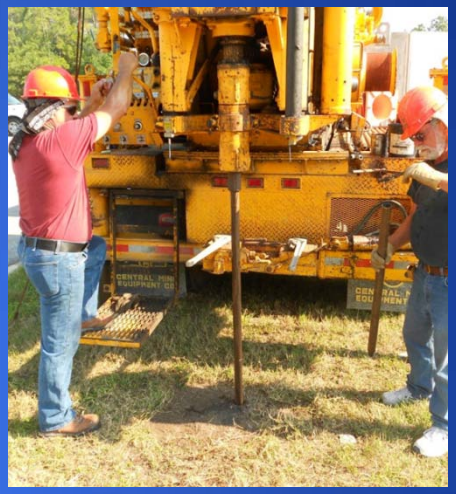
AWJ rod failure

2nd SMO Visit – Field Test

- Tested at depths of 5’ and 10’
- Probe was able to move through stages of flow by hand at 5’
- Large wrench was used at 10’
- Flow was monitored but not recorded



Probe attached to SPT rig


Probe insertion

Changing flow orientation

Jose monitoring flow

Field Test Results

- Probe functioned correctly at both depths
- At 5’ the probe was able to be closed off and pushed down to the next test depth of 10’
- Vertical flow was nearly the same at both depths
- Horizontal flow was slower than vertical at 5’ but was faster than vertical at 10’
- Probe was able to be closed off and extracted from the ground successfully
- The probe did show some unthreading issues during the last test

FDOT Field Test Recommendations

- Resolve unthreading issues
- Develop a system to track the probes rotation and vertical movement underground during stages of lift
- Design smaller probe

Field workers prepping SPT rig

Resolving Field Test Issues

- Placed set screws in 3 locations to prevent unthreading
- Developed Prototype tracking system to monitor rotational and vertical movement at the top of the hole

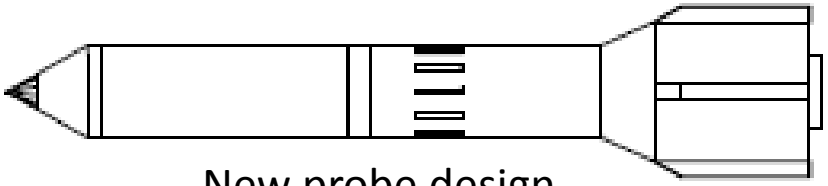
Probe with set screws added

Prototype tracking dial

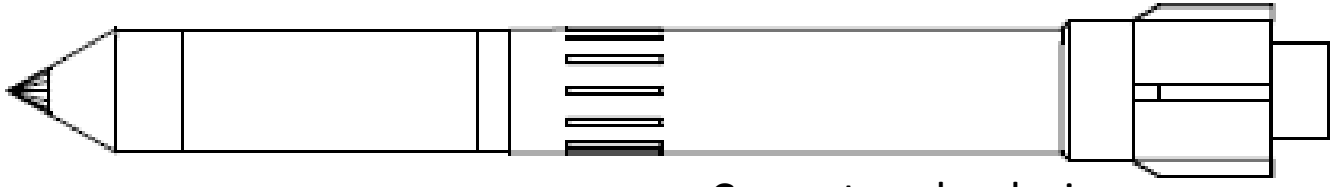
New Probe Design

Comparison	Old Probe	New Probe	Difference	Reduction
Length-closed (in)	21.2	13.25	7.95	-37.50%
Length-open (in)	24	15.75	8.25	-34.38%
Diameter (in)	2	1.5	0.5	-25.00%
Volume (in^3)	57.26	25.38	31.88	-55.68%

Comparison chart



New probe design



Current probe design

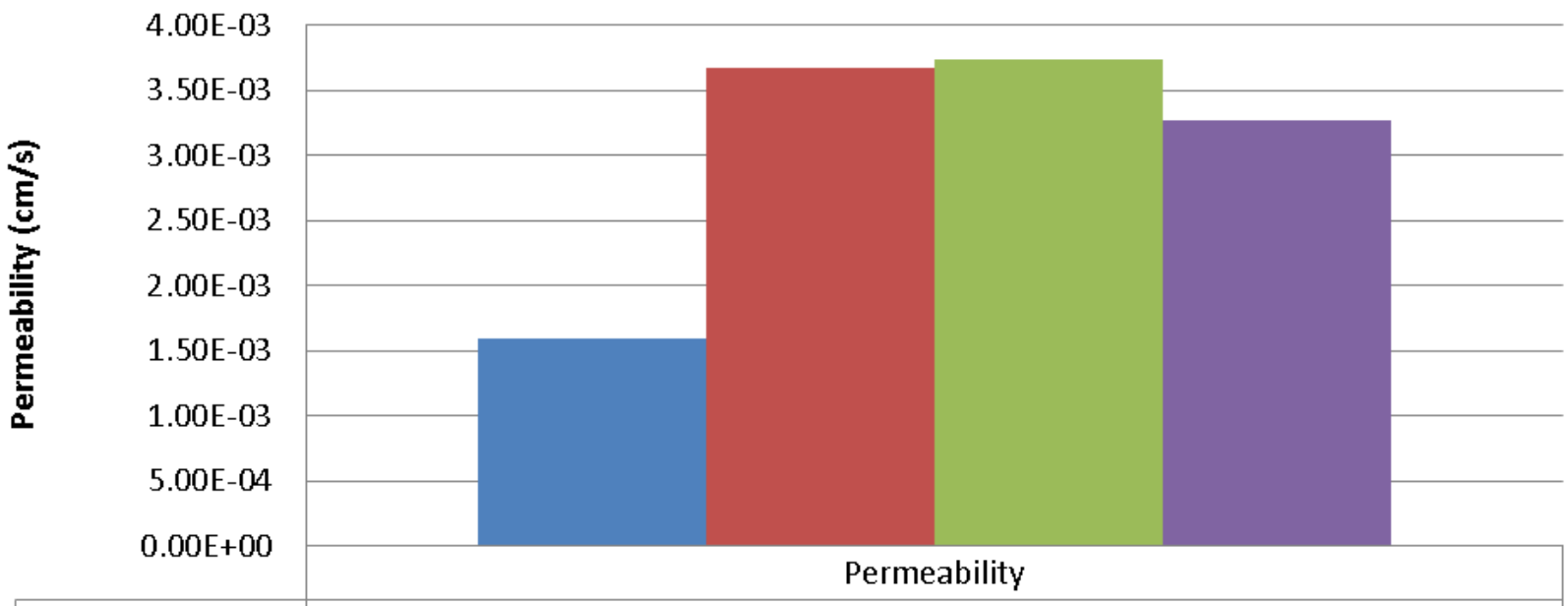
Small-Scale Testing Reinitiated

- 3 methods of probe insertion (backfill, push, vibrate)
- Recorded data per test
  - Moisture content
  - Sieve Analysis
  - Relative Density
  - Lab Permeability Tests
    - Falling Head
    - Constant Head

Soils Tested

8 - 30 **20 - 30** **A - 2 - 4**

Lab vs. Sand Barrel Testing

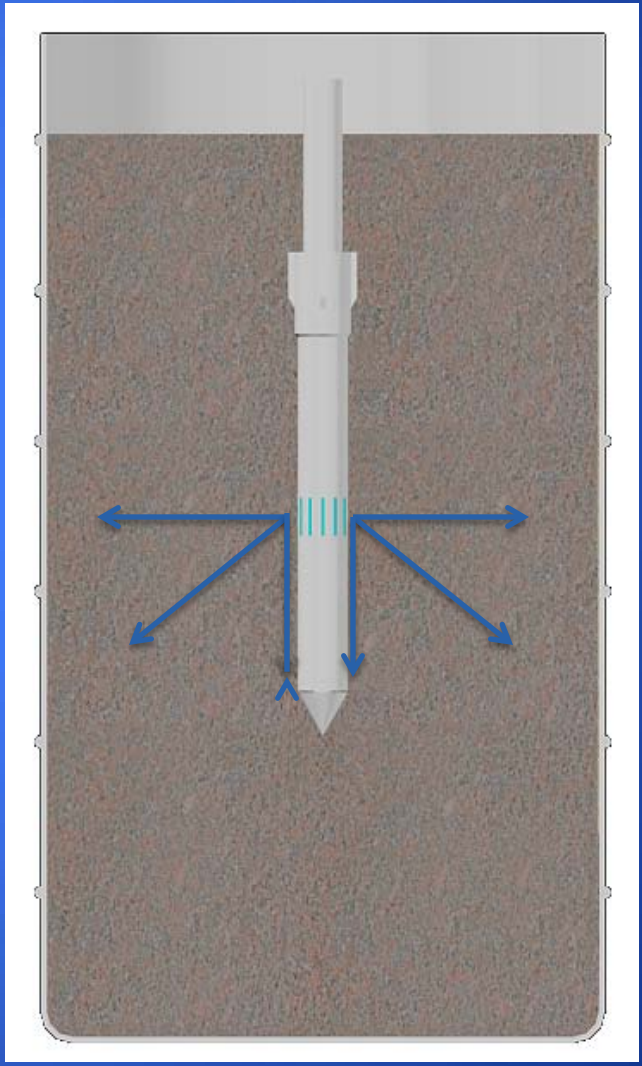


	Permeability
Probe Horizontal	1.59E-03
Probe Vertical	3.67E-03
Constant Head	3.73E-03
Falling Head	3.27E-03

Constant and falling head (lab) permeabilities vs. sand barrel (probe) permeabilities

Where Does the Water Go?

- Our determination of permeability is based on Hvorslev's theory
- We need to find a way to map the flow as it exits the probe horizontally



Soil Moisture Sensors

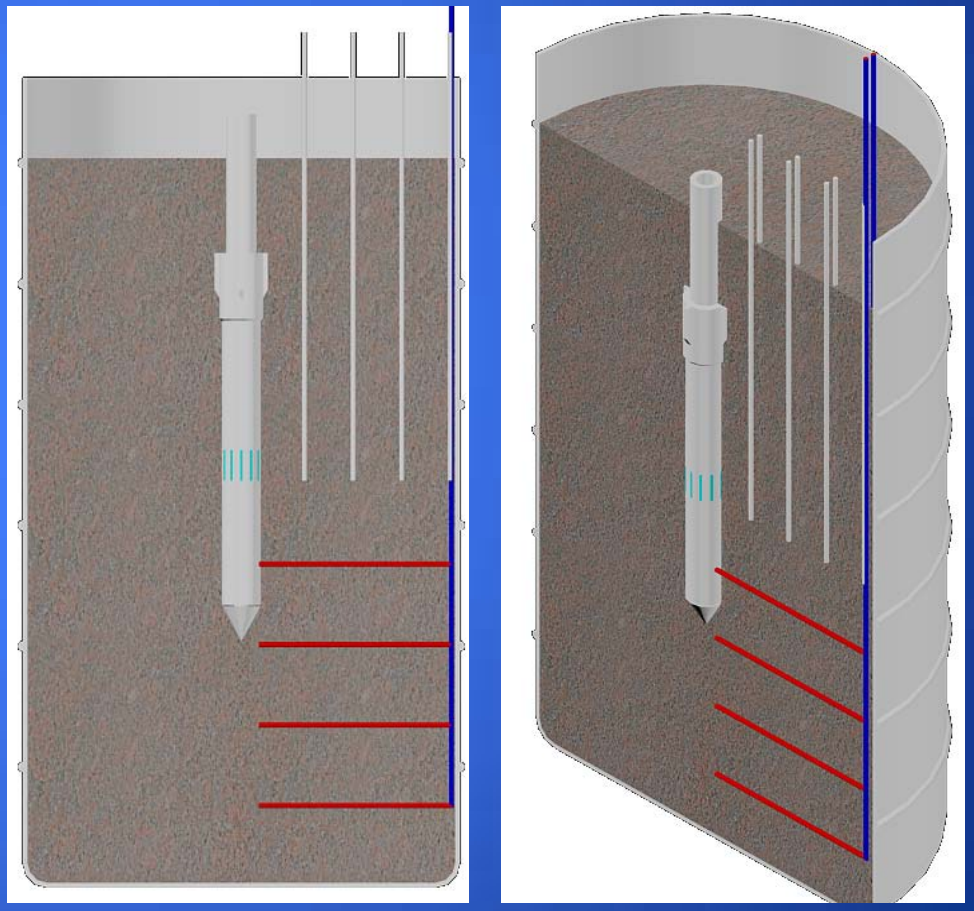
- Using voltmeters we can create soil moisture sensors
- In the presence of water, electrical resistance decreases
- In dry soil the resistance reads in Mega-Ohms
- In saturated soil the resistance reads in Kilo-Ohms

Testing in dry soil

Testing in wet soil

Mapping the Flow

- 4 sensors placed parallel to the horizontal flow port to track horizontal flow
- 4 sensors placed perpendicular to horizontal flow port to track vertical flow
- The travel of flow in both directions will be recorded vs. time



Flow mapping diagrams

Initial Sensor Trials

- Fine grained and coarse grained soil were tested for horizontal flow
- Flow in the fine grained soil traveled 7.5 in.
- Flow in the coarse grained soil did not even travel to first sensor, 2.5 in. away

Testing in fine grained soil

Testing in coarse grained soil

Upcoming Plans

- More small-scale testing
- Investigate compaction of soil effects
- More lab testing
- Investigate mapping the flow
- Continue developing shape factors
- Test in soil box at coastal lab
- Field test
- Submit final report

Questions?