In situ permeability measurement with the BAT Permeameter

Quick Manual
Outflow test

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BAT Geosystems AB (BAT) warrants all new BAT products against defects in materials and workmanship for a period of 12 months from the date of invoice. During the warranty period, we will repair or, at our option, replace at no charge a product that proves to be defective provided that it is returned, shipping cost prepaid, to BAT.

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All warranty service will be completed as soon possible. If delays are inavoidable customers will be contacted immediately.

Contents

Pre-test measures

1) Installation of BAT MKIII Filter Tip

Install a BAT MKIII Filter Tip at desired depth and location. Follow the instructions from the “Installation of the BAT MKIII Filter Tip”-guide.

2) Measurement of pore pressure

Measure the actual pore pressure. Follow the instructions given in the “BAT Pore Pressure Guide”.

Dissipation of disturbance effects

When the BAT Filter Tip is pushed into the soil, excess pore pressures will be generated due to disturbance effects. The time needed for dissipation of these disturbance effects varies with the type soil. In soft, plastic clays lays it may take several days until the original pore pressure is restored. On the contrary, in stiff clay, silt and fine sand the dissipation of the excess pressures goes much quicker. The process of dissipation of excess pore pressures can be logged by the BAT Sensor.
Make sure that the installation excess pore pressure has dissipated.before starting a permeability test. If unsure, leave the sensor connected to the BAT Filter Tip for 10 minutes. If , during this period, the he reading is stable (±0.01m H_2O) a permeability test can be performed.

3) Checking BAT Sensor

Make sure that the battery unit of the sensor contains a fresh, akaline battery. If unsure, change the battery. Normal life time of a battery when constant logging (1 minute interval) is about 3-4 weeks.

Introduction BAT Permeameter

The BAT Permeameter can measure permeabilites, k, in the range from $1*10^{-7}$m/s and lower.

An example of typical k-values for different soil types:

Fine gravel:	$1 - 1*10^{-2}$m/s
Coarse sand:	$1*10^{-1}$m/s - $1*10^{-3}$m/s
Medium sand:	$1*10^{-2}$m/s - $1*10^{-4}$m/s
Fine sand:	$1*10^{-3}$m/s - $1*10^{-5}$m/s
Coarse silt:	$1*10^{-4}$m/s - $1*10^{-6}$m/s
Medium silt:	$1*10^{-6}$m/s - $1*10^{-7}$m/s
Fine silt:	$1*10^{-7}$m/s - $1*10^{-8}$m/s
Clay:	$<1*10^{-8}$m/s

Typical time for stabilisation for different k-values, i.e. <u>time of testing</u>:

$k \approx 10^{-7}$ m/s ; $t_{stab} \approx 1$ minute
$k \approx 10^{-8}$ m/s ; $t_{stab} \approx 10$ minutes
$k \approx 10^{-9}$ m/s ; $t_{stab} \approx 1$ hour
$k \approx 10^{-10}$ m/s ; $t_{stab} \approx 10$ hours

Theory of the BAT Permeability Test

´The BAT Permeability Test is a type of ”falling head” test. The evaluation of the test is made by using Hvorslev´s equation *).

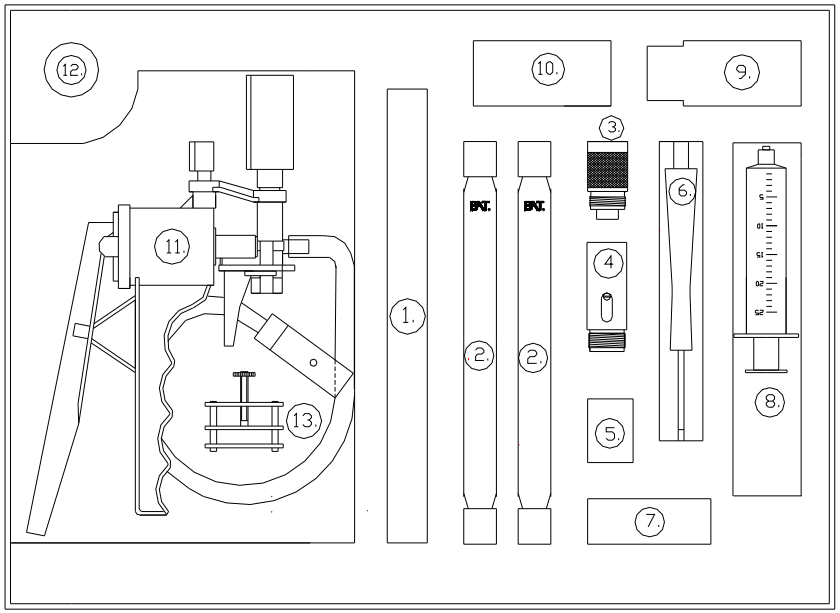
Parameters:

F	=	Hvorslev´s flow factor BAT MKIII Standard: 230 mm BAT MKIII Vadose: 194 mm	mm
k	=	coefficient of permeability	m/s
U_0	=	equilibrium pore pressure in-situ (absolute)	m H_2O
P_0	=	initial system pressure (absolute)	m H_2O
P_m	=	system pressure at time t (absolute)	m H_2O
V_0	=	initial system volume of air	ml
t	=	time for the test	s

At any time t the corresponding coefficient of permeability k can be calculated using the following equation:

$$k = P_0 \cdot V_0/(F \cdot t \cdot 10^3) \cdot \{1/U_0 \cdot P_0 - 1/U_0 \cdot P_m + 1/U_0^2 \cdot \ln[(P_0 - U_0)/P_0 \cdot P_m/(P_m - U_0]\}$$

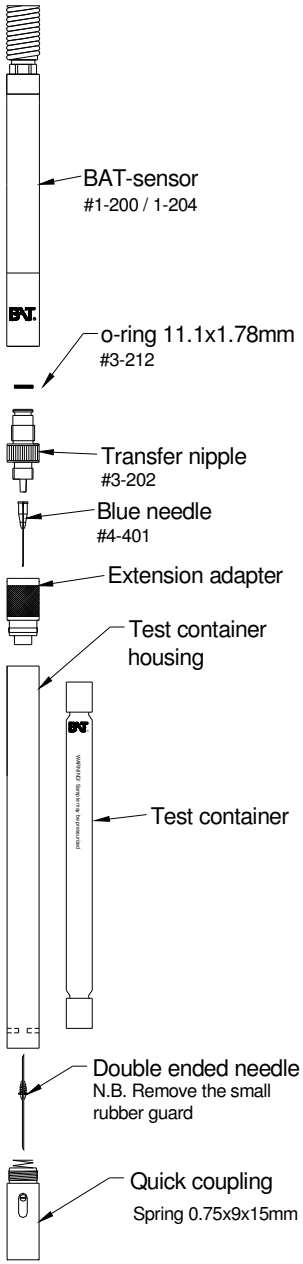
BAT Permeameter Equipment



Contents:

1. Test container housing
2. Test container (35 ml)
3. Extension adapter
4. Quick coupling sleeve
5. Spare screws and springs
6. Screwdriver for mounting of double ended needle
7. Spare septas
8. Syringes (25 ml & 10 ml)
9. Container for used needles
10. Double ended needles
11. Vacuum pump with Manometer(see APPENDIX 1 for use of the Vacuum Pump)
12. Blue needles
13. Cable Clamp

Assembly of equipment Layout



PRECAUTIONS

- Handle all parts carefully, especially the glass containers.
- Use only sharp needles. In general do not re-use needles, especially in case the set is used for sampling.
- Store the set in a dry climate.
- Do not use any tools to assemble the set. Finger tight is enough.

Assembly of equipment - Stepwise

Transfer nipple & extension adapter

- screw the transfer nipple until it seats in the sensor cavity. Firstly, make sure the parts all are dry.
- Attach a blue needle onto the transfer nipple.
- Mount the extension adapter onto the transfer nipple.

Test container

***Outflow test* - unsaturated soil conditions**

- Open the test container in one end by removing the screw cap and the septum.
- Fill the test container with a selected volume of water, using a syringe. See **PAGE 7** for more details.
- Close the test container. Finger tight is enough!

Container housing assembly and connection of IS Field Unit

- Carefully insert the test container into the container housing.
- Screw the extension adapter onto the open end of the container housing .
- Connect the IS Field Unit, choose Display Mode (see page 7).
- The pressure in the test container can now be measured with the IS Field Unit (see also APPENDIX 1).
  After assembly hold the test unit horizontal or pointing downwards.

Application of initial system pressure P_0
Outflow test

- The initial system pressure P_0 is applied by injecting or extracting a volume of air, ΔV, to/from the test container, using a syringe, equipped with a blue, hypodermic needle. The applied pressure P_0 is directly displayed by the IS Field Unit.
- For calculation of P_0 and ΔV , see APPENDIX 1.

N.B. Normally, when the test equipment is lowered down the extension pipe the temperature will drop. Accordingly the applied initial pressure will be changed. For example a temperature drop of 10°C will reduce the applied intial pressure P_0 by about 5%.

Double ended needle & Quick coupling sleeve

- Prepare the double ended needle for mounting.
  N.B. Remove the small rubber hose.
- By using the needle adapter in the handle of the screwdriver, screw the double ended needle until it seats into the quick coupling sleeve.
  IMPORTANT! Make sure that the needle seats properly in the thread.
- Finally, screw the quick coupling sleeve onto the container housing.

Unsaturated soil conditions & negative pore pressure situation

For unsaturated soil conditions the BAT Permeability test must be carried out as an outflow test. It is also assumed that a negative pore pressure situation is prevailing, i.e.: $U_0 \leq p_{atm}$. This condition is normally prevailing for *compacted clay liners*.
For outflow tests in unsaturated conditions the BAT MKIII Vadose is needed.

The outflow test starts with a partly water-filled Test container.

Initial water volume ΔV_{H2O}

Porewater pressure interval $\mathbf{8 \leq U_0 \leq p_{atm}}$
For the porewater pressure interval of $\mathbf{8 \leq U_0 \leq p_{atm}}$: $\Delta V_{H2O} = 10$ (ml)

Porewater pressure interval $\mathbf{1 \leq U_0 < 8}$
The water volume, ΔV_{H2O}, for pressure interval $\mathbf{1 \leq U_0 < 8}$ is calculated as follows:

$$\Delta V_{H2O} \approx (35 - 3{,}1 \cdot U_0) \quad \text{(ml)}$$

The volume ΔV_{H2O} is injected without using the blue needle.

Initial system pressure P_0

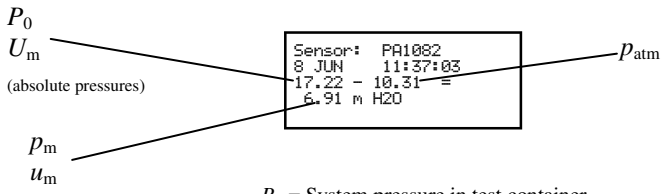
Depending on the magnitude of the equilibrium pore pressure U_0 the following initial system pressures P_0 are recommended:

Equilibrium pore pressure interval (m H_2O):	$9 < U_0 \leq p_{atm}$	$8 \leq U_0 \leq 9$	$1 \leq U_0 < 8$
Recommended initial system pressure (m H_2O):	$P_0 = 1{,}1 \bullet U_0$	$P_0 = 1{,}25 \bullet U_0$	$P_0 = p_{atm}$

All pressures are in absolute values.

With the sensor and field unit connected the system pressure P_0 is adjusted with a syringe and blue needle.

Continue to page 9!



P_0 = System pressure in test container
U_m = sensor pressure (if BAT Permemeter not connected)
U_0 = pore pressure = U_m + 0.2m H2O (pressure head compensation)

Starting the BAT Permeameter test

With the system pressure P_0 (and ΔV_{H2O} for the outflow test) set correctly the next step is as follows:

Temperature equilibrium
With knowledgde of the installation depth, use the cable clamp to fix the cable and let the BAT Permeameter rest above the filter tip before the test.
With the BAT/IS-Field Unit connected you can monitor the temperature equilibrium process. When the system pressure P_0 is stable note this value in the test sheet.

Starting the test
1) Prior to the start of the test, prepare the Field Unit by opening the "Start Measure" menu. Select both *sensor* and *temperature* logging (sensor+temp) and a suitable time interval. To start with it is recommended to use 1 min logging interval. At a later stage of the test the logging interval can be changed (increased) without any inteferece with the ongoing logging of test data.

2) Thereafter, place the marker on the OK-option at the bottom of the menu, without starting the logging.

3) The next step is to connect the test equipment to the BAT Filter Tip. Thus, remove the cable clamp and gently lower the equipment the remaining 0.2 – 0.3 m down to the Filter Tip. At the same moment the equipment connects to the Filter Tip, **press** OK on the Field Unit and the test is running. Open the "Display" menu of the Field Unit to have a visual check that the test is running, i.e the pressure shall gradually change.

4) Depending on soil type the testing time may vary from 5 minutes up to 24 hours or more. After about one hour the measuring interval of the sensor can be increased to 10 minutes or more. This is simply done by activating the "Start measure" function of the BAT/IS-Field Unit and select a new logging interval.

5) The test can normally be evaluated at a pressure equalization of 50-80% (P_{50} - P_{80}). Before finishing the test take a reading of the atmospheric pressure and fill in the value in the Test Protocol.

Finishing the test

When P_{50} (or P_{80}) is reached the test can be terminated by following the steps below:

1) Note the value of P_{end} in the test sheet.

2) Gently pull the equipment from the installation and measure the volume water inside the test container. This is the V_{end}-value in the test sheet. The volume can be measured by pouring the liquid into a syringe sealed with a rubber septa to the needle. It can also be measured more accurately at the office at a later stage.

3) Note the atmospheric pressure at the end of the test. This might be of importance if dramatic weather (pressure) changes has occurred during the test.

Now the field part of the test is completed. Please refer to the "**In situ permeability measurement with the BAT Permeameter**"-manual for evaluation of the permeability.

If running more tests before downloading the data to a PC, just remember do not clear the data between the tests. Keep notes on the starting time and starting pressures of each test and each set of test data is easily separated when processing it on a PC.

TEST SHEET - OUTFLOW TEST

Site _____ Date/Time _____

Measuring point: _____ BAT Sensor no _____

Installation depth of filter tip _____ m Test performed by _____

Type of filter tip BAT MKIII Standard _____

BAT MKIII Vadose _____

Initial atmospheric pressure _____ mH_2O time _____

Final atmospheric pressure _____ mH_2O time _____

U_0, pore pressure at equilibrium _____ mH_2O
($U_0 = U_m + 0.2\ mH_2O$)

P_0, system pressure at start of test (at temperature equilibrium) _____ mH_2O
(displayed P_m value)

P_{50}, system pressure at 50% pressure recovery (calculated) _____ mH_2O
$P_{50} = P_0 - 0.5(P_0 - U_0)$

P_{80}, system pressure at 80% pressure recovery (calculated) _____ mH_2O
$P_{80} = P_0 - 0.5(P_0 - U_0)$

Pend, final system pressure (measured) _____ mH_2O

V_V, volume liquid in system at start of test _____ ml

V_0, volume of air in system at start of test ($35-V_V$) _____ ml

V_{calc}, calculated volume liquid in system at end of test _____ ml
$V_{calc} = [P_0V_V - 35(P_0 - P_{end})]/P_{end}$

V_{end}, measured volume liquid in system at end of test _____ ml

Coefficient of permeability, k = _____ *10- _____ m/s, calculated at _____ % pressure equalisation

Notes: _____