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Comparing Hydraulic conductivity through both inverted Auger Hole and constant head methods

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Abstract
Hydraulic conductivity is a criterion for measuring soil ability to transfer water and also is a term for describing ground water units that depends on soil's properties such as soil type (for example sandy or clay), size, shape and compression. The purpose of this paper is hydraulic conductivity comparison through both inverted auger hole and constant head methods in two zones that has been done in water engineering group's area of agriculture faculty of Urmia University in Aug 2007. Considering this point that under studying soil up to 30 cm has made of one layer and soil's texture is clay loam. Therefore two auger holes have been excavated in two zones by the radius of about 5 cm and depth of 30 cm. First in each hole the inverted auger hole experiment has been done in the zone and after sampling constant head method has been done in the laboratory. The average of hydraulic conductivity which achieved from inverted auger hole method was 0.444 m/day and for constant head method was 0.563 m/day that showed the soil has low infiltration. The comparison of outcomes from both methods indicated that constant head method evaluates hydraulic conductivity 21% more than auger hole method. This variance shows proves that in constant head method soil sample was touched and also because of smallness of the sample it can not introduce natural condition of area's soil but auger hole method is much precise because it is being done in the area.

Keywords: Hydraulic Conductivity, Inverted Auger Hole Method.

INTRODUCTION

Hydraulic conductivity is a term to explain hydrologic units. This is a way to evaluate or explain soil's infiltration ability. Hydraulic conductivity also is a criterion to measure soil ability to transmit water.

Considering electricity points, it can be said that the more conductivity of a thing, the easier electricity flow through it (metal is high conductive while wood and plastic are not conductive). About water, conductivity is the ability of passing water through soil. Therefore hydraulic conductivity is amount of the quality of water passing from a geologic material.

Historically, this phrase was introduced by a French engineer called Henry Darcy in 1856 that in every drainage project, determining hydraulic conductivity parameter has the most significant importance.

Hydraulic conductivity or infiltration depends on soil's properties and specifications such as kind (clay, sand), size, shape and condensing. The general criterion for under ground water flow is Darcy theorem. Hydraulic conductivity has relation with other specification of soil such as amount of water and in non saturated form, its amount quickly reduces by water reduction and descends to zero in dry soil. Hydraulic conductivity depends on special weight of water (ρg), viscosity (μ), diameter of soil particles (d), soil porosity and amount of water. Hydraulic conductivity in non saturated soil is called capillary conductivity whose equation is as bellow:

$$K_s = KI.\frac{\rho g}{\mu} \quad (1)$$

In which Ks is hydraulic conductivity of saturating soil and KI is soil intrinsic permeability or natural conductivity.

$$KI = N.d^2 \quad (2)$$

Soil intrinsic permeability does not consider any factor but soil porosity or pores diameter and examining with any kind of liquid, the same result will gain. Soil intrinsic permeability dimension is length 2nd square (L^2).

Hydraulic conductivity is constant only when soil structure remains constant. In alkaline soils water leaching causes Hydraulic conductivity reduction.

In Darcy Law, hydraulic conductivity is being seen as proportional factor but it doesn't mean that its amount is constant or it should be.

Because of physical, chemical and biological processes, continues changes are occurring during water flow in soil. Any change in quality or quantity of soil's ions is in company with changing in soil hydraulic conductivity, and for this, it is needed to prepare solutions with different compositions and pass them from soil. If we use the kind of soil whose salts density is almost high for irrigation in this case hydraulic conductivity increases. Existence sodium in irrigation water causes soil swelling and spreading particles, thus, it is affects hydraulic conductivity reduction.

Hydraulic conductivity can be introduced as interaction of length and time. For instance, hydraulic conductivity may be shown a number in foot per day. Or this number can be meter per second. Many different numbers of these digits can be used. But all of them are related to an equal value of hydraulic conductivity. In a general mode, the number can be used for presenting speed of water movement from a material.

Two other factors can affect hydraulic conductivity too. Viscosities and density.

Methods of determining soil hydraulic conductivity:

These methods are generally divided into two methods: Laboratory and field methods. Laboratory methods are rarely compatible with field methods. As a general fact, field methods are more reliable than laboratory methods. Because they are much nearer to natural condition (Scott 2000). In all drainage projects, the hydraulic conductivity should be determined under water table but may be in some cases hydraulic conductivity is investigated in upper water table or under water table in a high depth. In another hand, some of these methods are laboratory and are proper for research while for drainage cases, field methods should be used.

The purpose of starting this research is to investigate soil permeability of two regarded areas and comparing the results of two methods, Inverted auger whole method and constant head method. Therefore we can say that the purpose of presenting this paper is the comparison of hydraulic conductivity through both inverted auger hole and constant head methods in two areas.

Necessary materials and tools:

The method which is being used to determine hydraulic conductivity in this paper is inverted auger whole method and its comparison with constant head method. In inverted auger hole method it is needed to dig a hole which is done by auger (Fig.1) the depth of water level is being measured by a device presented in fig 2. The scheme by which determining hydraulic conductivity through constant head method has done, is also shown in (Fig.3)

Fig.1. measurement device

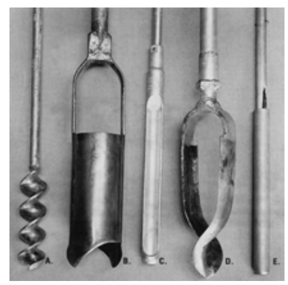

Fig.2. auger

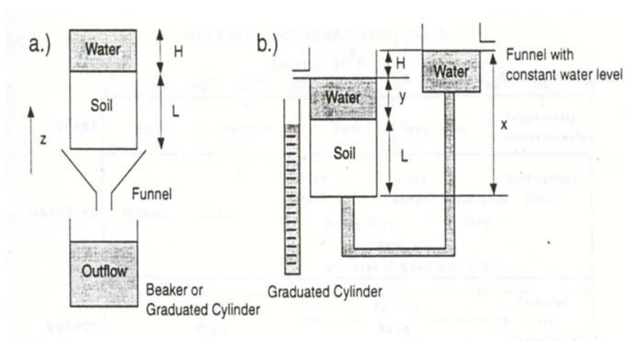

Fig.3. Schematic of constant head method

Experiment Method:

The experiment of determining hydraulic conductivity was done in two areas of the Agriculture faculty of Urmia University (Nazloo) on Aug 2007on East longitude $44^\circ\ 58'\ 30''$ and North latitude $37^\circ\ 39'\ 30''$.

Because of the very low level of water in the mentioned area, inverted auger hole method was chosen to determine hydraulic conductivity in upper water table. Also, according to the percent of existing clay, silt and sand, the soil's texture was clay loam and involves one layer up to 30 cm depth. To perform this experiment in two areas through inverted auger hole method, a hole with 10cm diameter and 30cm depth was digged in a flat surface by auger. While digging the hole, this point was considered that inner wall of the hole was not compacted or destroyed, also it was digged completely vertical in order to not make any disturbance for water infiltration into soil.

Then we will pour the hole with water and wait a few minutes till water penetrates into the soil and the soil becomes saturated. At the beginning, the amount of water level reduction is quick because the soil is dry but by increasing soil moisture penetration and water level reduction will descend. Now we will put measuring device on the hole and record the number on the measuring device in different times. At the start point of the experiment time interval is counted lower because water level reduction is high inside the whole but by decreasing the reduction in the hole, the time interval increases.

The experiment continued till the water level reduction inside the hole comes to zero (the level of water in the hole did not change any more). By same method the experiment was done in the other area and outcomes were recorded.

A sample of the soil of that area, then, brought to laboratory to determine its hydraulic conductivity by constant head method.

In this method the principle is in a way that water current in soil is from the bottom to top in order to gradual solve the existent air in water for not making bubbles in the sample soil. Additionally, touching and disordering the surface of the soil which can be made by water current turbulent, should be prevent. After putting the soil sample in a cylinder, a constant water head was created on the sample then output discharge of the soil was attained in volume. Thus, hydraulic conductivity was determined by Darcy equation in which:

$$Q = k.\frac{H}{L}.A \qquad (3)$$

Q = passing discharge from soil (cm^3/sec)

H = water head between two constant water level at top and bottom of the sample (cm)

L = Length of soil sample (cm)

A = cross section of soil sample (cm^2)

K = hydraulic conductivity of soil (cm/sec)

Experiment steps are photographically shown in Fig.4.

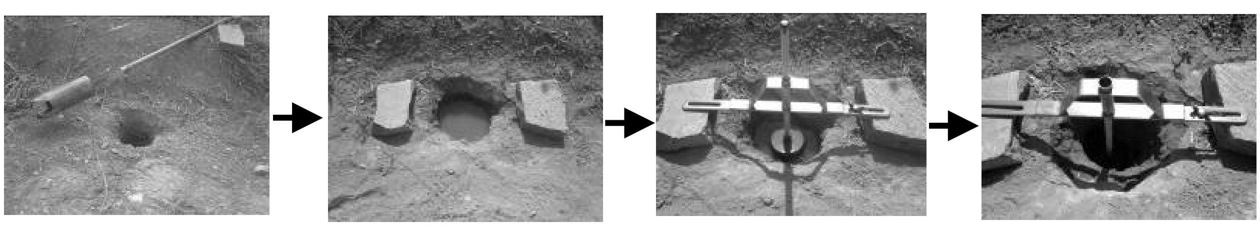

Fig .4. Steps of Experiment

Result and discussion:

Data of three experiments were set in tables 1 and 2 after collecting.

Table1. Data related to hole No.1.

t_i (sec)	h_i (cm)	h_i +r/2 (cm)
0	25	28
30	24.6	27.6
60	24.3	27.3
120	23.3	26.3
240	22	25
360	20.9	23.9
480	19.9	22.9
600	18.9	21.9
720	18.1	21.1
840	17.4	20.4
960	16.8	19.8
1080	16.1	19.1
1200	15.6	18.6
1320	15.1	18.1
1440	14.7	17.7
1560	14.35	17.35
1680	13.9	16.9
1800	13.45	16.45
1920	13.05	16.05
2040	12.7	15.7
2160	12.4	15.4
2280	12.1	15.1
2400	11.8	14.8
2760	11	14
3000	10.5	13.5
3300	10.05	13.05
3600	9.5	12.5
3900	9	12

Table 2. Data related to hole No.2.

t_i (sec)	h_i (cm)	h_i +r/2 (cm)
0	27	29.5
30	26.5	29
70	25.8	28.3
120	25	27.5
240	23.7	26.2
360	22.55	25.05
480	21.6	24.1
600	20.8	23.3
720	20.05	22.55
840	19.25	21.75
1000	18.5	21
1080	18.05	20.55
1200	17.55	20.05
1365	16.9	19.4
1440	16.65	19.15
1560	16.3	18.8
1740	15.85	18.35
1860	15.5	18
2100	15	17.5
2400	14	16.5

In which:

r = Hole radius (cm)

$hi =$ Depth of water level inside the hole (cm)

$t_i =$ Time (sec)

Hydraulic conductivity by inverted auger hole method was get through Equation 4:

$$K = \frac{1.15r[\log(h_o + \frac{r}{2}) - \log(h_n + \frac{r}{2})]}{t_n - t_o} \quad (4)$$

In which:

K = hydraulic conductivity (cm/sec)

r = hole radius (cm)

h_n = Depth of water level inside the hole (cm)

t_n = End time (sec)

t_o = Start time (sec)

That is also shown in (Fig.5)

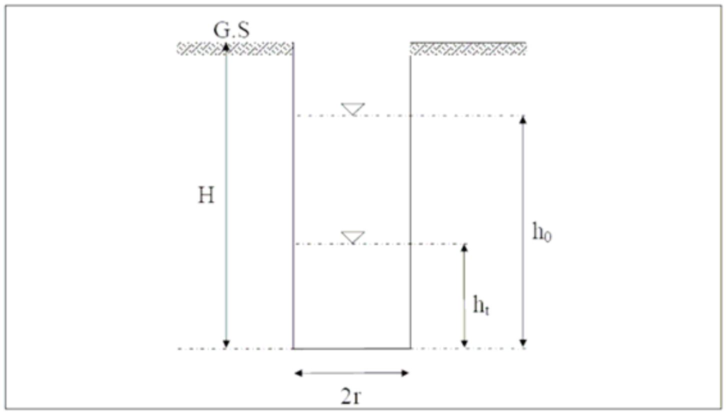

Fig. 5. inverted auger hole method

If we draw $h_t + \frac{r}{2}$ on vertical logarithm axis and t on horizontal axis on a semi logarithm graph then gained line gradient will be $\tan\alpha$. (Fig. 6 & 7) in this case the above equation can be written as follow:

$$K = 1.15 r \tan\alpha \qquad (5)$$

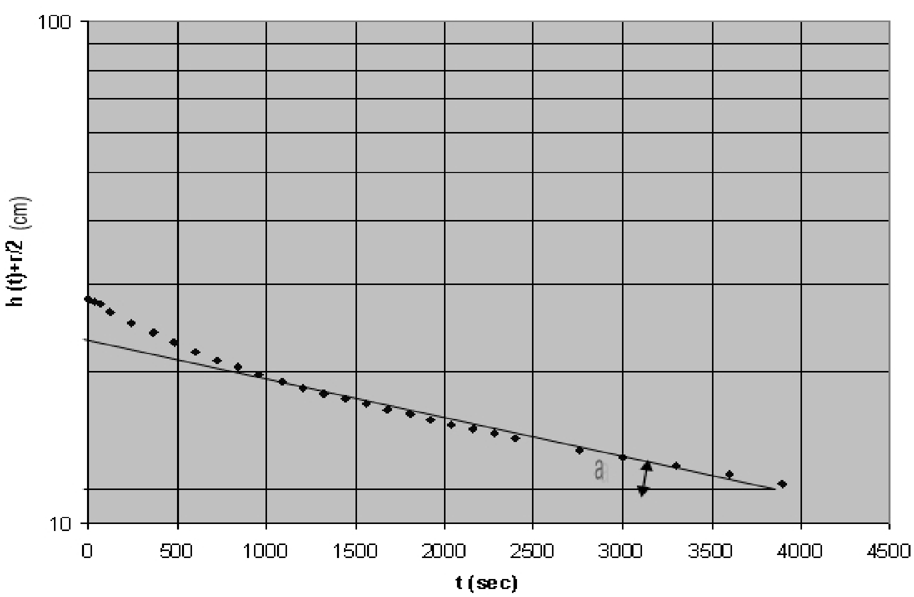

Fig .6. semi logarithm graph for hole No.1

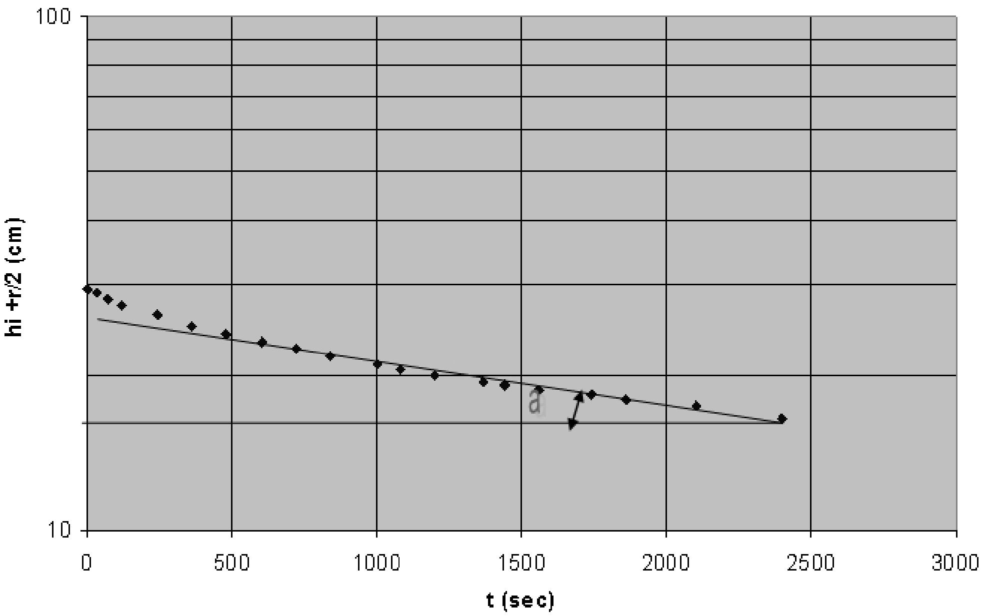

Fig.7. semi logarithm graph for hole No.2

As it was seen, few initial points were not rest on the curve line gradient therefore, we would omit these very beginning points because the soil was not saturated at the beginning of the experiment.

According to Fig.6, almost 9 data were not rest on the best gradient line. So these data were not involved in counting hydraulic conductivity. By same order, according to fig.7, five points were omitted in counting hydraulic conductivity too.

$$K_1 = \frac{1.15_r \left[\log(h_o + \frac{r}{2}) - \log(h_n + \frac{r}{2}) \right]}{t_n - t_o}$$

hole No.1 radius is 6cm.

$$K_1 = \frac{1.15 \times 6 \times (\log 20.4 - \log 12)}{3900 - 840} = 0.0005196 cm/\sec = 0.0187 m/h = 0.448 m/day$$

Also for hole No.2:

Hole No.2 radius is 5cm.

$$K_2 = \frac{1.15 r [\log(h_0 + \frac{r}{2}) - \log(h_n + \frac{r}{2})]}{t_n - t_0}$$

$$K_2 = \frac{1.15 \times 5 \times (\log 25.05 - \log 16.5)}{2400 - 360} = 0.000511 cm/\sec = 0.0183 m/h = 0.441 m/day$$

Hydraulic conductivity means by inverted auger hole (K_1 and K_2) got 0.444m/day. For calculating hydraulic conductivity by constant head method, equation 3 was used and table 3 was arranged:

Table 3. analysis of the constant head method

Volume(cc)	Cumulative time(sec)
100	508
200	1068
300	1592
400	2173
500	2810

$\Delta h = 47 - 12.5 = 34.5cm$

$D = 9.6cm \longrightarrow A = \pi r^2 = 72.38cm^2$

$L = 9cm$

$\forall = 100cm^3 \quad t = 508s \quad Q = 0.197cm^3/s$

$\forall = 100cm^3 \quad t = 560s \quad Q = 0.179cm^3/s$

$\forall = 100cm^3 \quad t = 524s \quad Q = 0.191cm^3/s$

$\forall = 100cm^3 \quad t = 581s \quad Q = 0.172cm^3/s$

$\forall = 100cm^3 \quad t = 637s \quad Q = 0.157cm^3/s$

$$Q = k\frac{\Delta h}{L}A \Rightarrow k = 0.000652cm/s = 0.563m/day$$

By comparing and analyzing hydraulic conductivity output amount from two methods, it is seen that constant head method presents hydraulic conductivity 21% higher than inverted auger hole method. Also medium amount of hydraulic conductivity proves average permeability of area's soil (Burea of Reclamation, 1977). From other sources same level of clay loam soil of the area is shown (EPA. 1986).

The differences of two methods is because of that in constant head method the soil sample was touched and also small size of the sample can not present natural mode of the area's soil, But inverted auger hole method can give much exact results because it was done in the field. In constant head method water current is from bottom to top but in inverted auger hole method water penetration is vertical and horizontal. Constant head method is usually used for the soils with light texture. Sufficient water gradient in this method is small and about 1 to 2 cm. The water is rather been distilled but in order to prevent bacteria growth, solution water with 0.1% phenol can be used too. Inverted auger hole method also has its own disadvantages and limitations. While using this method to determine hydraulic conductivity, the experiment must repeat for several times to make the soil saturated and reject the faults.

Reference:

-C.Waring, Y.Stepanyants, S.Hankin, C.Smith, P.Airey. (2007)Measurement of Hydraulic Conductivity Porosity and Lithology by Neutron Activation Borehole Logging at high spatial resolution increments

-Cristion Kremer F.Bea 558 UI .Some Field method to Measured Saturated Hydraulic Conductivity (K_{sat})

-Dr .pengfei Zhang .Darcy's Low and Hydraulic Conductivity

-Josh Linard (2007). Methods Used to Determine Hydraulic Conductivity

-Manoucher Heydarpour, Jahanshir Mohammadzadeh 2003.Copparing hydraulic conductivity from inverted auger hole method by pumping into hole method.National conference of irrigation and drainage systems management. May.2003

-Mohammad Hosein Rahimian, 1993, Evaluation and adjustment of auger hole and inverted auger hole methods in comparison with Guelph in measuring soil hydraulic conductivity.