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Land Gradation Effect Analysis on Permeability and Ponding Time on Repeat Rain Frequency: Laboratory Study with Rainfall Simulator

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Abstract

Analysis of Effect of Land Gradation on Permeability and Ponding Time in Frequency of Repeated Rain (Laboratory Studies with Rainfall Simulator) guided by Darwis Panguriseng and Mahmuddin. That soil permeability is the ability of soil to pass water or air. Soil permeability is usually measured in terms of the speed of water flowing in a certain time specified in units of cm/hour. Ponding time (tp) is the time difference between when it rains and the time when water begins to pool above ground level. The purpose of this study was to determine the effect of soil grading on permeability and inundation time with repeated frequency of rainfall with the same intensity on mixed soil types. This research method is a type of laboratory experimental research, using a rainfall simulator. The soil used in this study is mixed soil types. Furthermore, artificial rain is given with an intensity of I15, each intensity is used five times the frequency of rain and the inundation time readings and inundation height are carried out in the Rainfall Simulator experiment tank and for the permeability test, observation is done with the constant head test. The results showed the value of the permeability coefficient is inversely proportional to the increase in rainfall intensity and frequency of rain. Inundation height and final inundation time are directly proportional to increasing rainfall intensity and rainfall frequency.

Introduction

Soil/land is a collection of grains of natural minerals that are attached but not tightly, so it is still easy to separate. Land that is moved from its location formed due to the flow of water, wind, and ice is called (transported soil). Land that is not moved from where it was formed is called residual soil.

Soil permeability is the ability of soil to pass or pass water. Soil permeability is also one of the factors affecting water infiltration into the soil (Hardiyatmo, 2010). Land with high permeability can increase the infiltration rate thereby reducing the run-off water rate (Rohmat, 2009). Aggregate gradation is a distribution of variations in the size of aggregate grains (Arum, 2013). Aggregation of different sizes as a percentage of total aggregates, or cumulative percentage of grains that are smaller, or larger than each series not filtered.

Aggregate gradation will affect the surface area of the land which at the same time will affect a smaller amount of water paste (Fookes, 1980). When viewed from the pore volume (empty space) between the grains, the soil with varying aggregate grains will result in smaller pore

volume, in other words, the density is high. This is different from the uniform aggregate size which will have a greater volume of empty space.

Permeability is defined as the nature of a porous material that allows seepage flow from liquid in the form of water or oil to flow through the pore cavity. Soil pores are interconnected with one another, so that water can flow from a high energy high point to a low energy high point (Hardiyatmo, 2010).

Soil permeability is the level of soil mass that is passed through the flow of water mass or the speed of water flow to pass through the landmass (Hanafiah, 2005).

During the rain, water will pool on the surface only if rain intensity is greater than the infiltration capacity of the soil (Cooper & Gregory, 1987). Ponding time (ponding time) is the time difference between when it rains and the time when water begins to pool above ground level.

Surface runoff occurs when the soil infiltration capacity cannot balance the intensity of rainfall at the ground surface. In general surface runoff does not occur immediately after a rain falls on the surface of the soil, but it takes time to meet the infiltration capacity (Famiglietti & Wood, 1991). The time from the beginning until the surface runoff begins is called ponding time.

Darcy's law explains the ability of water to flow in cavities (pores) in the soil and the properties that influence it. There are two main assumptions used in the determination of Darcy's law. The first assumption states that the flow of fluid/liquid in the soil is laminar. While the second assumption states that the land is in a saturated state. Flow velocity and quantity/water discharge unit time is proportional to the hydraulic gradient in the book (Djatmiko & Edy, 1993).

The purpose of this study was to determine the effect of soil grading on permeability and determine the effect of soil grading on ponding time.

Methods

This type of research is a "testing (Experimental Model)" research, using a rainfall simulator tool where the conditions of this study are designed and regulated in such a way by referring to the sources of references/literature relating to the research.

Location and Time of Research

The study was conducted at the Soil Mechanics Laboratory and the Hydrology Laboratory of the Faculty of Engineering, Muhammadiyah University, Makassar and the data collection was carried out on April 23 to May 16, 2018.

Source of Data

This study uses data sources namely; (a) Primary data, i.e. data obtained directly from simulations and direct observations from physical models in the Civil Engineering Hydrology Laboratory of the Muhammadiyah University of Makassar; (b) Secondary data, i.e. data obtained from relevant agencies such as rainfall data for the Gowa Regency Region from the Department of Public Works and BMKG Gowa Regency, as well as data obtained from existing literature and research results, both laboratory and direct research in the field related to this research.

Research Design

To facilitate this research a research design was carried out which included: preparation of tools and materials, research procedures as well as research data and variables. The description of the study design is organized as follows:

Tool

Figure 1: rainfall simulator

Material

The materials used in the study include; (a) Soil, the type of soil used is sand, loam, and silt which is varied; (b) Water, the type of water used is water that is not contaminated with wastewater, to make artificial rain using a rainfall simulator.

Research Procedures and Implementation

The study involves; (a) Research and Inspection of Soil Media; (b) Procedure for Soil Media Setting; (c) Running Test Procedures; (d) Permeability Observation Procedure; (e) Ponding Time Observation Procedure

Variables that are varied and observed, with operational definitions as follows;

Grading of land

Soil gradation or commonly called aggregate gradation is an aggregate size distribution. It can also be called aggregate groupings of different sizes as a percentage of the total aggregate or cumulative percentage of grains that are smaller or larger than each series instead of a filter.

There are three variations of soil used in this study, using three types of soil, namely: sand, silt, and clay. All three are varied with the following composition:

Table 1: Gradation Plan

Sample Number	**Sand**	**Silt**	**Clay**
1	± 80%	± 15%	± 5%
2	± 60%	± 30%	± 10%

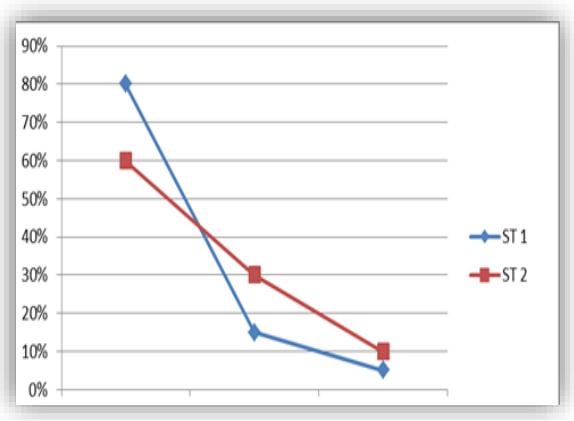

Figure 2: Gradasi Rencana

Repeated rainfall

Repeated rainfall is the average amount of rainwater that has the same intensity that falls repeatedly. Repeated rainfall used in this study is a rain simulation with a rainfall simulator that uses the same repetitive rainfall frequency.

Permeability

Soil permeability is the ability of soil to pass or pass water. Soil permeability is also one of the factors affecting water infiltration into the soil. In this study, soil permeability was observed when the soil began to be bombarded until the soil could no longer pass water.

Ponding time

Inundation time is a condition when the water starts to be on the surface / stagnant when the rain stops and how much time is needed until the water runs out on the surface.

Inundation time is observed when the rain is greater or equal to the magnitude of the infiltration rate and when the soil needs time to reach saturated conditions.

Results and Discussion

Permeability in Soil Gradation

Penyajian data dan analisis permeabilitas dapat dilakukan secara berturut-turut pada 3 jenis gradasi tanah dan frekuensi hujan berulang. Uraian mengenai permeabilitas pada gradasi tanah tersebut disajikan sebagai berikut :

Table 2: Permeability in soil gradation

Rain Frequency (F)	**Permeability in soil gradation**	
	Sample 1	Sample 2
	(cm/detik)	(cm/detik)
F1	0.00064	0.00051
F2	0.00056	0.00045
F3	0.00034	0.00030
F4	0.00026	0.00023
F5	0.00020	0.00011

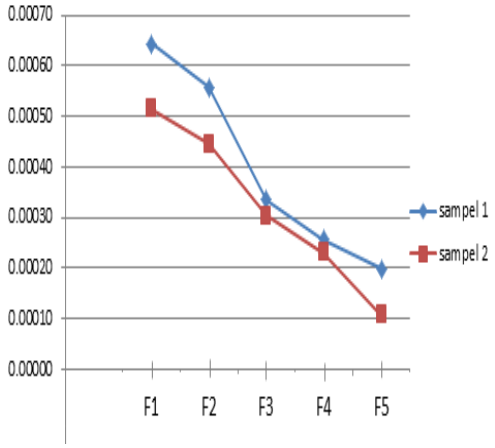

Figure 3: permeability graph on soil gradation

Inundation Time at Frequency of Repeated Rain

Presentation and analysis of inundation time can be carried out in succession on three variations of gradation of sample 1 and sample 2, with the same rainfall intensity I15.

Table 3: Inundation Time At Frequency of Repeated Rain

Rain Frequency (F)	**the final time of inundation tf (minutes), at the frequency of rain (F)**	
	Sample 1	Sample 2
	(minute)	(minute)
F1	280	420
F2	300	450
F3	330	480
F4	330	510
F5	360	540

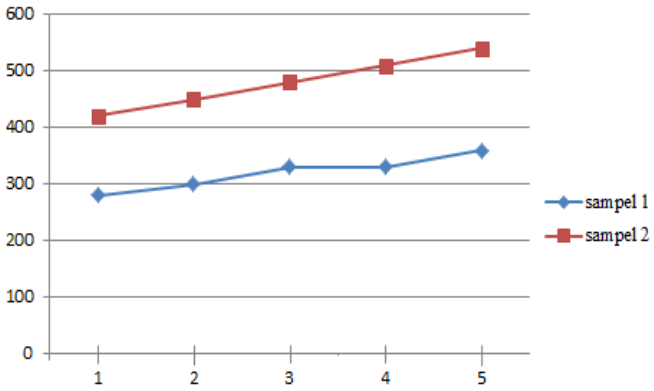

Figure 4: Inundation Time At Frequency of Repeated Rain

Effect of Soil Gradation on Permeability

From the presentation of data and permeability analysis, succession on three variations of soil gradation namely, sample 1 and sample 2, with the same rainfall intensity I15 can be done.

Tabel 4: Soil gradation to permeability

Soil Sample	Soil gradation to permeability				
	F1	F2	F3	F4	F5
	(cm/second)	(cm/second)	(cm/second)	(cm/second)	(cm/second)
Sample 1	0.00064	0.00056	0.00034	0.00026	0.00020
Sample 2	0.00051	0.00045	0.00030	0.00023	0.00011

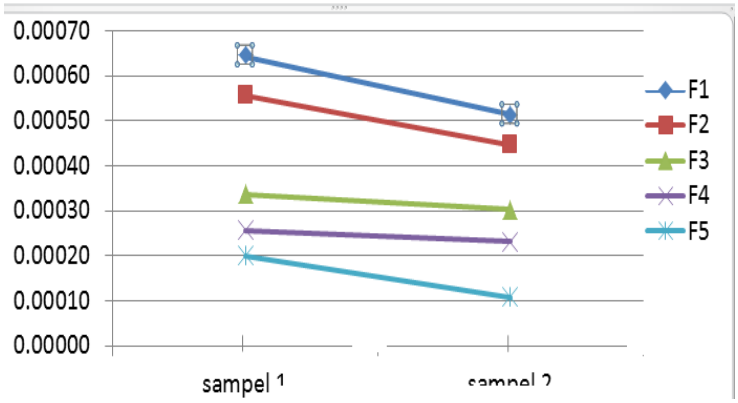

Figure 5: variation of soil samples

Effect of Soil Gradation on Ponding Time

Presentation of data and analysis of the final time of inundation can be carried out in succession on three variations of soil gradation namely, sample 1 and sample 2, with the same rainfall intensity.

Tabel 5: Effect of soil gradation on inundation time

Soil Sample	Final time of inundation tf (minutes), in soil grading				
	F1	F2	F3	F4	F5
	(minute)	(minute)	(minute)	(minute)	(minute)
Sample 1	280	300	330	330	360
Sample 2	420	450	480	510	540

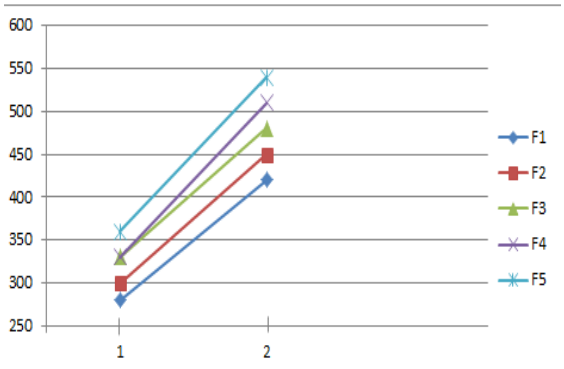

Figure 7: variation of soil samples

The effect of soil gradation on permeability on the frequency of repeated rain (F1, F2, F3, F4, and F5), namely the value of the permeability coefficient obtained is inversely proportional to the increase in the frequency of rain carried out, so the more often the soil is bombarded with repeated rainfall intensity (I15), then the soil structure and pore size are smaller so it is increasingly difficult to pass water and the lower the coefficient of permeability. The value of the permeability coefficient in soil grading for sample 1 is 0.00020 cm/sec and the value of the permeability coefficient in soil grading for sample 2 is 0.00011 cm/sec.

The effect of soil gradation on ponding time on the frequency of repeated rain, namely the final time of inundation in soil samples whose grain is varied is directly proportional to the number of rain frequencies that occur with repeated rainfall intensity (I15), the soil structure is denser and the pore number is smaller so the final time puddles that occur more and more. This is because the more often the soil is bombarded the smaller the particle size and the size of the pores so that the soil is more difficult to escape the water and the final time of inundation is higher. The value of the final time of inundation on the frequency of repeated rain sample 1 is 360 minutes and the value of the final time of inundation on the frequency of repeated rain sample 2 is 540 minutes.

In this study, the rainfall intensity in the Gowa Regency was used, with the frequency of repeated rain (F1, F2, F3, F4, and F5) whose intensity was the same (I15) with the type of soil whose gradations varied, namely sand, clay, and silt. From the experience of conducting research, taking data on several types of samples is very limited, so with missing data, one sample of the analysis and discussion stage becomes difficult (Allison, 2001; Little & Rubin, 2019). Therefore it is recommended in subsequent studies to use 4 to 5 types of soil grains or soil samples and the intensity of rainfall in different regions and varying rainfall intensities.

Conclusion

The more often the soil is bombarded with repeated rainfall intensity (I_{15}), the smaller the soil structure and pore size, making it more difficult to pass water and the lower the permeability coefficient. The value of the permeability coefficient in soil grading for sample 1 is 0.00020 cm/sec and the value of the permeability coefficient in soil grading for sample 2 is 0.00011 cm/sec. The effect of soil gradation on ponding time on the frequency of repeated rain, namely the final time of inundation in soil samples whose grain is varied is directly proportional to the number of rain frequencies that occur with repeated rainfall intensity (I_{15}), the soil structure is denser and the pore number is smaller so that the final time puddles that occur more and more.

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