Falling Head Permeability Test

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User Guide
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The falling head permeability test is a common laboratory testing method used to determine the permeability of soils with a permeability of less than about 10^{-3} cm/s. The test involves flow of water through a relatively short soil sample connected to a standpipe which provides the water head and also allows measuring the volume of water passing through the sample.

This testing method can be applied to an undisturbed sample.

Equipment

- Permeameter similar to that shown in fig 1
- Perforated metal or plastic discs, circular wire screens or porous stones
- Glass standpipe with support
- Transparent flexible hoses, screw clamps etc.
- De-aired distilled water
- Watch or clock
- Thermometers, 0-50ºC x 0.1ºC
- Balance readable to 0.1g
- Oven
- Ruler

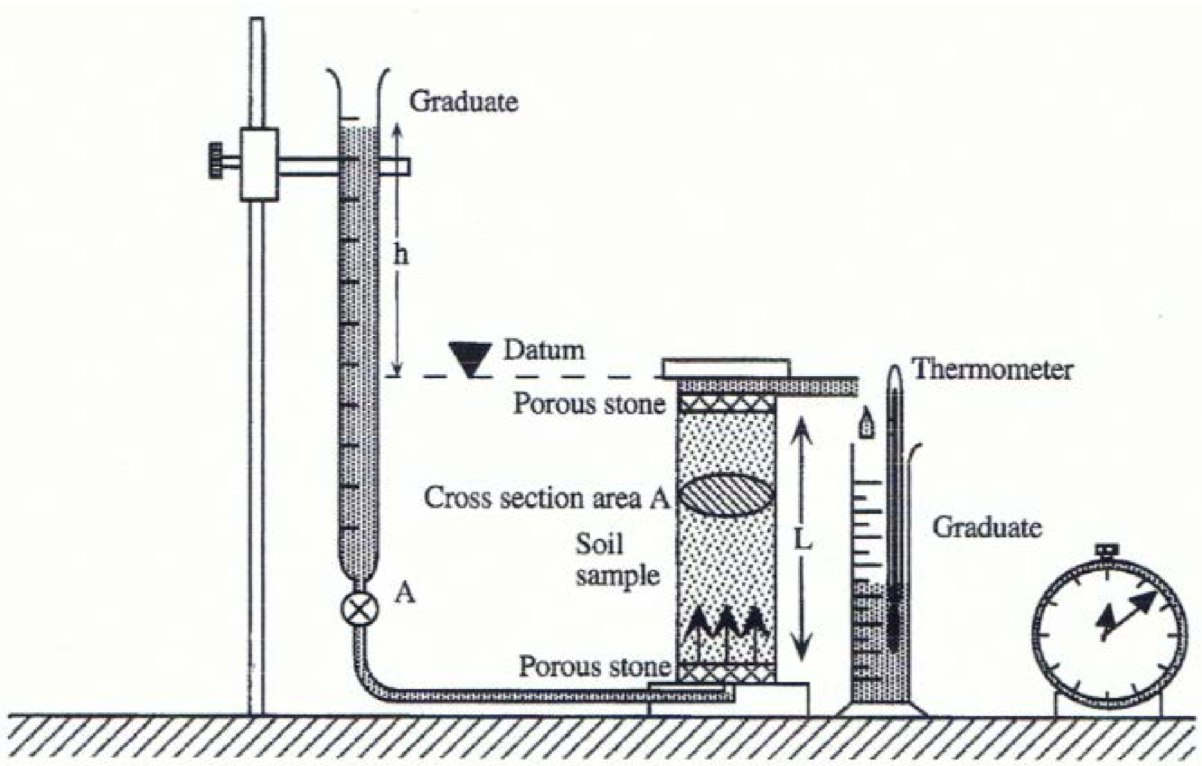

Fig 1

Procedure

1. Dry specimens are prepared as for the constant head test. Wet specimens may be trimmed and fitted into the permeameter mould.
2. Measure the specimen height, diameter and dry weight. Determine the standpipe internal diameter by measuring the volume of water contained in a standpipe section of given height.
3. Saturate the specimen by immersing it in water for several days. The specimen must be fully saturated, otherwise the test will give erroneous results.
4. Fill the standpipe with de-aired water, well above the discharge level of the permeameter cell. Should the water level fall slowly and the test lasts a few days, a few drops of oil may be added on the water surface in the standpipe to prevent water from evaporating.
5. To begin the test open the inlet valve, simultaneously starting the timer. As water flows through the specimen, measure the water elevation above the datum and the water temperature at various times t.

Permeability Test with Consolidometer

Soil permeability can also be measured during the consolidation test by using the falling head method.

Fig 2 shows the falling head permeability test during a consolidation test. The specimen in the rigid container is squeezed by a constant vertical load. The standpipe is attached to the consolidation cell and forces water through the specimen. The specimen is subjected to the falling head test after being consolidated.

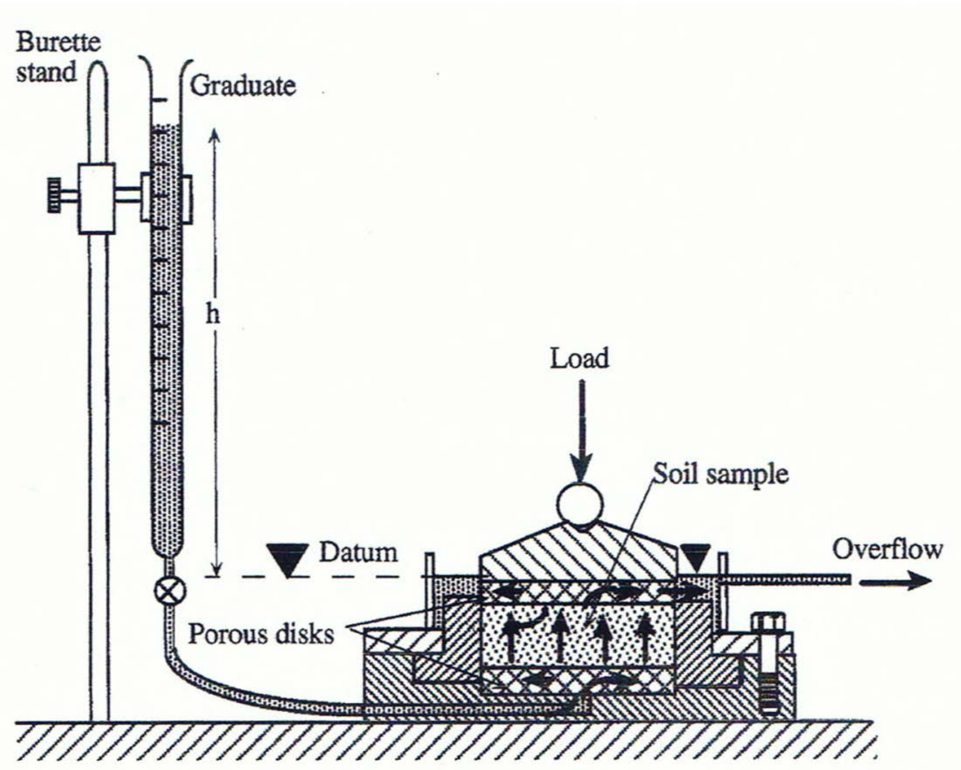

Fig 2

The permeability is calculated using Eq. 1.

For dry samples, the void ratio and dry unit weight are calculated as for the constant head test.
The coefficient of permeability k_T is calculated as follows:

$$k_T = \frac{aL}{At} \log \frac{h_o}{h_f} \qquad (1)$$

Where $a = \pi d^2/4$ is the inside area of the standpipe, $A = \pi d^2/4$ is the cross-sectional area of the specimen, L the length of the specimen, d the internal diameter of the standpipe, D the diameter of the sample, h_o the elevation of water in the standpipe above discharge level at time t. The coefficient of permeability $k_{20°C}$ is calculated as for the constant head test.
For smaller diameter standpipes, the capillary rise h_c may not be neglected compared to h_o and h_f. In this case, Eq. 1 becomes

$$k_T = \frac{aL}{At} \log \frac{h_o - h_c}{h_f - h_c} \qquad (2)$$

Example
Figure 3 shows the results of a falling head permeability test. The formulas used in Fig 3 are listed in Fig 4. Figure 5 shows the variation of k computed by using Eq 1 for different times and also shows the mean value of k calculated by using average and linear regression. The average method consists of averaging the values of k calculated at each sampling time. The linear regression method consists of fitting the variation of water height for the complete test duration. By using Eq 1 the water column height h, varies with time t as follows:

$$\ln(h_t) = \ln(h_0) - \frac{kA}{aL} t \qquad (3)$$

The value of k can therefore be computed from the slope S of the linear regression passing through the data points $(t_i, \ln(h_i)), i = 1, \ldots, n$:

$$k = -\frac{SaL}{A} = -\frac{d^2}{D^2} SL \qquad (4)$$

Where d is the diameter of the standpipe and D is the diameter of the sample. As shown in Fig 6, the average and regression methods give similar results.

	A	B	C	D	E	F	G
1	Falling Head Permeability						
2	Analyst Name: Kate Allison, Paul Murphy, Francis Chin, L.P Chua						
3	Test Date: 6/8/95						
4	Soil Sample: Sample 4, Westport sand, New Brighton sand and silica flour 100						
5			Specific gravity G_s =	2.65			
6			Specimen dry mass M =	1756.00	g		
7			Specimen height H =	12.18	cm		
8			Specimen diameter D =	10.09	cm		
9			Diameter of standpipe d_s =	0.95	cm		
10			Initial height in standpipe h_0 =	141.90	cm		
11			Initial void ratio e =	0.47			
12			Dry unit weight γ_d =	17.69	kN/m^3		
13							
14	Time (min)	Height of water in standpipe (cm)	Temperature (°C)	Permeability (cm/s)	Permeability at 20 ° C (cm/s)	Height predicted by average (cm)	Height predicted by regression (cm)
15	t	h_t	T_e	k_T	k		
16	1	134.1	16.5	1.02E-04	1.11E-04	134.47	134.66
17	2	127.3	16.5	9.77E-05	1.07E-04	127.43	127.79
18	3	120.7	16.5	9.71E-05	1.06E-04	120.76	121.27
19	4	114.3	16.5	9.73E-05	1.06E-04	114.44	115.08
20	5	108.3	16.5	9.73E-05	1.06E-04	108.44	109.21
21	6	102.8	16.5	9.67E-05	1.06E-04	102.77	103.64
22	7	97.7	16.5	9.60E-05	1.05E-04	97.39	98.35
23	8	92.7	16.5	9.58E-05	1.05E-04	92.29	93.33
24	9	88.2	16.5	9.51E-05	1.04E-04	87.46	88.57
25	10	83.7	16.5	9.50E-05	1.04E-04	82.88	84.05
26	11	79.4	16.5	9.50E-05	1.04E-04	78.54	79.76
27				Permeability calculated by average k_{Ta} =	9.68E-05	cm/s	
28				Permeability calculated by regression k_{Tr} =	9.43E-05	cm/s	
29				Permeability calculated by average $k_{20°C}$ =	1.06E-04	cm/s	

Fig 3

Example of data set for the falling head permeability test

	C	D	E
11	Initial void ratio e = =Gs/gd*9.81-1		
12	Dry unit weight γ_d = =M/H/PI()*4/D^2*9.81		kN/m^3

	D	E	F	G
14	Permeability (cm/s)	Permeability at 20 °C (cm/s)	Height predicted by average (cm)	Height predicted by regression (cm)
15	k_T	k		
16	=ds^2*H/D^2/(t*60)*LN(h0/ht)	=kT*VISCO(Te)/VISCO(20)	=h0*EXP(-kTa*D^2/ds^2/H*t*60)	=h0*EXP(-kTr*D^2/ds^2/H*t*60)
17	=ds^2*H/D^2/(t*60)*LN(h0/ht)	=kT*VISCO(Te)/VISCO(20)	=h0*EXP(-kTa*D^2/ds^2/H*t*60)	=h0*EXP(-kTr*D^2/ds^2/H*t*60)

	D	E	F
27	Permeability calculated by average k_{Ta} =	=AVERAGE(kT)	cm/s
28	Permeability calculated by regression k_{Tr} =	=-SLOPE(LN(ht),t)*ds^2/D^2*H/60	cm/s
29	Permeability calculated by average $k_{20°C}$ =	=AVERAGE(k)	cm/s

Fig 4

Formulas used for the falling head test

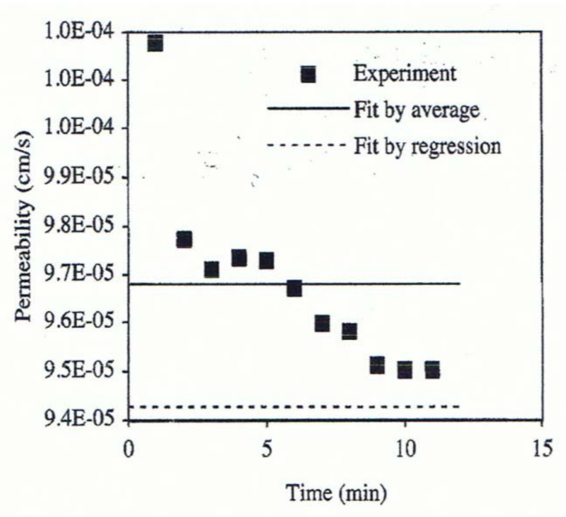

Fig 5

Permeability coefficient
computed at various time intervals, and average permeability coefficient calculated by average and linear regression.

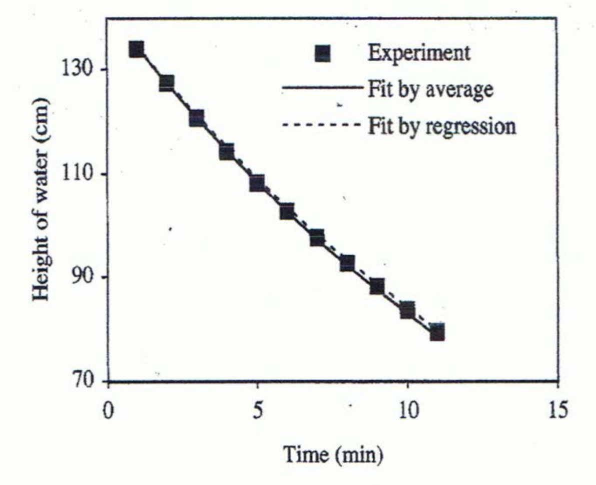

Fig 6

Variation of height of water column
versus time predicted by the average and linear regression methods.