How to: *Measure permeability using a constant head permeameter*

Introduction

The in-situ permeability of a soil can be measured using a constant head permeameter. In a constant head test, water that runs out of an unlined test hole and into the soil is replenished at the same rate from a reservoir to maintain a uniform head of water in the hole throughout the test. The constant head test is based on Darcy's Law and relies on the soil, to some depth below the base of the hole, not being saturated and exerting a capillary suction that draws water out of the test hole. The test results are only valid when the water table is at least 500 millimetres below the base of the test hole. The rate at which water is lost from the reservoir is measured and a mathematical model is used to calculate the saturated soil permeability/hydraulic conductivity (K_{sat}). A variety of constant head permeameters are available. The Australian Standard AS/NZS 1547:2012 (Standards Australia 2012) describes the use of the Talsma-Hallam constant head well permeameter to determine the permeability of a soil.

This Talsma-Hallam permeameter is suitable for use in soils with permeability in the range 0.009 to 2.9 metres/day (8.6 to 2,900 mm/day or $1x10^{-7}$ to $3x10^{-5}$ metres/second). This covers the range of soils to which treated effluent is typically applied.

Equipment

The following equipment is required to measure permeability in the field using a Talsma-Hallam permeameter:

- 75mm Jarrett head auger
- Tape measure
- Anti-scouring device to pre-fill holes
- Talsma-Hallam permeameter
- Tripod
- Jerry can full of water
- Suction flask or pump to remove excess water from test hole
- Stopwatch
- Recording sheet
- Calculation spreadsheet

Method

The test is typically conducted at a depth of 500 mm, but may be conducted at other depths depending on the soil of interest and the depth at which treated effluent may be applied.

Record the type of vegetation at the test site on the field recording sheet.

Using a 75mm Jarrett head auger, auger a cylindrical test hole to a depth of 500 mm. An auger with sharp cutting edges is preferred. Do not overfill the auger as this tends to cause compaction of the soil both within and around the auger. It is preferable to remove the soil from the hole in small amounts.

Do not use a power auger as these cause severe compaction and smearing of the test hole wall, both of which result in erroneous and inappropriately low permeability values.

First, it is necessary to confirm that the soil to be tested is not saturated. This may be done by inspecting a piece of soil from the bottom of the test hole. If the soil glistens in the sunlight it is saturated or nearly saturated. This indicates the presence of the water table or a perched water table at the depth of the test hole and testing is not possible. Alternatively, a separate hole may be augered to a depth of 500 mm below the selected depth for the test hole. If, after a period of time, water enters this hole, the water table is too high for the test to provide useful data.

The depth to any impermeable layer and to the water table should be recorded (in cm) on the field recording sheet.

Assuming that the soil conditions are such that a valid test may be undertaken, use the tape measure to carefully measure the diameter of the test hole. Calculate the radius of the test hole (radius = 0.5 x diameter) and record the average radius (r) of the test hole (in cm) on the field recording sheet.

Use the tape measure to carefully measure the depth of the test hole. Record the depth (D) of the test hole (in cm) on the field recording sheet.

In a 500 mm test hole, the test is typically conducted with a constant head of 250 mm of water. It is possible to conduct the test with alternative depths of constant head as long as the constant head is both measured accurately and maintained throughout the test.

Set and secure the tripod at the correct position on the permeameter to ensure that the selected constant head depth is achieved. This requires the bottom of the air inlet tube of the permeameter to be at the level of the selected constant head.

Record the depth of water (H) in the test hole (in cm) on the field recording sheet.

The outer reservoir of the permeameter is then filled with water from the Jerry can and, using the tripod for support, the full permeameter is rested on the ground adjacent to the test hole at an angle which prevents the water from draining out.

Often, potable water is used for the test; however, this will have different characteristics to the treated effluent which will eventually be applied to the soil. In particular the organic content, sodium content and salinity will be lower. As these components can have a marked impact on the soil structure, permeability estimates based on clean water may be misleading and significantly higher than would be achieved with treated effluent. More accurate estimates of the soil permeability with respect to treated effluent may be obtained by adjusting the composition of the water used for the test to match that of the treated effluent. This may be done by adjusting the sodium absorption ratio (SAR) of the test water. If the soil is dispersive or sodic it is particularly important to recognise the potential impact of treated effluent on the permeability of the soil.

Using the anti-scouring device, which is designed to prevent stirring up sediment in the test hole when water is poured in, prefill the test hole with water from the Jerry can to a depth a little higher than 250 mm below the top of the hole.

Slowly remove the anti-scouring device from the test hole.

Record the time at which the test hole is first filled with water on the field recording sheet.

Temporarily cover the open end of the permeameter with your hand and quickly place the open end of the permeameter in the test hole. Typically some water will run out of the permeameter and into the hole raising the level of the water in the hole. If the water level in the hole is higher than the level of the bottom of the air inlet tube, no further water will pass out of the reservoir until the water level in the test hole is lowered below the bottom of the air inlet tube. Only then will the test commence.

Excess water in the test hole can be removed by use of a pump or suction flask. The pump or suction flask tube is placed in the water in the test hole adjacent to the permeameter and water is slowly removed from the test hole until the first bubble rises through the permeameter reservoir.

Record the time at which the first measurement is made on the field recording sheet.

Recordings of the level of the water in the permeameter reservoir are made at suitable intervals. For soils of high permeability (e.g. sands) it might be necessary to record the water level every 10 seconds, whilst for soils of very low permeability (e.g. heavy clays) there might be very little movement and the recordings might only be taken every hour. It is important to note the time intervals that the level readings are taken at, in minutes or seconds as appropriate, and this should be recorded on the field recording sheet.

Ideally, readings should be taken at a fixed interval of time appropriate to the permeability of the soil. Each reading of the water level in the permeameter reservoir is in turn recorded on the field recording sheet then subtracted from the preceding one and the drop in water level calculated also recorded on the field recording sheet. Once the rate of flow of water from the permeameter reservoir stabilises to the extent that three successive readings vary by no more than 10%, infiltration is deemed to be stable and the test can be terminated. On occasions, the interval between readings is too short and bubbles rising just before or just after a reading is taken result in successive readings having alternately high and low values. In this case, stable infiltration is achieved when the sum of two successive readings approximates to the sum of the next two high and low readings on three successive occasions.

Multiple test holes

If the permeability of the soil is not too high, it is possible to run several permeameters in relatively close proximity, simultaneously. The basic test method is as outlined for individual holes, but a series of permeameters and field recording sheets is required.

Multiple tests can be undertaken as follows:

Prepare the required number of auger holes.

Set the tripods at the appropriate positions on the permeameters to maintain the same constant head of water in each hole. Place the permeameters and tripods adjacent to each hole.

Use the anti-scouring device to fill each hole to a depth of just over 250 mm.

Fill each permeameter reservoir and immediately insert it into the hole.

Successively withdraw water from each hole in turn until the first air bubble rises.

Set a stopwatch at 0:00 min and start the time. Read the water level in the first permeameter and record it. Move to the second permeameter and read the water level at 0:30 min. Move to the third permeameter and read the water level at 1:00 min. Continue to do this for each permeameter at 30 second intervals. Once one round of water level measurements has been completed, wait for the appropriate interval to elapse before commencing a second round of readings, which should be completed in the same order as the first.

Calculation of permeability

The rate of loss of water from the permeameter reservoir (Q) in cm^3/min is calculated from the data collated on the field recording sheet.

The values of Q, H (depth of water in the test hole in cm) and r (radius of the test hole in cm) are entered in the following equation from which the permeability/hydraulic conductivity of the soil (K_{sat}) is calculated using the calculation spreadsheet.

$$K_{sat} = \frac{4.4Q\left[0.5\sinh^{-1}\left(\frac{H}{2r}\right) - \sqrt{\left\{\left(\frac{r}{H}\right)^2 + 0.25\right\}} + \frac{r}{H}\right]}{2\pi H^2}$$

References

Standards Australia 2012. AS/NZS 1547:2012 On-site domestic wastewater management. SAI Global, Sydney.

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Soil Permeability Field Record Sheet

Job Number: 2?rfl	Date: !Cf.1.-.
Operator:	
Location: K nv' 'lc:"YU-A k-r: Ylv'E . l'-f.M-"1 - M hN	
Test site#: l	

Depth of auger hole (D):	JR cm
Depth of water in auger hole (H):	.}..'S° cm
Average radius of auger hole (r):	.fl,. cm
Depth to any impermeable layer:	'J D cm
Depth to water table:	., O cm

Vegetation at test site: S/4lr:- Af.r	
Time elapsed between first filling hole and start of measurement:	2- mins
Soil moisture status at time of excavation:	**(tick)**
Dry	.,/
Moist	
Wet	

Comments:
(seasonal waterlogging, soil structure, burrowing animal or root pores etc)
J/D;t';..{ l>.I,4-1_ , JD Mc A L

Permeameter water level and time readings (minutes/seconds)					
Test#			Test#		
Time	Level in tube	Drop in level	Time	Level in tube	Drop in level
Cf.W	('J-r		tf.k	(b	6..)
q.11	{ , ,;.;-	4.J...	'ts	Jrt,.	
<(.t.l	/lv	-/---r	Cf.1')		(.J
1.2-1	10/;f.U	f .1,,{"	r.11	42-	(,
f.'Ut	er	f.'u	It-r	JC.< -.	r.S
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Test#

Time	Time after start	Level in Tube	Drop of Level	Rate of Water Level Drop
(hr:min:sec)	(min)	(cm)	(cm)	(cm/min)
	0	121.0		
	1	116.8	4.3	4.3
	2	112.5	4.3	4.3
	3	104.3	8.3	8.3
	4	96.0	8.3	8.3
	5	89.S	6.5	6.5
	6	82.0	7.5	7.5
	7	77.0	5.0	5.0
	8	72.0	5.0	5.0
	9	66.5	5.5	5.5
	10	60.0	6.5	6.5
	11	54.5	5.5	5.5
	12	48.0	6.5	6.5
	13	42.0	6.0	6.0
	14	36.5	5.5	5.5
	15	31.0	5.5	5.5
	16	26.5	4.5	4.5
	17	22.0	4.5	4.5
	18	18.0	4.0	4.0
	19	13.5	4.5	4.5
			0.0	0.0
			0.0	0.0
			0.0	0.0
			0.0	0.0
			0.0	0.0
			0.0	0.0
Selected Steady Rate of Water Level Drop			(cm/min)	4.3
Rate of Loss of Water from Reservoir			(cm^3/min)	32.1

Enter data in green cells

Select Steady Rate of Water Level Drop from Rate of Water Level Drop Column (Column E) and enter in pink cell (E34). This value should be the average of three consecutive values with no more than 10% variation

Disclaimer: CET does not warrant data produced by use of this spreadsheet or any interpretation based on that data

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Parameter	Symbol	Value
Depth of Water in Test Hole (cm)	H	25
Radius of Test Hole (cm)	r	4.125
Inner Tube External Diameter (cm)	Di	0.9
Outer Tube Internal Diameter (cm)	Do	3.2
Rate of Water Level Drop (cm/min)	L	4.3
Inner Tube Cross Sectional Area (cm^2)	Ai	0.64
Outer Tube Cross Sectional Area (cm^2)	Ao	8.04
Flowrate (cm^3/min)	Q	32.07
Saturated Hydraulic Conductivity (cm/min)	Ksat	0.0199
Saturated Hydraulic Conductivity (m/day)	Ksat	0.29

Confirm data in green cells and adjust if necessary

Ksat = 0.29 m/d

REF. TABLE L1, APPENDIX L . /hf/,.1.,.-J l r 7 ; l-Or,J_

Category 4 Weakly structured clay loam Ksat 0.12-0.5 m/d

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