Analysis of Soil Absorption Capacity of Rainwater in Biopori Infiltration Holes in Purwoyoso Village Semarang City

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Abstract. Drought and floods that hit Semarang City were caused by problems with water distribution and capacity. The ongoing conversion of land functions in the city of Semarang has resulted in reduced green open space and increased building density. This resulted in reduced infiltration of rainwater so that surface water runoff increased. Thus, causing a flood disaster that hit the city of Semarang in 2022, in which 7 out of 16 sub-districts were affected. This condition is exacerbated when rainfall is high and causes stagnant water because the existing drainage system is not optimal. The application of biopore infiltration holes in an effort to expand the rainwater infiltration area is a form of defense that can be carried out by the people of Semarang City in minimizing the occurrence of floods and groundwater crises. This study aims to analyze the absorption capacity of soil against rainwater in biopori infiltration holes in Purwoyoso Village. The method used is the Constant Head and Falling Head tests. The results of the groundwater absorption test showed that in sample B.1. and B.2. are 8.976.E-05 cm/sec and 9.488.E-05 cm/sec respectively. These results indicate that the absorption capacity of the soil in the biopori infiltration holes for rainwater is low or lacking.

1 Introduction

Drought and flood are environmental problems that often occur in various parts of the world, including Indonesia [1]. Quantitatively, the droughts and floods that hit, especially in the city of Semarang, were due to problems with water distribution and capacity. When entering the dry season there is drought because water supplies are limited, otherwise excessive amounts of water during the rainy season will result in flooding [2]. The conventional Semarang City drainage system is not sufficient to accommodate water discharge, especially during the rainy season. In addition, the distance of the river which is quite far from the road causes the

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disposal of water cannot flow optimally. This condition is exacerbated when rainfall is high and causes stagnant water because the existing drainage system is not optimal.

The ongoing conversion of land functions in the city of Semarang has resulted in reduced green open space and increased building density. This condition triggers a decrease in rainwater infiltration so that surface water runoff increases. This has an impact on the occurrence of a flood disaster that hit the city of Semarang in 2022, where 7 out of 16 sub-districts were affected by the flood disaster [3]. The conversion of green areas (forests, agricultural land, plantations) into settlements and urban areas has narrowed water catchment areas. In just 10 years (2006 – 2014) the total area of residential land in Semarang City has increased by 2,465 ha or 6% of the city area. As of 2018, 16,027.49 or 76% of the residential area has been built [4].

If this condition is not immediately corrected by increasing the ability of the soil to absorb water, the City of Semarang will continue to be hit by floods and groundwater crises. One of the efforts that can be made to manage rainwater so that it can seep back into the ground and become a groundwater reserve is by making biopore infiltration holes. Biopori infiltration holes can be applied to conserve groundwater, overcome floods and droughts [5].

City Spatial Regional Regulation Number 5 of 2021 concerning Amendments to Regional Regulation Number 14 of 2011 concerning Semarang City Spatial Plans for 2011-2031 explains that the area of Semarang City Spatial Plan is approximately 39,923 hectares as a conservation area and open space green. Through the Semarang City Environment Service (DLH), data on biopori infiltration holes made from 2018 to 2022 totaled 6,760 units spread across 39 sub-districts and Kehati Parks as a manifestation of groundwater conservation and overcoming floods and droughts. The advantages of biopore infiltration holes are very appropriate for application in residential areas of Semarang City which are densely populated and have limited water catchment areas..

Flood as one of the potential natural disasters in Semarang City, is a natural phenomenon that occurs due to high rainfall intensity where excess water occurs which cannot be accommodated by the drainage network [6]. Meanwhile, drought itself is a condition where the availability of water is far below the need for water for the necessities of life, agriculture, the economy and the environment [7]. Based on data on disaster reporting in the period 2018 to 2022 that occurred in the city of Semarang tends to increase [8].

The application of biopore infiltration holes in an effort to expand the rainwater infiltration area is a form of defense that can be carried out by the people of Semarang City in minimizing the occurrence of floods and groundwater crises. Groundwater is a source of water which, due to its quality and quantity, has the potential to be developed to meet the basic needs of living things [9]. Movement of water in the soil, occurring in the spaces between the soil particles that form it, and in the cracks of the rock.

Permeability is the largest pore space that is still filled with water, so that the pore space for fast drainage along with aggregate stability has the greatest correlation/effect on permeability. The more the proportion of pore space with the larger size interval and the more stable the pore space is in the soil aggregate, the more pore space that can conduct water so that the permeability is greater [10].

Purwoyoso Village, which is located in the Ngaliyan sub-district, is one of the sub-districts affected by the flood disaster. Based on the description of the problem, it is important to conduct research on the analysis of soil absorption capacity for rainwater in the application of biopore infiltration holes in Purwoyoso Village, Semarang City.

 https://doi.org/10.1051/e3sconf/202344803030

2 Research Method

2.1 Research Location

Research was conducted in . Purwoyoso Village, Ngaliyan District, Semarang City with the location of the Geographic coordinates 6°59'36,7''S 110°21'21.1''E The research station is located at Bukit Persada Indah Housing Complex (BPI). The research location is the Proklim Purwokeling RW 10 area in Purwoyoso Village. The location is clearly depicted in Figure 1.

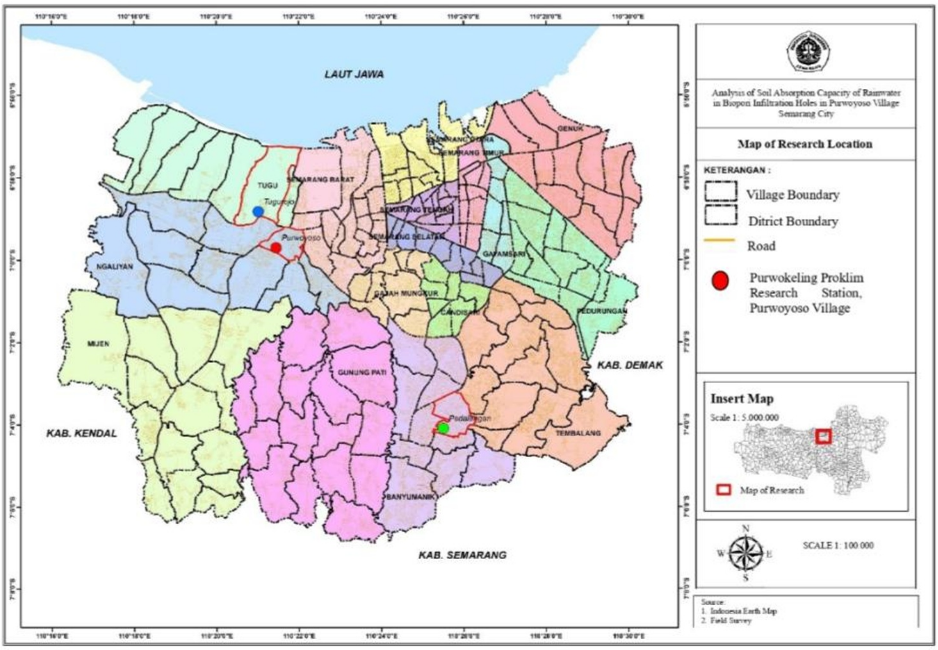

Fig 1. Map of Research

The research station is included in the administration of the Ngaliyan District which is topographically located at an altitude of 67.3 meters above sea level with an amount of rainfall ranging from + 2,413 mm/year. This research station represents the city of Semarang with a mid-land topography between the highlands and the coastal area. Purwoyoso Village was chosen as the research station because it has topographical characteristics in the form of slopes with a slope level of 15-25%, soil type in the form of gray alluvial associations, engineering geology in the form of sandstone with high-medium bearing capacity.

2.2 Methodology

The method used in conducting soil investigations in tests to determine the permeability of the soil to rainwater is by using the Constant Head and Falling Head tests. The tests were carried out at the Soil Mechanics Laboratory, Civil Engineering Department, Faculty of Engineering, Diponegoro University. There are 3 (three) stages in the absorption capacity test, namely: (i) Preparation, (ii) Sampling of Undisturbed Soil (UDS) and (iii) Laboratory Testing.

2.2.1 Preparation Stage

The first stage is work that involves personnel, starting from field workers, repairs/agencies/calibration of equipment to be used such as manual sondir and other supporting equipment

2.2.2 Sampling of Undisturbed Soil (UDS)

Field investigations carried out included taking soil samples (sampling) to investigate regarding Index Properties and Mechanical Properties. The process of taking undisturbed soil samples is carried out as follows:

- Sampling of undisturbed soil is carried out on native soil.
- Sampling is done with a cylinder tube (cylinder with advanced trimming)
- The soil sample in the tube is immediately given paravin at both ends, so that its authenticity can be guaranteed.
- Sample identity includes: sample code or number, point location and depth.
- The depth of the test is 100 cm.

2.2.3 Laboratory Testing

The purpose of laboratory testing is to test soil samples obtained from the field, and to determine the technical parameters of the soil samples qualitatively. The laboratory test methods carried out are:

a. Index Properties Test

1. Water Content

The standard procedures for water content used include: AASTHO T 100-90; ASTM D 265-86 ; and PB D 117-76. The equipment used is: an oven equipped with a temperature controller; cup/container; Scales and Desiccators.

Result :

$$\text{Water Content} = \frac{Water\ Weight}{Dry\ Sample\ Weight} x\ 100\% \quad (1)$$

2. Spesific Gravity

The standard procedure used is AASHTO T 100-90 ; ASTM D 854-92 ; PB 0108-76. The equipment used includes: Picnometer; thermometer scales; Filter No.4, 10, and 40 ; Bottle filled with distilled water and Electric furnace and cup filled with glycerin. The results of the investigation are calculated by the soil specific gravity formula:

$$Gs = \frac{W2-W1}{(W4-W1)-(W3-W2)} \quad (2)$$

Dimana :
W1= picnometer weight (gram)
W2= picnometer weight + dry sample (gram)
W3= picnometer weight + sample + water (gram)
W4= picnometer weight + water (gram)

The specific gravity of soil is the ratio of the grain weight of the soil to the same weight of distilled water at a certain temperature.

3. Natural Density

The standard procedures used are ASTM D 2937-72 and PB 2024-76. And the equipment used includes calibrated rings and scales.

To calculate the unit weight of soil using the formula below:

$$\text{Soil Volume Weight} = \frac{Wet\ Soil\ Weight}{Fill\ Wet\ Soil} \quad (3)$$

b. Engineering Properties Test
The test carried out was a seepage test with ASTM D 325-68 standard procedure. Measurement with a changing voltage (variable falling head). The equipment used included: a glass pipette tube with a diameter of 1.47 cm with an area of 1.696 cm2 and a brass tube containing the sample with a weight = 300-350 grams, a diameter = ±5 cm and a height of ±10 cm. Results of measurements of laboratory seepage values (k) in units of cm/s.
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3 Results and DIscussion

Testing the absorption capacity of the soil for rainwater in the Purwokeling Proklim, Purwoyoso Village, Ngaliyan District, Semarang City was carried out using sampling at 2 points. Point 1 (B1) is located at the coordinates S $6^0$59'36.213" and E $110^0$21'21.559". From point 1, the soil profile is obtained as shown in Figure 2.

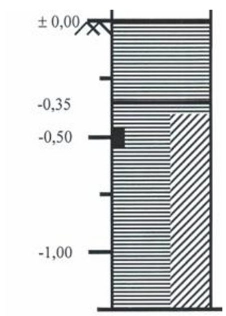

Fig 2. Soil Profil B1 (First Sample)

Meanwhile at point 2 (B2) on the coordinates S $6^0$59'35.715" and E $110^0$21'21.628", obtained soil profile as follows:

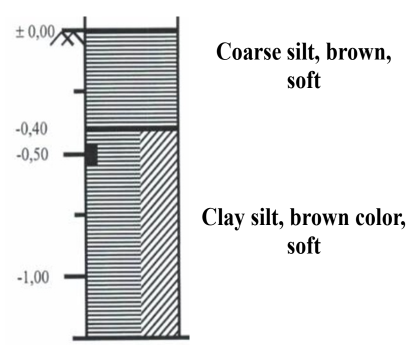

Fig 3. Soil Profil B2 (Second Sample)

Based on the results of a soil profile investigation at Proklim Purwokeling, Purwoyoso Village, it shows that the type of soil at the research station is a coarse-grained silt type with a brown color and a soft texture at a depth of ±0.00 m – 0.40 m. While at a depth of 0.40 m-1 m the type of soil is clay silt with a light brown to brown color and a soft texture.

Silt soil is soil or granules composing soil or rock that are between sand and clay in size. While loamy silt soil is silt soil mixed with clay components.

Table 1. Results of Soil Test

No.	Sampling Location	Sample Code	Soil Profil	Water Content (w) %	Spesific Grafity Of Solid (Gs)	Unit Weight γ gr/cm^3	Dry Unit Weight γ_d gr/cm^3	Porosity (n) %	Void Ratio (e)
1	Proklim Purwokeling Purwoyoso Village Ngaliyan Distric Semarang City	B.1	Fine Sandy Clay	35.14	2.6867	1.6807	1.2437	53.71	1.1603
2		B.2	Fine Sandy Clay	34.84	2.6869	1.6817	1.2471	53.38	1.1545

In 2 soil samples at Proklim Purwokeling, the results B.1 and B.2 were as follows: water content of 35.14% and 34.84%; specific gravity of solids 2.6867 and 2.6869; unit weight of 1.6807 gr/cm3 and 1.6817 gr/cm3 ; dry unit weight 1.2437 gr/cm3 and 1.2471 gr/cm3 ; with a porosity of 53.71% in B.1. and 53.38% for B.2. ; and the value of the solid ratio is 1.1603 and 1.1545 respectively.

Table 2. Result of Permeability Test

Determination	Sample Length	Temperature ^0C	Elapsed Time ihn Sec. For Flow From		Permeability AT T^0 C, kT IN cm/sec	$\frac{Vicosity\ at\ T}{Viscosity\ at\ 20°C}$	Permeability AT 20^0 C, $k20^0$ C In cm/sec	Void Ratio (e)	e^2	$\frac{e^2}{1+e}$	$\frac{e^3}{1+e}$
No	In cm		h_0T_0 V h_0h_1	h_0T_{0h} 1							
1	10.500	27	925	1800	8.976.E-05	0.8285	7.437.E-05	1.655679	2.7413	1.0322	1.7090
2	10.500	27	926	1800	9.488.E-05	0.8285	7.861.E-05	1.655877	2.7419	1.0324	1.7095

In measuring the permeability or absorption capacity of soil to rainwater in Proklim Purwokeling RW 10, Purwoyoso Village, Ngaliyan District, Semarang City, the results show in sample B.1. and B.2. are 8.976.E-05 cm/sec and 9.488.E-05 cm/sec respectively. These results indicate that the absorption capacity of the soil in the biopori infiltration holes for rainwater is low or lacking.

The results of low absorption power are influenced by the type or texture of the soil in Purwoyoso Village which is fine textured. The finer the texture of the soil, the more difficult it is for runoff water from rain to seep into the ground, resulting in flooding.

4 Conclusion

Analysis of soil tests and permeability or soil absorption capacity of rainwater in Purwokeling Proklim RW 10, Purwoyoso Village, Ngaliyan District, Semarang City shows that the soil type in the area is silt with brown soil color and fine texture. The absorption capacity showed low results, namely 8,976.E-05 cm/sec and 9,488.E-05 cm/sec in sample B.1. and B.2., the result of low absorption is influenced by the type of soil and its ability to absorb runoff or rainwater.

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