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Rain Effect Frequency of Infiltration Rate and Infiltration Capacity in Common Soil: Laboratory Test with Rainfall Simulator

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Abstract

Analyzing the Influence of Rain Frequency Infiltration Rate and Infiltration Capacity in Common Soil Type (Laboratory Testing Study With Rainfall Simulator). Infiltration is the flow of water into the ground through the soil surface. This process is a very important part of the hydrological cycle and in the process of transferring rain into the flow of water in the soil before reaching the river. Infiltration (infiltration rate and capacity) is influenced by various variables, including soil type, slope inclination, density and type of vegetation, soil moisture content, and rainfall intensity. This study aims to determine the effect of rainfall frequency on the infiltration rate and infiltration capacity on common soil types. This research is a type of laboratory experimental research, using rainfall simulator tool. The soil used in this study is common soil type. Furthermore, artificial rain was provided with intensity I5, I15, and I25 and performed infiltration rate reading on the Drain Rainfall Simulator. The rate and capacity of infiltration in common soils increase proportionally to the increased intensity of rainfall, the higher the intensity of rainfall the higher the infiltration occurring at the same level of rain frequency. The rate and capacity of infiltration in common soils decrease proportionally to the increasing frequency of rain, the more the frequency of rain the smaller the infiltration occurring at the same level of rainfall intensity.

Introduction

Much of the water absorbed by the soil is largely determined by the infiltration speed, intensity and duration of rain and into the layers of soil that can deviate from the water (Ritsema & Dekker, 2000; Horton, 1933). Infiltration speed is greatly affected by the condition of water saturation that existed before the rain and permeability of the soil profile above groundwater level (groundwater level). If the soil is saturated with water before the rain, the infiltration speed is very slow and close to zero so that most of the rain will run off into surface runoff. The infiltration rate of the soil, soil moisture, intensity of rainfall, amount of rainfall and length of rain are usually the most important determinants in determining infiltration capacity and runoff water volume (Seeger et. al., 2004; Ziadat & Taimeh, 2013; Kleinman et. al., 2006). The purpose of this study was to determine the effect of rain frequency on the rate and capacity of infiltration in common soil types.

Rainfall Intensity

In this study, Mononobe formula is used to calculate the intensity of rainfall.

$$I = \frac{R_{24}}{24}\left(\frac{24}{t}\right)^{m} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Description:

I = Rainfall intensity (mm/hour)

t = duration of rainfall (minutes), or for 4 in (hours) a, b, n, m: settings

R_{24} = Maximum rainfall in 24 hours (mm).

Infiltration

Infiltration is the flow of water into the soil through the soil surface. In infiltration, there are two terms, infiltration capacity and infiltration rate, expressed in mm/hour. Infiltration capacity is the maximum infiltration rate for a particular type of soil, while the infiltration rate is the rate of infiltration of water entering the surface per unit of time, expressed in mm per hour or centimeter per hour.

Each type of soil has different infiltration rate characteristics, which vary from very high to very low. Sandy soil types generally tend to have high infiltration rates, but clays, on the other hand, tend to have low infiltration rates. This is due to differences in pore numbers in these soil types. (Triatmodjo, 2010).

Infiltration Measurement

The method commonly used to determine the infiltration rate and infiltration capacity is measurement with an infiltrometer and hydrograph analysis. Infiltrometer can be divided into inundation infiltrometer and rain simulator (rainfall simulator) (Triatmodjo, 2010).

Rainfall Simulator (Rainfall Simulator) is to apply artificial rain that is desired for research, among others: Erosion, infiltration, and interception. Rainfall simulators can control rain as desired (Harto Br, 1993). Rainfall simulator is a tool that can be used to study hydrological parameters such as infiltration and runoff under controlled rain use (Harto Br, 1993). In this study the measurement of the infiltration rate using a rain simulator.

Figure 1. Rainfall Simulator

If the rainfall intensity (*I*) is greater than the infiltration capacity (*f*) there will be inundation on the ground surface. At one time a pool of water will overflow and the overflow of water is collected in a container.

By knowing the intensity of rain (*I*), the volume of reservoirs in containers and inundation height, the infiltration capacity (*f*) will be calculated (Triatmodjo, 2010).

Based on the Standards for rainfall intensity in an artificial rain simulator determined by the United States Department of Defense (DOD) MIL-STD 810F. Method 506.4 standard), then the rainfall intensity standard for a simulator has been determined for several rainy conditions.

In this study using these standards, the following is the standard rainfall intensity displayed on the Rainfall Simulator tool used in this study.

Table 1. Standard of Rainfall Intensity Standard in Rainfall Simulator

Rain Condidtion	Rain Fall Rate	Flow Rates
Extreme	More than : 14 mm/min 840 mm/hour 33.1 inchi/hour	More than : 16,8 L/min
High	8 mm/min - 14mm/min 480 mm/hour-840 mm/hour 18,9 inchi/hour -33,1 inchi/hour	9,6 L/min - 16,8 L/min
Medium	1,7 mm/min - 8 mm/min 102 mm/hour - 480 mm/hour 4,0 inchi/hour - 18,9 inchi/hour	2,04 L/min - 9,6 L/min
Low	1,07 mm/min - 1,7 mm/min 64,2 mm/hour- 102 m/hour 2,5 inchi/hour-4,0 inchi/hour	1,28 L/min - 2,04 L/min
Very Low	0mm/min - 1,07 mm/min 0 mm/hour - 64,2 mm/hour 0 inchi/hour - 2,5 inchi/hour	0 L/min - 1,28 L/min

Source: Obus (2016)

Infiltration Rate Formulation

When rainwater collects above ground level, the water will be infiltrated through the surface and enter the soil at an initial infiltration rate (f0) whose value depends on the groundwater content at that time (Triatmodjo, 2010).

When the rain continues, the rate of infiltration will decrease because the soil will become wetter. According to Hadisusanto (2011), a simple approach but can describe the process of inflation is the Horton model.

Hadisusanto (2011) and Triatmodjo (2010) describe soil infiltration with an empirical approach which is a function of time, that is:

$$f_t = f_c + (f_0 - f_c)e^{-kt} \ldots (2) \; f_t - f_c = (f_0 - f_c)e^{-kt}$$

Description:

f_t	=	infiltration rate at time t (mm/hour)
f_0	=	initial infiltration rate (mm/hour)
f_c	=	constant infiltration rate, which depends on soil type (mm/hour)
e	=	2.71828
t	=	time
k	=	constant which indicates the rate of evaporation of the infiltration rate
m	=	line gradient of linear regression graph of time relationship with - ln {(ft - fc)/(fo - fc)}

Methods

This type of research is an experimental laboratory study, using a rainfall simulator tool where the conditions of this study are designed and regulated by researchers with reference to the sources of reference/literature relating to the research. This research was conducted at the Civil Engineering Hydrology Laboratory of the University of Muhammadiyah Makassar and conducted in March 2017 to October 2017.

Source of Data

Primary data were obtained from simulation results and direct observations from physical models and samples at the Civil Engineering Hydrology Laboratory, Muhammadiyah University, Makassar. Secondary data were obtained from rainfall data for the Makassar City Region from the Department of Public Works and BMKG (Meteorology Climatology and

Geophysics Council) Makassar city, as well as data obtained from existing literature and research results, both laboratory and direct research in the field related to this study.

The research procedures that will be carried out include; (1) Stages of Preparation; (b) Cleaning; (c) Checking tools and materials to be tested; (d) Preparation of equipment and instruments needed; and (e) Preparation of observation personnel as well as a unity of perception in carrying out test, observation, and data recording actions.

Stages of determining the type of soil

Determination of soil type by testing soil characteristics. Soil characteristics that were tested in this study include; (a) Sand cone test; (b) Testing groundwater content; (c) Testing of soil permeability; (d) Testing of filter analysis; (e) Compaction Testing; (f) Testing the Atterberg limits (plastic limits and liquid limits).

Stages of media settings

Before the procedure of testing the rainfall simulator model is carried out it is necessary to stage the media settings in the test tank in layers with the thickness of the coating according to the planned sample height, while the planned sample height is 30 cm and every 10 cm in each layer per layer.

Staging Ranning test

1^{st} running test. First frequency infiltration measurement I5. Each interval of 5 minutes runoff and infiltration that is accommodated in the drain, measured the volume of water and record it in the observation table. Until the observation as long as the soil is saturated and infiltration is constant, artificial rain is stopped. For the second running test until the third running test the same as the first running test stage by using five rain frequencies and three rainfall intentions when returning

Data Processing

Existing data will then be processed using the infiltration rate formula and infiltration capacity using the horton method.

Results and Discussion

Rain Intensity Analysis

Rain intensity analysis uses the Mononobe formula because the rainfall data obtained are daily rainfall data. Mononobe formula with rainfall data for the 5, 15 and 25 year return period plan obtained from successive calculations: 246,841 mm, 307,489 mm and 344,900 mm. Examples of calculations for t = 5 minutes can be seen in the following description.

$$I_5 = \frac{135.842}{24}\left(\frac{24}{5/60}\right)^{2/3} = 246.841\ {}^{mm}/_{jam}$$

$$I_{15} = \frac{160{,}339}{24}\left(\frac{24}{5/60}\right)^{2/3} = 307{,}489\ {}^{mm}/_{jam}$$

$$I_{25} = \frac{189.906}{24}\left(\frac{24}{5/60}\right)^{2/3} = 344.900\ {}^{mm}/_{jam}$$

For further calculations described in table 2 on the next page.

Table 2. Recapitulation of Rainfall Intensity Calculation Results

No	Waktu (menit)	I_5 mm/jam	I_{10} mm/jam	I_{25} mm/jam
1	5	246,841	290,335	344,900
2	10	155,500	182,899	217,273
3	15	118,669	139,578	165,811
4	20	97,959	115,219	136,874
5	25	84,418	99,293	117,954
6	30	74,757	87,929	104,454
7	35	67,456	79,341	94,253
8	40	61,710	72,584	86,225
9	45	57,050	67,102	79,713
10	50	53,180	62,551	74,306
11	55	49,906	58,700	69,732
12	60	47,094	55,392	65,802

Source: Calculation result

Infiltration Rate

The following table is the value of a constant infiltration rate (fc) at rainfall intensity I_5, I_{10}, I_{25} and the relationship between ft and fc is observed every 5 minutes until the infiltration is considered constant using the Horton Method. As well as a comparison chart Comparison of the value of the infiltration rate between the calculation results and the Horton Method.

Table 3. Value of Infiltration Rate Calculation Results and Horton I5 F1

Time (hour)	Infiltration Speed (mm/hour)	Horton (mm/hour)
0	52.400	52.400
0.08	51.400	42.515
0.17	32.900	34.499
0.25	14.900	27.998
0.33	12.500	22.725
0.42	10.400	18.449
0.50	9.700	14.981
0.58	8.300	12.168
0.67	7.400	9.888
0.75	6.300	8.038
0.83	5.500	6.538
0.92	5.000	5.321
1.00	4.700	4.334
1.08	4.300	3.534
1.17	4.000	2.885
1.25	3.800	2.359
1.33	3.600	1.932
1.42	3.200	1.585
1.50	3.000	1.305

Source: Calculation result

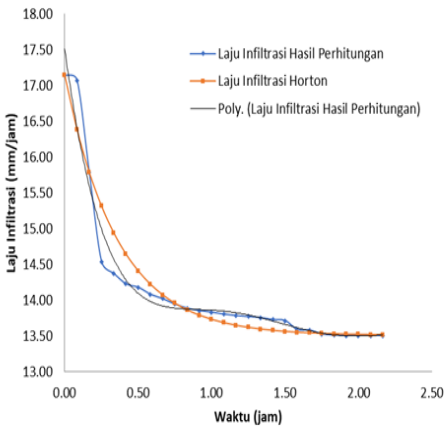


Figure 3. Comparison of Infiltration rate values between the calculation results and the Horton method I_5

Table 4. Value of Infiltration Rate Calculation Results and Horton I_{10}

Waktu (jam)	Laju Infiltrasi Hasil Perhitungan (mm/jam)	Laju Infiltrasi Horton (mm/jam)
0	53.700	53.700
0.08	45.600	36.182
0.17	10.800	24.410
0.25	3.500	16.501
0.33	2.500	11.186
0.42	2.300	7.615
0.50	2.000	5.215
0.58	1.500	3.603
0.67	1.500	2.519
0.75	1.100	1.791
0.83	1.400	1.302
0.92	1.200	0.973
1.00	1.100	0.752
1.08	0.900	0.604
1.17	0.400	0.504
1.25	0.400	0.437
1.33	0.300	0.392

Source: Calculation result

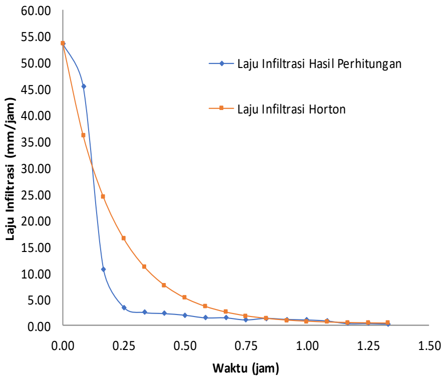


Figure 4. Comparison of Infiltration rate values between Calculation results and Horton I15 method

Table 5. Value of Infiltration Rate Calculation Results and Horton I_{25}

Waktu (jam)	Laju Infiltrasi Hasil Perhitungan (mm/jam)	Laju Infiltrasi Horton (mm/jam)
0	55.100	55.100
0.08	51.500	37.702
0.17	30.300	26.059
0.25	7.300	18.267
0.33	7.000	13.052
0.42	7.000	9.562
0.50	6.700	7.226
0.58	5.600	5.663
0.67	5.600	4.617
0.75	4.600	3.917
0.83	4.100	3.448
0.92	3.200	3.134
1.00	2.500	2.925

Source: Calculation result

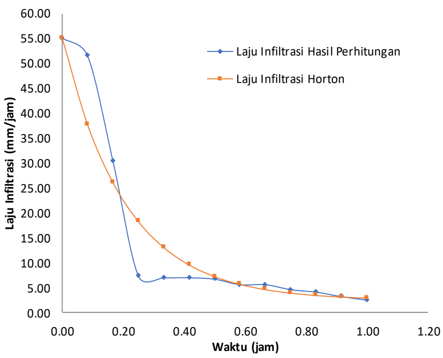


Figure 5. Comparison of Infiltration rate values between the calculation results and the Horton method I_{25}

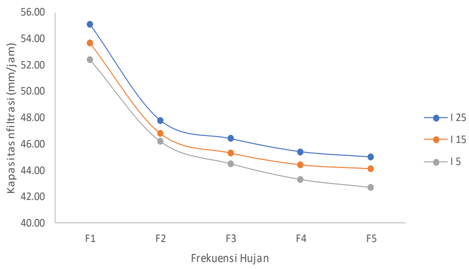
Comparison of Infiltration Capacity between Rainfall Intentions Variables and Rainfall Frequency Variations

Data presentation and infiltration capacity analysis can be carried out in succession on three variations of rainfall intensity plans I5, I15 and I25 and five variations of rainfall frequency. A description of the comparative results of the process is presented as follows:

Table 6. Comparison of Inflation Capacity Between Variations in Rainfall Intensity and Variations in Rain Frequency

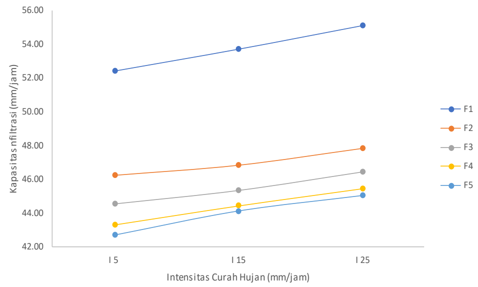
Frekuensi Hujan	Kapasitas Infiltras Pada Intensitas Curah Hujan, I		
	I 5	I 15	I 25
(mm/jam)	(mm/jam)	(mm/jam)	(mm/jam)
F1	52.40	53.70	55.10
F2	46.20	46.80	47.80
F3	44.50	45.30	46.40
F4	43.30	44.40	45.40
F5	42.70	44.10	45.00

Source: Calculation result



Source: Calculation result

Figure 6. Comparison of Inflation Capacity Between Variations in Rainfall Intensity and Variations in Rain Frequency



Source: Calculation result

Figure 7. Comparison of infiltration capacity variations between rainfall intentions and rainfall frequency variations

Table 7. Comparison of Cumulative Infiltration Between Variations in Rainfall Intensity and Variations in Rain Frequency

Frekuensi Hujan	Infiltrasi Kumulatif		
	I 5	I 15	I 25
(mm/jam)	(mm/jam)	(mm/jam)	(mm/jam)
F1	1168.80	943.80	746.20
F2	1001.50	777.50	590.10
F3	678.20	586.50	437.80
F4	657.40	521.90	415.40
F5	613.00	508.70	404.20

Source: Calculation result

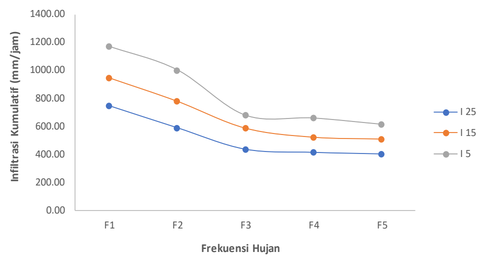
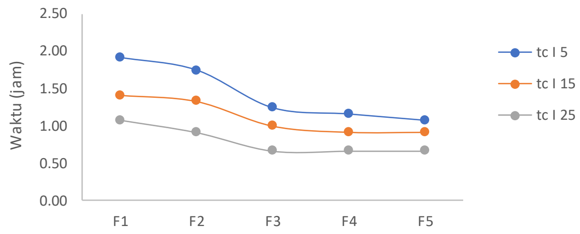


Figure 8. Comparison of Cumulative Infiltration Between Variations in Rainfall Intensity and Variations in Rain Frequency

Table 8. Comparison of Constant Time and Ending Time Between Variations in the intensity of rainfall with variations in rainfall frequency

Frekuensi Hujan	tc I 5	tc I 15	tc I 25
	(jam)	(jam)	(jam)
F1	1.92	1.42	1.08
F2	1.75	1.33	0.92
F3	1.25	1.00	0.67
F4	1.17	0.92	0.67
F5	1.08	0.92	0.67

Source: Calculation result

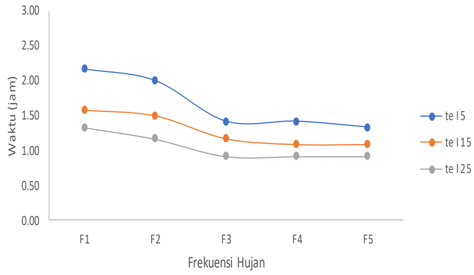


Source: Calculation Result

Table 9. Comparison of Ending Infiltration Time with Variations in Rainfall Intensity and Variation in Rain Frequency

Frekuensi Hujan	te I 5 (jam)	te I 15 (jam)	te I 25 (jam)
F1	2.17	1.58	1.33
F2	2.00	1.50	1.17
F3	1.42	1.17	0.92
F4	1.42	1.08	0.92
F5	1.33	1.08	0.92

Source: Calculation result



Source: Calculation result

Figure 10. Comparison of Ending Infiltration Time With Variations in Rainfall Intensity and Variation in Rain Frequency

Conclusion and Suggestion

The rate and capacity of infiltration in common soils increases directly proportional to the increase in rainfall intentions, the higher the rainfall intentions, the higher the infiltration that occurs at the same frequency of rainfall. The rate and capacity of infiltration in common soils decrease proportionally with increasing frequency of rainfall, the more frequency of rain the smaller the infiltration that occurs at the same level of rain intention. In this study, the intensity of rainfall in the Makassar area was used, with periods of repeated rainfall intensity I5, I15, and I25, using five times the frequency of rain, and using common soil types, it is recommended in subsequent studies to use rainfall intensity for different regions, and types different soils of different vegetation, as well as different types of soil.

References

Hadisusanto, N. (2011). *Aplikasi Hidrologi*. Mediautama. Yogyakarta

Harto Br, S. (1993). *Analisis Hidrologi*. PT Gramedia Pustaka Utama. Jakarta.

Horton, R. E. (1933). The role of infiltration in the hydrologic cycle. *Eos, Transactions American Geophysical Union*, *14*(1), 446-460.

Kleinman, P. J., Srinivasan, M. S., Dell, C. J., Schmidt, J. P., Sharpley, A. N., & Bryant, R. B. (2006). Role of rainfall intensity and hydrology in nutrient transport via surface runoff. *Journal of environmental quality*, *35*(4), 1248-1259.

Obus (2016). *Basic Hidrology Study System*. Jurusan Teknik Sipil Fakultas Teknik Universitas Muhammadiyah Makassar.

Ritsema, C. J., & Dekker, L. W. (2000). Preferential flow in water repellent sandy soils: principles and modeling implications. *Journal of Hydrology*, *231*, 308-319.

Seeger, M., Errea, M. P., Beguerıa, S., Arnáez, J., Martı, C., & Garcıa-Ruiz, J. M. (2004). Catchment soil moisture and rainfall characteristics as determinant factors for discharge/suspended sediment hysteretic loops in a small headwater catchment in the Spanish Pyrenees. *Journal of Hydrology*, *288*(3-4), 299-311.

Ziadat, F. M., & Taimeh, A. Y. (2013). Effect of rainfall intensity, slope, land use and antecedent soil moisture on soil erosion in an arid environment. *Land Degradation & Development*, *24*(6), 582-590.