Global Journal of Engineering and Technology Review
Journal homepage: http://gatrenterprise.com/GATRJournals/index.html
Global Journal of Engineering and Technology Review 1 (1) 122 – 128 (2016)

The Nature of Curve Infiltration Pattern Circumstantially in Parit Raja Using Tension Infiltrometer

Nur Aini Mohd Arish[1]*, Sabariah Musa[2] and Khairun Nisa'a Ismail[3]

[1,2,3] Department of Water and Environmental Engineering, Faculty of Civil and Environmental Enginering, Universiti Tun Hussein Onn Malaysia, Parit Raja, 86400, Batu Pahat, Johor Malaysia

ABSTRACT

Objective – Infiltration is a process whereby water from land surface infiltrate into soil through pore space such as cracks and silt and it can be represented the as largest components of water loses from precipitation source.The objective of this study is to determine infiltration curve at Parit Raja, Batu Pahat Johor.
Methodology/Technique – The characteristic of the infiltration rate at land surface is identified by using Tension Infiltrometer. Tension disc infiltrometer tests were carried out on top soil at ten different locations. All the measured data were analyzed using Wooding's (1968) analytical solution where it used to calculate the hydraulic conductivity versus water content relationship from unconfined infiltration. The data also were analyzed by using Horton Infiltration Equation.
Findings – The hydraulic conductivity obtained from the in-situ test shows that the average rate is 0.0001mm/hr and the soil type is silty clay. Apart from that, this study proves that infiltration rate in Parit Raja area, Batu Pahat Johor was low between 1.00 mm/hr to 15mm/hr which is clay soil. However, the low infiltration rate can cause devastating effects on the landscape of the developing watersheds.
Novelty – Soil infiltration for these ten stations must be increased in order to prevent floods. For examples increase the amount of organic materials added to the soil to increase the stability of soils aggregates. Soil can be an excellent medium storage for water, depending on type and condition of the soil.

Type of Paper: Empirical

Keywords: Horton, Infiltration, Tension Infiltrometer, Watersheds, Wooding's.

1. Introduction

Parit Raja area is a land which consists of strata mainly the clay soil. The clay soil characteristics have very fine grained material which is low permeability, high compressibility and low strength. (E.M.Wilson, 1992). Flooding is a phenomenon where it can occur on any land surface and usually related with low rate of infiltration. Water infiltrates into the sub surface of soil and result the bulk density during infiltration and as a

* Paper Info: Revised: July, 2016
Accepted: November, 2016
* Corresponding author:
E-mail: nuraini@uthm.edu.my
Affiliation: Department of Water and Environmental Engineering, Faculty of Civil and Environmental Enginering, Universiti Tun Hussein Onn Malaysia, Malaysia

consequence of wetting. Soils that have minimum infiltration will increase of overall amount of runoff. Therefore, in reducing the flooding problem, the test using tension infiltrometer can be used which it can examine and characterize small scale flow process during infiltration in low permeability soils. The objective of this study is to determine the infiltration curve in Parit Raja, Batu Pahat Johor.

Infiltration is the process of water entering the soil. The rate of infiltration is the maximum velocity at which water enters the soil surface. It is measured in inches per hour or millimeters per hour. The rates decrease as the soil becomes saturated. If the precipitation rate exceeds the infiltration rate, runoffs usually occur unless there is some physical barrier. When the soil is in good condition, it has stable structure and continuous pores to the surface. This allows water from rainfall to enter unimpeded throughout a rainfall event. Porosity and pore size distribution are the main determinations of infiltration. Although particle size and particle distribution may be a major determinates of infiltration rates (Table 1), the pore size distribution is modified by organic matter content, aggregation, tillage, and compaction.

Table 1: Infiltration rates for certain particle-size classes (FAO 1979).

Textural	**Infiltration rate (cm/h)**		
Class	**Minimum**	**Mean**	**Maximum**
Clay	0.01	0.05	0.1
Silty Clay	0.03	0.25	0.50
Clay Loam	0.25	0.8	1.5
Loam	0.8	1.3	2.0
Sandy Loam	1.3	2.5	7.6
Sand	2.5	5.0	25.0

A study on infiltration and particle size distribution has been done in the most area of UTHM campus. It is found that the rate of infiltration is in range of 0.004-0.007 mm/s and the soil classification based on particle size is between silt to fine sand. That is means the top soil surface has low infiltration rate and high of moisture content caused by the types of soil. (Sabariah Musa. et al.,2009)

2. Materials and Methods

Tension Infiltrometer has been developed for measuring infiltration rates of soils in the field and measuring unsaturated hydraulic conductivity. Field measurement with a tension infiltrometer is usually made on the land surface and infiltrate down the soil strata. Water is allowed to infiltrate soil at a rate, which is slower than when water is ponded on the soil surface. This can be accomplished by maintaining a small negative pressure on the water as it moves out of the infiltrometer disc into the soil. The tension infiltrometer has gained great popularity as field measurement device in recent years because of its efficiency and apparent simplicity. The availability of several commercials model has further contributed to widespread use. Tension or disc infiltrometer method provides measures of both field saturated and near saturated soil hydraulic properties for water pressure heads ranging between about -0.2 m and + 0.02m.

The infiltration surface was prepared carefully by removing the vegetation surface and thin layer (approximately 0-2 cm) of soil to ensure a level surface. In this study, 0.20 m diameter disk infiltrometer used for steady state at each tension nominally 2.0, 1.5, 1.0, and 0.5 kPa. Steady state was determined by following the drop in water column height per unit time and nominally takes 30 minutes to achieve stable state.

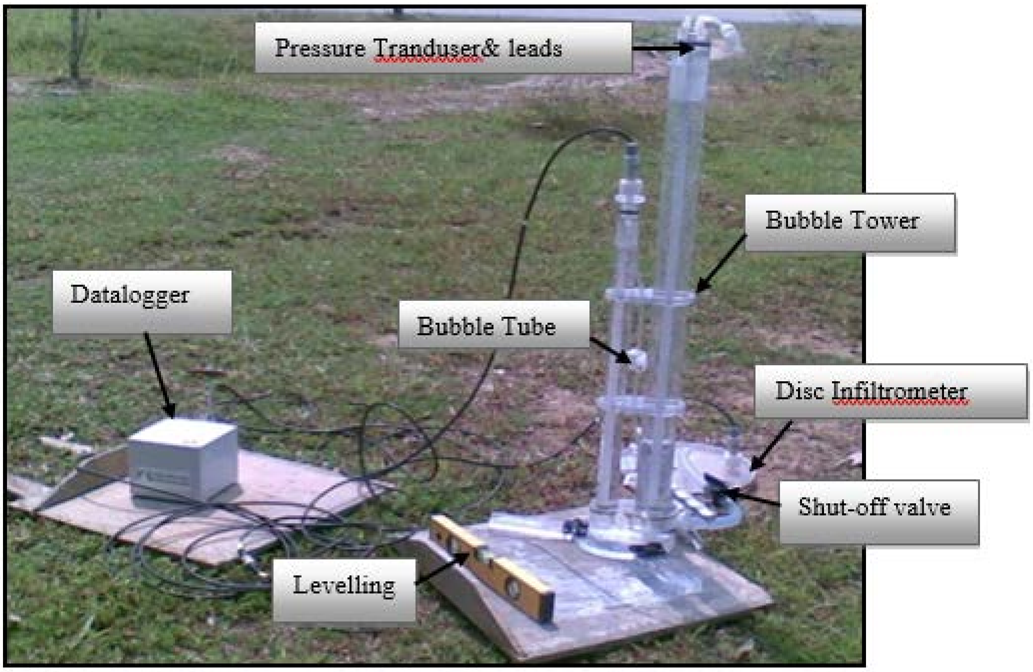

Figure 1: Tension Infiltrometer

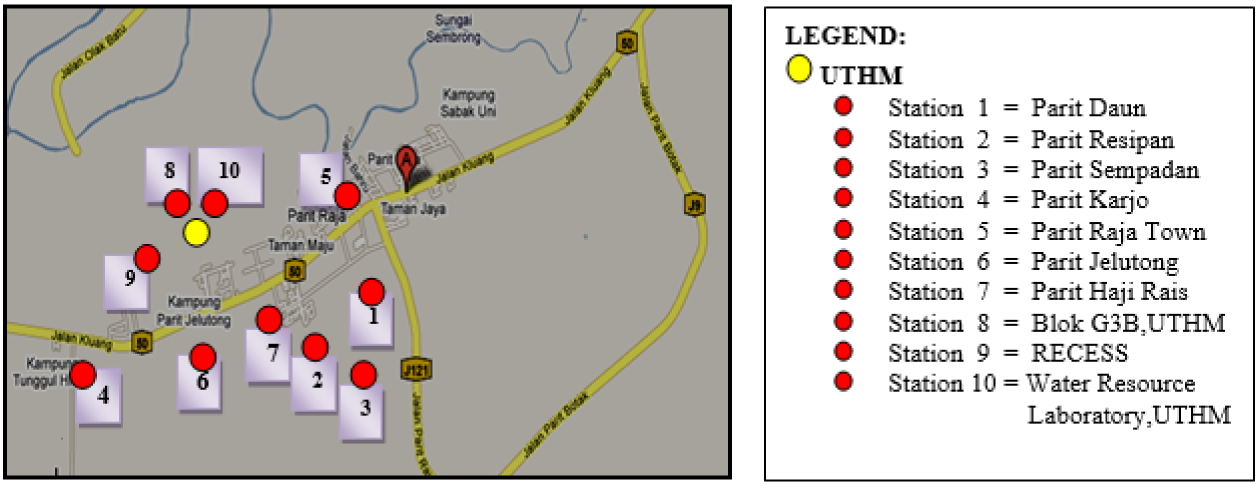

Figure 2: Parit Raja areal map

Infiltration Data Analysis

The following method based on Wooding's work (1968) can be used to calculate the hydraulic conductivity versus water content relationship from unconfined infiltration. Wooding proposed the following algebraic approximation of steady state unconfined infiltration rates into soil from circular source of radius r (cm).

$$Q = \pi r^2 K \left[1 + \frac{4}{\pi r \alpha}\right] \quad (1)$$

Where Q is the volume of water entering the soil per unit time ($cm^3 hr^{-1}$), K ($cm\ hr^{-1}$) is the hydraulic conductivity and h (cm) is the metric potential or tension at the source. The value of h will normally be negative corresponding to a tension at the water sources, however it can be zero. It is assumed that the unsaturated hydraulic conductivitVy of soil varies with matric potential h (cm) as proposed by Gardner (1958).

$$K(h) = K_{sat} \exp(\alpha h) \qquad (2)$$

Where K_{sat} is the saturated hydraulic conductivity (cm hr^{-1}). It is applies only for $h \leq 0$. With the tension infiltrometer one measures the volume of water (Q) entering the soil per unit time through the porous membrane at a minimum of two tensions, examples h_1 and h_2. For unsaturated soil and after substitution of h_1 and h_2, respectively for h in the combined equation one obtains:

$$Q(h1) = \pi r^2 \, Ksat \exp(\alpha h1) \left[1+ \frac{4}{\pi r \alpha}\right]$$

$$Q(h2) = \pi r^2 \, Ksat \exp(\alpha h1) \left[1+ \frac{4}{\pi r \alpha}\right]$$

Dividing and solving for α yields:

$$\alpha = \frac{\text{In}\left[Q(h2) / Q(h1) \right]}{h2-h1}$$

Once K_{sat} and α are known, their values can be substituted, yielding the relationship between hydraulic conductivity and tension for the soil. This relationship can be used to calculate the unsaturated conductivity at the desired tensions. (Manual Operating Instruction Tension Infiltrometer, 2008 *Eijkelkamp Agrisearch Equipment*.)

3. Analysis and Discussion

Based on the results from laboratory test, the property of soil was determined by the Atterberg Limit Test and Specific Gravity Test. The results for plastic limit and liquid limit test from ten different locations, showed that the average moisture content for all soil type range from 37% to 54%. RECESS has the highest moisture content which is 54% but Parit Karjo has the lowest moisture content which is 37% **(Table 2).** This is due to the permeability of water. Soil that has sandy surface has high permeability compared to clay soil which low permeability. The factors which contribute to the permeability are texture of soil and amount of water in the soil. The type of soil (sandy, silty, clay) can control the rate of infiltration. For example, a sandy surface soil normally has higher infiltration rate than a clay surface soil. However, the infiltration rate is generally higher when the soil is initially dry and decreases as the soil becomes wet.

Table 2: Comparison of results analysis between liquid limit, plastic limit and specific gravity for each station.

Station	Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	Specific Gravity
Parit Daun	48.30	48.00	38.03	1.321
Parit Resipan	44.36	43.80	12.67	1.167
Parit Sempadan	53.13	53.20	17.00	1.210
Parit Karjo	37.00	39.00	8.00	1.277

Pekan Parit Raja	48.30	38.48	16.44	1.473
Parit Jelutong	40.00	39.80	11.94	1.560
Parit Haji Rais	46.67	46.20	13.84	2.120
Blok G3B,UTHM	43.00	43.00	14.58	2.520
RECESS	54.00	54.00	15.00	1.830
Water Resource Laboratory, UTHM	46.94	46.50	11.06	1.070

Besides, the plastic index for ten stations can also be determined. Plasticity index (PI) is the numerical difference between the liquid and the plastic limit. It is the range of water content which the soil shows the properties of a plastic solid. From the result, the range of plastic index for all station is 7% to 17% which the degree of plasticity is medium plastic and it shows that the soil is silty clay. The investigate soil having high cohesiveness to allow water flow into the soil. Cohesive soils usually needed a force such as impact or pressure. The high forces cohesiveness shows that the attractiveness between fine particles in soil without imposed any external force. The analysis result of specific gravity test from ten different stations shows that the range of specific gravity is 1 to 2.6 and can be categorized as organic soil. Therefore, the Parit Raja soil is suitable to use in agriculture sector.

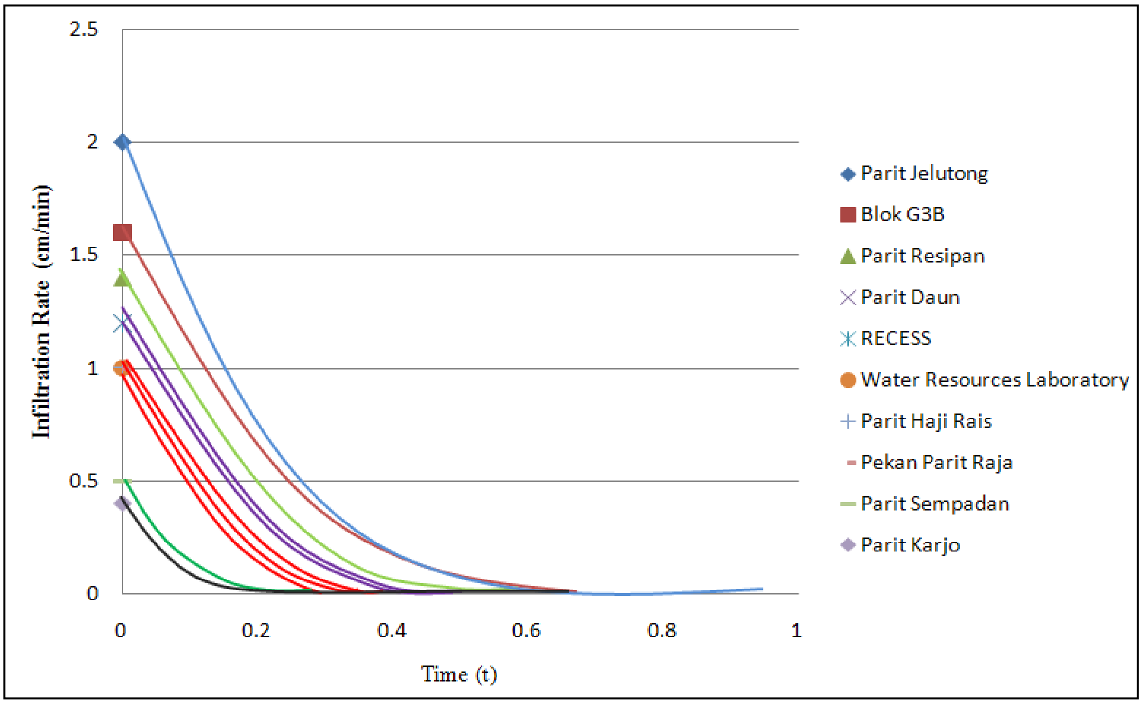

Figure 3. Graph of infiltration rate versus time for ten stations

Based on Figure 3, Parit Jelutong has the highest initial infiltration capacity (*fo*) which is 2.0cm/min while Parit Karjo has the lowest initial infiltration capacity (*fo*) which is 0.4 cm/min. However, the final infiltration capacity (*fc*) equal to zero. All the data was analyzed by using Horton equation. The results from Table 3 shows that, Parit Resipan has the higest infiltration rate is 15 mm/hr than Parit Karjo has lowest infiltration rate which is 7.80 mm/hr. The factor that influence infiltration rate is the effect of rain before the infiltration test was conducted. The stations that had a rain before infiltration test were Parit Daun, Parit Resipan, Parit Sempadan, Parit Karjo, Parit Haji Rais, and Block G3B. While Parit Raja Town, Parit Jelutong, RECESS and Water Resource Laboratory at campus UTHM does not received rain before infiltration test was conducted. The effect for this test is the infiltration rate is generally higher when soil is in dry condition and decrease as the soil becomes wet. Moreover, an increased amount of plant material, dead or alive, generally assists the process of infiltration. Organic matter increase the entry of water by protecting the soils aggregates from breaking down during the impact of raindrops. Particles broken from aggregates can clog pores seal the surface and decrease infiltration during a rainfall. Therefore, the factor of weather can be influenced the infiltration rate before infiltration test conducted.

Due to infiltration rate, the soil type can be determined from hydraulic conductivity. All the measured data was analyzed using *Wooding's* (1968) analytical solution where it is used to calculate the hydraulic conductivity versus water content relationship from unconfined infiltration. The hydraulic conductivity obtained from the site test shows that the soil is silty clay type and also the rate of infiltration is extremely slow with rate of 0.0001mm/hr. Based on (Table 3), Water Resources Laboratory at campus UTHM has the highest hydraulic conductivity which is 2.208×10^{-4} mm/s and Parit Karjo has the lowest hydraulic conductivity which is 1.944×10^{-5} mm/s. This condition happened because the factor of water permeates through the soil. The factors influenced permeability are grain size of particles and the number of cracks and fractures. If the soils are very small grain such as clays and silts, so the space water flow through the soil is limited. Therefore, the hydraulic conductivity is commonly used as indicator of soils permeability.

Table 3: Infiltration rate and hydraulic conductivity for all stations

Station	Infiltration Rate (mm/hr)	Hydraulic Conductivity (mm/s)
Parit Daun	11.40	1.6944×10^{-4}
Parit Resipan	15.00	1.667×10^{-4}
Parit Sempadan	11.22	6.583×10^{-5}
Parit Karjo	7.80	1.944×10^{-5}
Pekan Parit Raja	9.84	1.2083×10^{-4}
Parit Jelutong	12.30	1.708×10^{-4}
Parit Haji Rais	11.82	2.333×10^{-5}
Blok G3B,UTHM	10.548	1.914×10^{-4}
RECESS	9.78	1.152×10^{-4}
Water Resources Laboratory, UTHM	13.2	2.208×10^{-4}

The results from laboratory and site test analysis show that the soil for all stations can be categorized as silty clay type. The silty clay had a low infiltration rate because factors of texture soil. It happened because silty clay has little a space particle to allow the infiltration of water compared the sandy soil has the highest infiltration rate. The pores of silty clay soil also influenced infiltration rate. Continuous pores which are connected to the surface are excellent conduits for the absorption of water into the soil. However, discontinuous pores in silty clay soil retarded the flow of water because of entrapment of air bubbles. As an impact, when storm water runoff from impervious surfaces occurred it causing devastating effects on the landscape of the developing watersheds. The thickness of soil layer and the clay sub surface also can make the flow rate become slow and flood can easily happen even the intensity rainfall is low. When the water supplied exceed the soil's infiltration capacity, it moves downslope as runoff on sloping land or ponds the surface of level land.

4. Conclusion

Based on the results it show that the infiltration rates of silty clay are extremely slow due the permeability of soil. The parameters and characteristics of the soil tested at ten stations have been obtained where it shows that the hydraulic conductivity is extremely slow with 0.0001mm/hr and the soil can be categorized as silty clay. Besides, this study proved that the infiltration rate in Parit Raja, Batu Pahat, Johor is low between 1.00mm/hr to 15 mm/hr. The impacts with very slow rate of infiltration can causes devastating effects on the landscape of the developing watersheds. Therefore, soil infiltration for these ten stations must be increased in order to prevent floods. For examples increase the amount of organic materials added to the soil to increase the stability of soils aggregates. Soil can be an excellent medium storage for water, depending on type and condition of the soil. Proper management of the soil can help maximize infiltration and absorb as much water as allowed by a specific soil type. In most cases, maintaining a high infiltration rate are desirable for a healthy environment.

Acknowledgement

Authors would like to thank the Faculty of Civil and Environmental Engineering, University Tun Hussein Onn Malaysia for the permission and assistance to use their lab and equipment in finishing this study and manuscript.

References

Wilson, E.M. (1992). " Engineering of Hydrology",4th. Ed. Macmillan Education Limited.
Gardiner, D.T., Miller, R.W (2004). " Soils In Our Environment." 10th. Ed. New Jersy, Prentice Hall.
Food and Agricultural Organization of the United Nations. (1979). "Soil Survey Investigations for Irrigation". Prepared by Soil Resources, Man. and Cons. Serv. Land and Water Rev. Div. Rome, Italy
Si, B.C.& Bodhinayake, W. (2005). "Determining Soil Hydraulic Properties From Tension Iifiltrometer Measurement: Fuzzy Regression." Canada: University of Saskatchwan.
Wendroth, O. & Genuchten, M. T. V.(1999). " Estimating Unsaturated Saturated Soil Hydraulic Properties From Laboratory Tension Disc Infiltrometer Experiments" Vol.35, No. 10. California: American Geophysical Union.
Sabariah Musa , Nor Azazi Zakaria , Dwi Tjahjanto and Lai Sai Hin (2009), "*The Potential of Recharge Well System in Flat Area with Low Infiltration Rate*," Water Resources (ICWR) Langkawi, Kedah, Malaysia.
Manual Operating Instruction Tension Infiltrometer, (2008) *Eijkelkamp Agrisearch Equipment.*