The Comparison of Hydraulic Conductivity Coefficient of Guelph Permameter and Inverted Auger Hole Method in Heavy Soil of Khuzestan Region

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Abstract: One of the important features of soil physics is hydraulic conductivity of soil saturation with wide applications in soil and water science. The accuracy of two methods of inverted auger method as the most common method and Guelph permameter as a new, cheap methods evaluated in determination of hydraulic conductivity at above groundwater level. To do this, a part of Khuzestan region field with silt clay with area of 500 m2is selected. At 30 sites, some auger holes were augured to determine hydraulic conductivity of two methods. The comparison of the results of two above methods showed that inverted auger hole averagely estimated hydraulic conductivity coefficient 20.9 times more than Guelph permameter method. In addition, the best relationship between hydraulic conductivity coefficient of two methods was a linear equation with correlation coefficient 0.51.
[Sorkheh Nezhad M, Dehghan M, Naseri A.A. **The Comparison of Hydraulic Conductivity Coefficient of Guelph Permameter and Inverted Auger Hole Method in Heavy Soil of Khuzestan Region.** *Researcher* 2017;9(5):58-61]. ISSN 1553-9865 (print); ISSN 2163-8950 (online). http://www.sciencepub.net/researcher. 9. doi:10.7537/marsrsj090517.09.

Keywords: Hydraulic conductivity, Inverted auger, Guelph permameter

1. Introduction

Measurement and determination of hydraulic conductivity in drainage plans, hydrological studies, underground water, the movement of contaminated water in soil, leaching designs are unavoidable phenomena. To measure hydraulic conductivity of soil saturation, various studies have been conducted and different methods are presented based on different conditions. If water level is close to earth level, auger hole method is a reliable and simple method to measure hydraulic conductivity coefficient. But if underground water level is decreased, auger hole method is not used easily and we should use the methods measuring hydraulic conductivity above underground water level with high complexity. One of the methods is the shallow well *pump*-in technique (SWPT) with relatively high precision. *Talsma* and Hallam (1980) created some changes in SWPT method and in later years, inverted auger hole method called Porsche and Kessler method in French resources was taken into attention. This method is the most common method but time-costly experiments and high executive costs are the disadvantages of this method. Then, *Reynolds* and Elrick (1983, 1984) made a practical and cheap instrument called Guelph permameteras simple Marriott *siphon*. This method has robust theoretical fundamental, high speed and cheap. By this method, hydraulic conductivity coefficient is computed at any depth and this measurement is performed by just one person. Various studies have been conducted for the precision of these methods or their comparison. For example, we can refer to some studies:

Kashkuli and Mashal (1990) in two types of loam sand and silt clay, compared Guelph permeameter method with two methods of inverted auger and *well pump* technique. In both study district, inverted auger hole showed relatively better results compared to that of *well pump* technique and Guelph permameter. Kashkuli and Mirbahresi (2000) in silt clay soil, compared Guelph permameter and auger methods. The results of study showed that Guelph method had high correlation with auger method (*R^2=0/97).* Heidarpour and Mohammadzade (2006) compared hydraulic conductivity coefficient of inverted auger hole and *well pump* technique. The results of two methods showed that inverted auger hole averagely estimated hydraulic conductivity coefficient 56% higher than that of well pump technique.

As it was said, a research has been conducted for the comparison of the hydraulic conductivity coefficient of inverted auger hole and Guelph permameter methods.

2. Materials and Methods

To conduct this study, a field in Vis region (30 km of northeast of Ahvaz) in Khuzestan province was selected. To determine the soil texture, samples of field soil were taken randomly at depths 0-30, 30-60 and 60-100cm and were placed in nylon to be transferred to lab for soil texture analysis by hydrometer method. After obtaining the percent of constituents, by soil texture triangle, the soil texture of the region was selected in accordance to the *international Soil Science Society (ISSS)*. As the experiment surface is small with the aim of determining soil texture, the soil of common depths from five sites was combined and the average texture of soil was determined at three depths, silt clay. After selection of site, 30 auger holes with diameter 6cm for Guelph permameter with the depth 45cm with different names were augured at distance 5m from each other. After auguring the hole, a brush was used to minimize wall smearing. The special brush should be entered fully vertically into the well and be removed. Then, Guelph permameter is placed on the auger hole and the end of supporting pipe (porous head of water drain) is connected with the hole bottom during the experiment. As the studied soil texture is heavy, the valve of reservoir is turned to use the internal reservoir with area of 4.22 cm2 (in this case, the direction of valve flush of reservoir is down). Hydraulic conductivity in each hole is measured using Guelph permameter with two 5, 10 cm. Conductivity coefficient equations and soil matric potential and alpha parameter are summarized as followings:

K_{GP} = (0.00425)(reservoir area)($R2$) – (0.00554)(reservoir area)($R1$) (1)

ϕ_m = (0.0588)(reservoir area)($R1$) – (0.0245)(reservoir area)($R2$) (2)

$$\alpha^* = \frac{k_{GP}}{\phi_m} \qquad (3)$$

K_{GP}= Soil conductivity coefficient($cm/\sec$) = ϕ_m Soil metric potential(($cm^2/\sec$) α^* =alpha parameter (unsaturated soil propertiescm^{-1})

Inverted auger hole method was conducted in the 30 holes in which Guelph permameter was performed with the difference that the diameter of the holes was changed by auger to 8cm. As the soil texture of site is heavy, it has good stability and installing wall pipe is not necessary and hole saturation was performed.

To saturate the wall and bottom of hole, the hole is filled with water and for at least one hour, its water level is kept constant. To avoid experiment error in each hole, inverted auger hole experiments were performed after auguring hole and their saturation in two replications and the second repetition was performed immediately after the first repetition. The mean of two replications was considered as hydraulic conductivity coefficient of hole. As the measurement of water loss in the hole from the bases level is recorded, the changes of water level from hole bottom are computed and the data are entered in Excel software. Based on the following equation, hydraulic conductivity coefficient of each hole is computed separately:

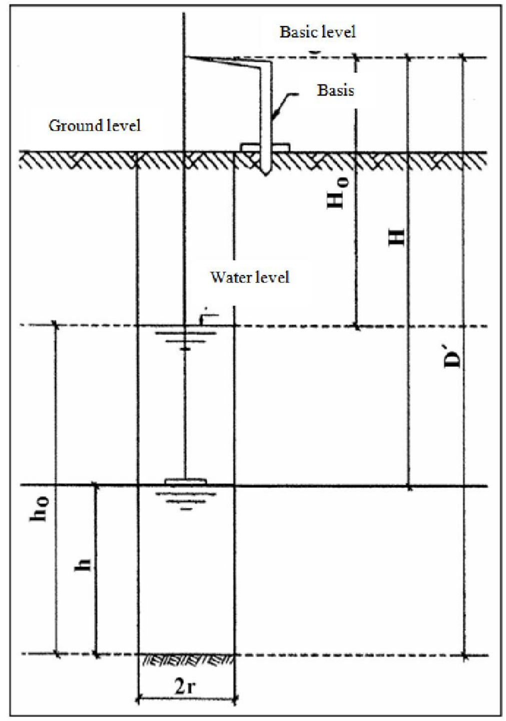

Figure 1.

$$h = D' - H \qquad (4)$$

$$k = 1.15r\frac{\log\left[h(t_1)+\frac{r}{2}\right]-\log\left[h(t_2)+\frac{r}{2}\right]}{t_2-t_1} \qquad (5)$$

3. Results

The results of measurement of hydraulic conductivity coefficient (K) by Guelph permameter in successful holes are shown in Table 1.

In the experiment by Guelph permameter, 14 experiment holes have negative values of K_{GP}, ϕ_m (unsuccessful holes) and only 16 holes had significant solutions (successful holes). The negative values are for the following reasons:

By the increase of depth, discharge reduction or water penetration stopping is occurred and K_{GP}values can be negative and it is not rational.

1- With the increase of depth, discharge is increased suddenly and ϕ_m values can be negative and it is irrational.

2- With the increase of depth, discharge is increased suddenly and ϕ_m values can be negative and it is irrational.

Table 1. The final results of hydraulic conductivity coefficient of soil saturation based on double depth and single depth analysis of Guelph permameter in successful holes

A30	A29	A22	A21	A20	A18	A17	A16	A15	A12	A10	A9	A7	A6	A3	A1	Hole name
2.14	1.48	0.23	1.07	0.05	0.29	0.47	2.68	0.47	0.12	0.40	2.26	0.42	0.42	0.28	8.82	$(m/s)^{7-}10^* K_{fs}$
3.82	2.46	0.82	1.91	1.09	1.91	1.64	3.00	1.64	0.41	4.10	2.46	0.55	0.55	0.98	9.01	$^{7}(m/s)^{-}10^* K_L$
2.14	1.37	0.46	1.07	0.61	1.07	0.92	1.68	0.92	0.23	2.29	1.37	0.31	0.31	0.55	5.04	$(m/s)^{7-}10^* K_S$
1.63	0.97	0.27	0.73	0.38	0.73	0.61	1.23	0.61	0.12	1.76	0.97	0.17	0.17	0.34	4.41	$(m/s)^{7-}10^* K_R$

Table 2. The normal distribution of hydraulic conductivity coefficients

Hydraulic conductivity coefficient	Arithmetic mean	Geometry mean	SD	Standard error	Coefficient of changes	Skewness coefficient	Kurtosis coefficient
K_{GP})m/day(	0.012	0.005	0.018	0.005	1.60	3.08	10.60
K_L)m/day(	0.019	0.014	0.018	0.004	0.93	2.33	6.75
K_S)m/day(	0.011	0.008	0.010	0.002	0.93	2.34	6.76
K_R)m/day(	0.008	0.005	0.009	0.002	1.11	2.64	8.27
K_{ih})m/day(	0.26	0.23	0.14	0.025	0.53	0.83	0.21

To remove this problem, Laplace single depth analyses (KL) with zero capillarity and Richards basic regression analysis (KR) and Richards

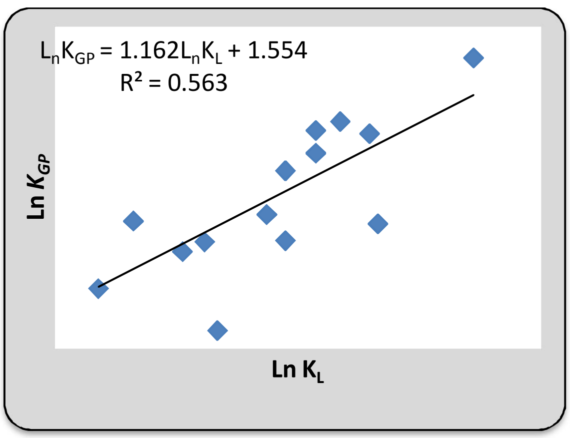

Figure 2. The chart of linear regression between LnKGP¬ LnKL data to determine ω,β parameters

single depth analysis (KS) with initial assumption $\alpha^* = 12$ for fixed load 10 cm is applied and the equations of these analyses are shown. It is worth to mention that to determine KR, β, ω values are obtained using linear regression fit (the least squares deviation) between LnK_L and LnK_{GP} using SPSS software. Based on the radius of hole (a) and fixed load 10cm (H) and soil texture, C value is achieved.

$$K_L = CQ / (2\pi H^2 + C\pi a^2) \quad (6)$$

$$K_R = \beta\, K_L{}^{\omega} \quad (7)$$

$$K_S = CQ / (2\pi H^2 + C\pi a^2 + (2\pi H / \alpha^*)) \quad (8)$$

By SPSS statistical software, normal distribution is taken of the data of both methods (Figure 2) and the results are shown in Table (2). Laplace single depth analysis has more average values compared to other analyses. This is due to infinite α^* (zero capillarity) in Laplace single depth analysis. By evaluation of t-student test between average values of single depth and double depth analyses of Guelph permameter, H0 hypothesis showing the equality of means shows the significance level 95% of Richards single depth analyses, Richards basic regression and double depth analysis of Guelph permameter. Richards basic regression analysis had equal geometry mean with double analysis of Guelph and as shown in Table 2, this analysis has lower standard deviation and standard error compared to that of other analyses. Totally, we can say Richards basic regression analysis is considered as K_{fs} as it is the best method of determining hydraulic conductivity of soil saturation in silt clay by Guelph permameter and this is consistent with the results of study of Mokhtaran (2004).

As shown in Figure 3, hydraulic conductivity coefficient of two above methods is different and inverted auger hole method has bigger values of hydraulic conductivity coefficient compared to Guelph permameter as inverted auger hole is 20.9 times more than that of Guelph permameter. Regarding the difference between the values of inverted auger hole and Guelph method, we can say two methods have different sample size and different boundary conditions. In inverted auger method, water load is different and in Guelph method, water load is constant. In inverted auger method in which water moves horizontally in soil, hydraulic conductivity is high and in Guelph method in which water moves at the same time vertically and horizontally, hydraulic conductivity is low. In Guelph method, entrapped air of unsaturated soil around hole is effective on the hydraulic conductivity value. In addition, in inverted auger hole method, the effect of surrounding unsaturated environment of auger hole on saturation flow is ignored and the water conductivity value of this method is higher than that of Guelph method. In order to evaluate the relationship between hydraulic conductivity coefficient of inverted auger hole (k_{ih}) and Guelph permameter (k_{fs}) in a coordinate of $k_{ih}$to $k_{fs}$is plotted in meter per day (Figure 4).

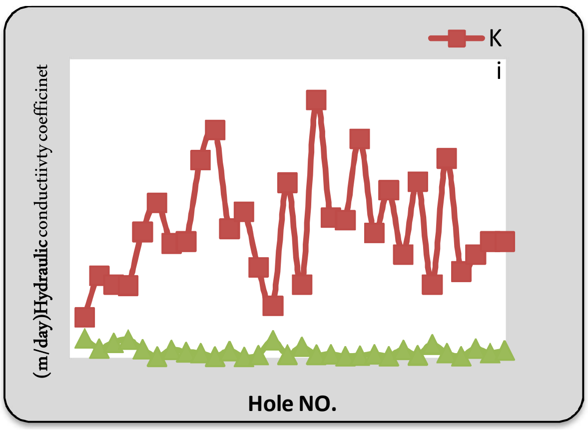

Figure 3. The changes of hydraulic conductivity coefficient in different holes

The results of regression analysis showed that the best equation for fit between the data of both methods is a linear relationship with correlation coefficient R^2=0.51 for silt clay. The equation is as follows:

$$k_{ih} = -7.224\, k_{fs} + 0.35 \qquad (9)$$

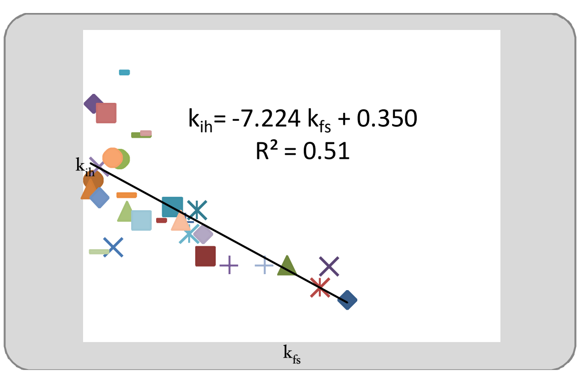

Figure 4. Regression chart between k_{ih},k_{fs}

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4. Discussions

The results showed that inverted auger hole method had higher values of saturation hydraulic.

Conductivity compared to Guelph permameter method. In silt clay texture, conductivity coefficient of inverted auger hole is 20.9 times more than that z of Guelph permameter method. The results of regression analysis showed that the best equation for fit of data of both methods was a linear equation as follows:

$$k_{ih} = -7.224\, k_{fs} + 0.35 \quad R^2 = 0.51 \qquad (10)$$

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