Reduce the Required time For Measuring the Permeability of Clayey Soils by Using New Manufactured Cell

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Abstract:

The main objective of this research is modify new cell to find the coefficient of permeability of the clayey soil, it may be used with the variable head method. The permeability of soils, as expressed by the coefficient K, is of considerable importance for many practical engineering problems, such as the water retaining capacity of earth dams, the capacity of pumping installations for the lowering of the ground-water level during excavations, and also the calculation of the rate of settlement of building.

The ordinary conventional permeability test takes a long time by preparing and test especially for clayey soils, this will cause some problems especially if there is a need to do a large number of this test and there are a limited number of technicians and apparatus.

From this point of view the importance of this research is clear, since the modified cell will reduce the time needed to prepare, saturated the sample and after that take the reading with time.

The modified cell made with dimension of 2 cm height and 10 cm diameter.

الخلاصة

ان الغرض الاساسي لهذا البحث هو تطوير خلية جديدة لايجاد معامل النفاذية للترب الطينية يمكن استخدامها مع طريقة الشحنة المتغيرة.ان نفاذية التربة متمثلة بمعامل النفاذية(k) مهمة في مختلف التطبيقات العملية الهندسية مثل القابلية الاستيعابية للسدود الترابية ,قابلية السحب لخفض منسوب المياه الجوفية اثناء عمليات الحفريات وايظا في حساب نسب الهطول للمباني.

ان فحص النفاذية التقليدي الاعتيادي يحتاج الى وقت طويل متمثلا بالتهيئة واجراء الفحص وبالاخص للترب الطينية,هذا سوف يسبب مشاكل وخصوصا اذا كان هناك حاجة لاجراء عدد كبير من الفحوصات وكان هناك عدد محدد من التقنيين والاجهزة.

من هذا المنطلق كانت الحاجة لهذا البحث طالما ان الخلية المطورة سوف تقلل من الوقت الازم للتهيئة وتشبيع النموذج وبعد ذلك اخذ القرائة مع الوقت.

ان الخلية المطورة تم تصنيعها بارتفاع (2 cm) و بقطر (10 cm)

Introduction:

In soil machines Permeability is one of the important Engineering properties, as it governs rate of settlement of saturated compressible soil layer and rate of flow of equifer. Permeability is that property of soil which permits flow of water through its interconnecting voids. The instrument that measures permeability is called permeameter. The results are used for pumping groung water, for functioning sites excavations, design of dams etc. Tests can be performed on remolded or undisturbed samples using constant head or falling head method.

Numerous studies have been conducted to determine K_s in the laboratory as well as in situ. Although field techniques are generally more reliable than laboratory techniques (Klute and Dirksen, 1986), but in situations where a large number of samples need to be analyzed, laboratory techniques are more efficient.

Permeability

Flow of soil water for non-turbulent conditions has been expressed by Darcy as

$$v = k\ i \qquad (1)$$

where

i = hydraulic gradient h/L

k = coefficient of permeability (or hydraulic conductivity) as proposed by Darcy, length/time

v = discharge velocity, which is due quantity of water flowing in unit time through a unit gross cross section area of soil at right angle to the direction of flow.

Table (1) lists typical order-of-magnitude (exponent of 10) values for various soils. The quantity of flow q through a cross section of area A is

$Q = k\ i\ A$ Volume/time (2)

Table (1): Order-of-magnitude values for permeability *k*, based on description of soil and by the Unified Soil Classification System, m/s (after Bowles, 1997)

10^{0}	10^{-2}		10^{-5}	10^{-9}	10^{-11}
	Clean gravel GW, GP	Clean gravel and sand mixtures GW, GP SW, SP GM	Sand-silt mixtures SM, SL, SC	Clays	

The term "permeability" has three separate, but related, meanings:

1. In soil science, permeability is defined qualitatively as the ease with which gases, liquids, or plant roots penetrate or pass through a soil mass or layer (SSSA, 2001).
2. "Intrinsic permeability" or permeability (k) is a quantitative property of porous material and is controlled solely by pore geometry (Richards, 1952). Unlike saturated hydraulic conductivity, intrinsic permeability is independent of fluid viscosity and density. It is the soil's hydraulic conductivity after the effect of fluid viscosity and density are removed. It is calculated as hydraulic conductivity (K) multiplied by the fluid viscosity divided by fluid density and the gravitational constant. Permeability (k) has the dimension of area (e.g., cm^2). Table 2 provides a comparison between saturated hydraulic conductivity and intrinsic permeability.
3. In some cases, permeability has been used as a synonym for *Ks*, even though some other quantity was originally used to convey permeability. For example, in the permeability studies by Uhland and O'Neal (1951), flux (under hydraulic gradient greater than one) was the true quantity measured to convey a soil's permeability. Darcy's law demonstrates that flux is numerically equal to *Ks* only when the hydraulic gradient is equal to one. Therefore, the flux values reported in these studies were not synonymous with *Ks*. Over time, however, the original flux values from Uhland and O'Neal became misrepresented as *Ks* without qualification. This misrepresentation has led to confusion and misapplication. (SSSAJ , 2005)

The different meanings for permeability are not scientifically interchangeable. Indeed, the explicit meaning of the term "permeability" may not be discernable from written or verbal context alone. The first of the three meanings carries no quantitative implications, whereas the second and third have specific, quantitative applications. Confusion often arises because the meanings are overlapping. Present scientific convention avoids use of the third meaning entirely and is an important reason for using saturated hydraulic conductivity (*Ks*).

Table 2.—A Comparison of Saturated Hydraulic Conductivity and Intrinsic Permeability (Skopp, 1994).

Saturated Hydraulic Conductivity (*Ks*)	Intrinsic Permeability (*k*)
Temperature Dependent	Temperature independent
Fluid viscosity dependent	Constant regardless of fluid viscosity, unless the liquid itself changes soil structure
Changes with change in structure	Changes with change in structure
Dimensions depend on flux and gradient; time is a component.	Dimensions are length^2 (cm^2), which is a unit of area; time is not a component.

Permeameters:

Usually there are two tests commonly used in the laboratory to determine *k* is the *constant-head* and *falling-head* methods. Figure (1) gives the schematic diagrams and the equations used for computing *k*. The falling-head test is usually used for *k* < 10~5 m/s (cohesive soils), and the constant-head test is usually used for cohesion-less soils. It is often necessary to determine the field value of *k* since it is usually larger than the laboratory-determined value, often by a factor of 2. An accurate6 determination of the field *k* is beyond the scope of this textbook but some procedures and equipment is described by Leroueil et al. (1988). (After Bowles, 1997)

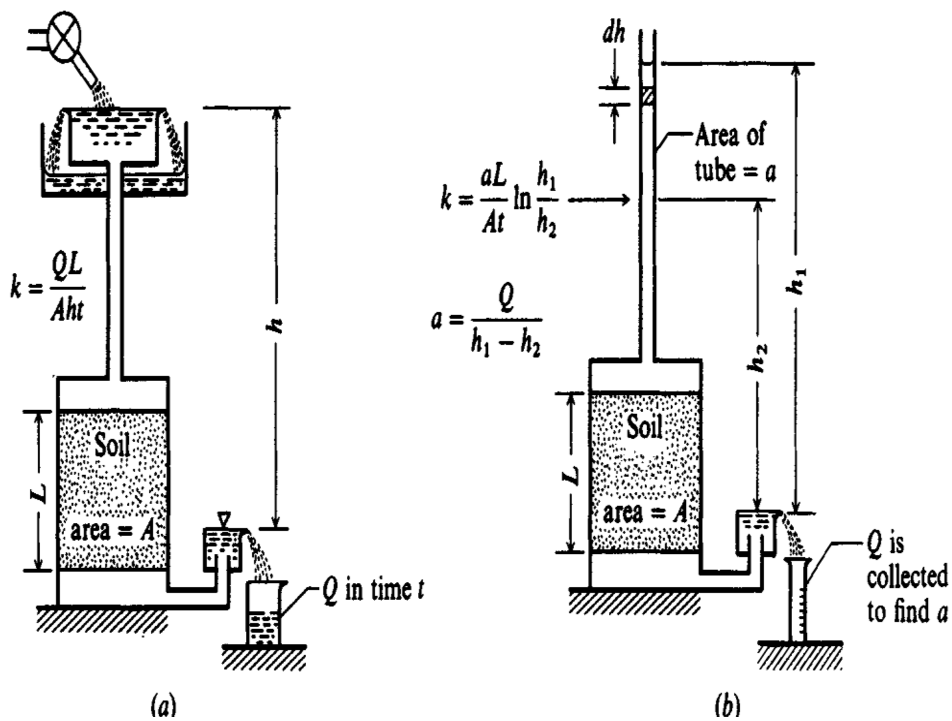

Figure 1 Schematic for permeability determination, *(a)* Constant-head permeameter; *(b)* falling-head permeameter;*t* = time for head to change from *h* to *hj*. (after Bowles, 1997)

Typically, permeability tests are conducted on soil samples to evaluate the coefficient of permeability. As much as possible, the soil samples are compacted to same density in the field

Ordinary method

When the soil With clayey soils Falling-head permeability test using the standard compaction-mold permeameter as shown in figure 2 where both a disassembled device and a test setup using a 100-ml burette. Note the very thick porous stone in the base and the small opening in the cap assembly which may erode a depression into the sample with a large hydraulic gradient. Great care is required in assembly to avoid leaks. Use a meter stick to measure the hydraulic heads, h_1 and h_2. and the coefficient of permeability could be fined by appling eguation no. 3 With small hydraulic gradients exercise care that sample does not drain.

$$k = \frac{a\,L}{A\,t} \ln \frac{h_1}{h_2} \tag{3}$$

where:

k = coefficient of permeability (or hydraulic conductivity) as proposed by Darcy, length/time

a=cross-section area of burette or standpipe,cm^2

A=cross section area of soil sample,cm^2

h_1= hydraulic head across sample at beginning of test (t=0)

h_2= hydraulic head across sample at end of test ($t=t_{test}$)

t= elapsed time of test , s

ln=logarithm to base 2.7182818

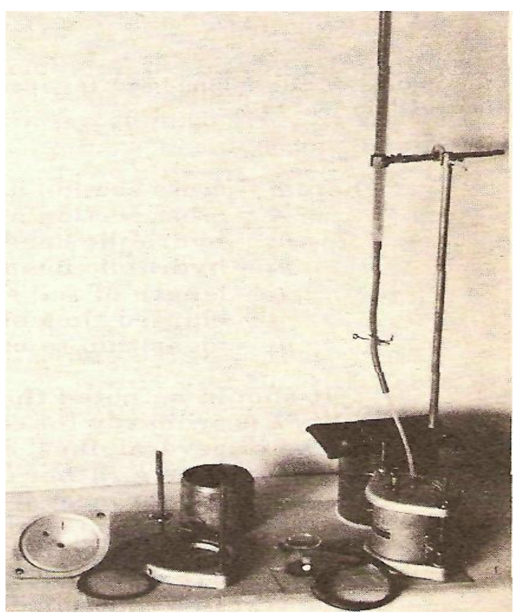

Figure 2-Falling-head permeability test using the standard compaction-mold permeameter.**(after Bowles,1982)**

The experimental work:

The experiments were carried out on soil specimens of 15 samples of Iraq soil taken from Al-Baladiat in Baghdad.

The experimental program goes in three series as below:

Series A:

Permeability test were carried out on samples by variable head method with ordinary cell which its height is 11.6 cm and diameter of 10 cm. as shown in figure (3)

Fig (3) – Ordinary cell of 11.6 cm used with Series A

Series B:

Permeability test were carried out same soil samples by variable head method but with modified cell (the cover of the compaction mould) which its height is 5.1 cm and diameter of 10 cm. as shown in figure (4)

Fig (4) – Compaction cover used as cell of 5.1 cm used with Series B

Series C:

Permeability test were carried out same soil samples by variable head method but with modified cell which its height is 2 cm and diameter of 10 cm. as shown in figure (5)

Fig (5) – Modified cell of 2 cm used with Series C

The experimental program made by making three cells for each sample with same density, the water content for each sample measured also at the time of preparing the cells (11.6, 5.1 and 2 cm) for each sample and makes it constant by covering the cells and keeps these cells in the insulator chamber till the time of testing which not be more than three days.

Each falling head device was placed over a sample that had been saturated with tap water at room temperature 24 h before measurement. Samples were filled with water and rubber stoppers were inserted into the falling head device until they were measured. These procedures were repeated for each cell and for each sample. Which mean 45 cells is tested by falling head device with different height. Figure (6) show the setup of the three cells used in this paper.

Modified cell description

The modified proposed cell is cylinder made from stainless steel with height of 2 cm and diameter of 10 cm as shown in figure (5)

1-The ordinary setup

2- The modified setup by using the mold cover

3-The modified proposed cell setup

Fig. (6) – Setup of the cells used in experimental program

Samples properties

The general soil properties such as soil texture, density, water content and specific gravity of the soils samples are given in Table (3).

Table 3 - The properties and the description of the samples.

Sample no.	Unit Weight kn/m^3	Specific Gravity	Water Content %	Soil Description
1	18	2.8	25.12	brown to gray stiff clay
2	18	2.73	29.64	brown clayey sandy silt soft to medium
3	19	2.78	22.71	brown silty clay stiff to medium
4	19	2.79	30.13	gray to brown silty clay to clayey silt medium to stiff
5	19	2.76	30.62	dark brown silty clay medium
6	19	2.76	25.76	brown silty clay with high salts
7	19	2.78	34.42	black to gray to brown silty clay to clayey silt medium with high salt
8	20	2.8	23.57	brown silty clay very stiff with salts
9	20	2.78	27.81	brown silty clay stiff to medium
10	20	2.8	24.23	brown clay stiff
11	20	2.79	25.64	brown silty clay stiff
12	21	2.77	23.89	brown silty clay stiff
13	21	2.8	25.49	brown clay stiff to soft
14	21	2.77	28.96	brown silty clay to clayey silt medium to soft
15	21	2.77	20.28	brown silty clay very stiff with high salts

Results and Discussion:

By fallowing the experimental program the following results data shown in table (4) for all the samples:

Table 4: - The results of the permeability for the samples.

Permeability (cm/sec) / Sample no.	Sample Height (cm)		
	11.6	**5.1**	**2**
1	6.57E-08	7.00E-08	7.07E-08
2	1.60E-07	1.86E-07	1.75E-07
3	8.67E-08	8.89E-08	8.63E-08
4	8.43E-08	8.53E-08	8.04E-08
5	5.50E-08	5.73E-08	5.91E-08
6	7.27E-08	7.55E-08	7.64E-08
7	8.07E-07	6.63E-07	6.81E-07
8	6.90E-08	6.51E-08	6.33E-08
9	4.40E-07	4.32E-07	4.19E-07
10	5.80E-08	6.98E-08	7.12E-08
11	5.30E-08	4.58E-08	4.53E-08
12	7.21E-08	7.38E-08	7.14E-08
13	6.80E-08	7.30E-08	7.10E-08
14	6.12E-08	5.65E-08	5.56E-08
15	6.00E-08	4.61E-08	4.57E-08

Analysis of results:

The results obtained from experimental work which illustrated in table (4), is analysis by figures no. 7 and figure no. 8 as below:

figure (7) show the relation between the coefficient of permeability which obtained by the cell its height 5.1 cm which represent the cover of the compaction mold and the coefficient of permeability which obtained by ordinary cell which its height 11.6 cm.

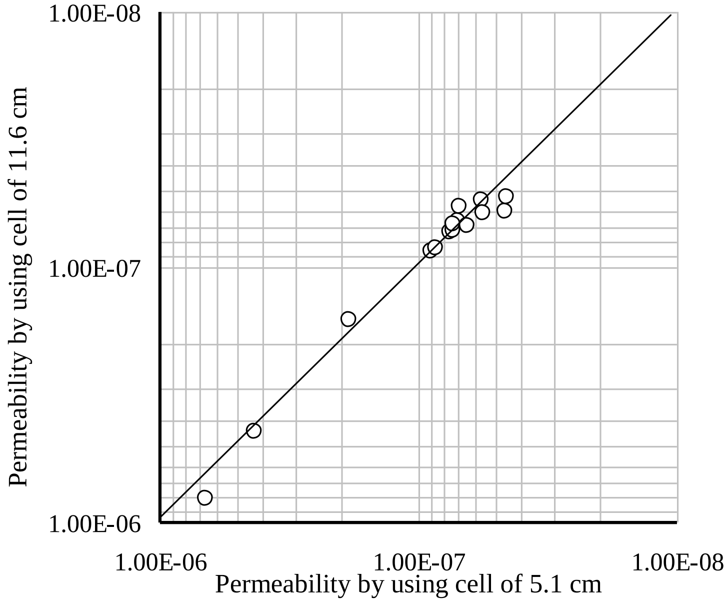

Fig (7) – relation between permeability found by cell of 5.1 cm and by using ordinary cell of 11.6 cm

As shown in figure (7) and by analyzing the coefficients of permeability which found by the cells their height 5.1 cm and the other cells which their height 11.6 cm; from that found the correlation factor equal to (0.99382) and with root square equal to (0.98770).

The obtained results were studied to find the compatibility of the coefficient of permeability which was found by modified cell and that found by the ordinary cell which was used in (falling head device) as shown below in figure (8):

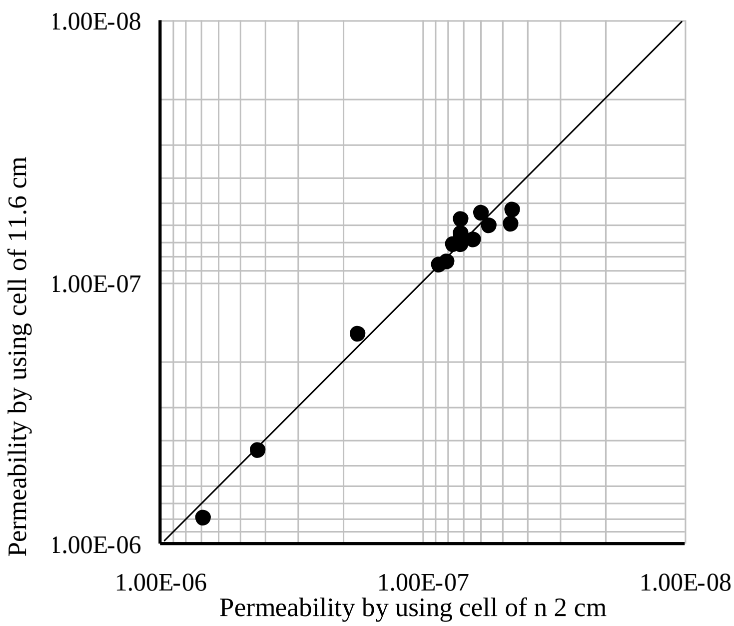

Fig (8) – relation between permeability found by modified cell of 2 cm and by using ordinary cell of 11.6 cm

From figure (8) and By Analyzing the results it found the coefficients of permeability which is found by the modified cells which their height 2 cm give a very good compatibility with that found by the other ordinary cells which their height 11.6 cm; with correlation factor equal to (0.99382) and with root square equal to (0.99370).

Conclusion:

The following conclusions can be drawn from the results of this research:

- It is found that the modified cell which it is height 2 cm and its diameter equal to 10 cm gives very accurate results to find the coefficient of permeability of soils.
- By The proposed cell the test was very fast and gives a very good results comparing with ordinary cell to found the permeability especially with clayey soils.
- The results which were found by the modified cell give a good compatibility with that found by the ordinary cell where the root square was (0.9583) and correlation factor equal to (0.9988)
- By The modified falling head permeameter cell, laboratory K measurements can be measured rapidly and efficiently
- The modified cell very easy to operate and one can measure a larger number of samples using this cell.

Recommendation:

i. Studying the effect of using this modified cell with gypsum soils.
ii. Studying the suitability of reducing the diameter of the cell.

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Samples used:

a=cross-section area of burette or standpipe,cm^2
A=cross section area of soil sample,cm^2
h_1= hydraulic head across sample at beginning of test (t=0)
h_2= hydraulic head across sample at end of test ($t=t_{test}$)
i = hydraulic gradient *h/L*
k = coefficient of permeability (or hydraulic conductivity) as proposed by Darcy, length/time
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q =The quantity of flow a cross section of area *A* .
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