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Analysis of Soil Physical Parameters in Landslide Prone Areas in West Battang Village, Palopo City as Early Mitigation of Landslide Disasters

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Abstract: This study investigates physical properties parameters of the soil in landslide prone areas in West Battang Village, Palopo City. This study aimed was to determine the grain size of the soil, the value of soil permeability, and the distribution characteristics of the soil in landslide-prone areas. The 30 samples were taken randomly at a depth of 30 cm, then tested the soil grain size, permeability, and the samples distribution. The results showed that the grain size of the soil consisted of gravel, coarse sand, medium sand, and fine sand, with a size of approximately 0.075 – 4.75 mm. The soils in West Battang Village are dominated by sandy soil. The grains soil in the West Battang Village is dominated by coarse sand. The physical characteristics of the soil grains in this area are classified as poorly graded due to incomplete grain size with soil permeability values in the range of 0.5 – 2.0 cm/hour which can absorb water in category of moderately slow. These permeability values can be categorized as a moderately slow and can stimulate landslides due to gradually accumulation of water in the soils.

Keywords: Grain size; Landslide; Mitigation; Physical characteristics; Soil permeability

Introduction

Disaster is a natural phenomenon that can cause human fatalities and damage to the environment. Disasters can be caused by nature or by human activities. Disasters often occur in landslides, floods, fires, tsunamis, and others. One of the areas in South Sulawesi that is frequently affected by landslides is Palopo City. The numbers of landslides in recent years in several locations in the City of Palopo tends to increase. The increasing land use in areas prone to ground movement causes this phenomenon as also reported by other studies (Dandridge et al., 2023; Galve et al., 2015; Glade, 2003; Karsli et al., 2009; Mugagga et al., 2012; Pereira et al., 2020; Persichillo et al., 2017; Tasser et al., 2003; Van Beek et al., 2004). This condition is exacerbated when high rain intensity occurs for a long duration (BPPD Compilation Team for Palopo City, 2018).

A landslide is a natural phenomenon of the wide range of soils movement caused by nature or by human activities. The impact of a landslide can be very large, including loss of life, destruction of infrastructure, damage to land and loss of natural resources. Therefore an effective treatment need be done. Recently, the efforts made by the community in tackling landslide disasters are by giving post-disaster assistance. This is considered ineffective way because it impacts the psychology of disaster victims and creates a great sense of anxiety that there will be aftershocks. The thing that is most needed by the community is initial mitigation in anticipation of landslides to minimize the impacts caused by landslide disasters. One of the initial mitigations that can be done is to educate the public about the physical characteristics of the soil. Physical soil properties are soil properties related to the shape of the original ground, which includes texture, structure, bulk density, porosity, stability, consistency, mineral content, morphology, permeability, color and soil temperature (Adams, 2012; Al-Shammary et al., 2018; Blanco-Canqui, 2017; Bryk et al., 2021; Chaudhari et al., 2013; Delsiyanti et al., 2019;

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Hao et al., 2007; Heuscher et al., 2005; Rabot et al., 2018; Wilke, 2005).

Palopo City is prone to landslides phenomena since it has a mountainous and hilly land surface. Areas prone to landslides in Palopo City are in 3 sub-districts, namely Wara Barat District, Sendana District, and also Mungkajang District (Nurfalaq et al., 2019). One of the landslide events that occurred in West Wara District was in West Battang Village. West Battang Village is an area in the form of mountains with steep slopes with an altitude of around 600–800 meters above sea level. This area is included in the Latimojong formation, which is composed of Malian quartz sandstone, malihan siltstone, quartzite, phyllite, and local limestone claystone (Center for Volcanology and Geological Hazard Mitigation, 2020).

This research was conducted in West Battang Village. The focus of this study was to analyze physical parameters of the soil in landslide-prone areas in term of testing the grain size of the soil using a sieve and measuring soil permeability using a permeameter with the falling head permeability method (Assaad et al., 2013; Elhakim, 2016; Lei et al., 2020; Nagy et al., 2013; Zhang et al., 2020). Previous research conducted by Pratama et al. (2017) in Batang Regency analyzed the physical parameters of the soil such as grain size and permeability. Analysis of the distribution of soil particles using a sifter (40 mm, 60 mm, 80 mm, 140 mm, and 200 mm) was conducted in order to obtain the distribution of soil aggregate grains or soil structure in the form of clay, silt, sand, and gravel. Additionally, analysis of permeability is carried out to analyze the absorption of water in the soil using a hydraulic tool.

Similar research was also carried out by (Nurwidyanto et al. (2006) in Ngrayong, Kerek, Ledok, and Selorejo, namely analyzing the physical parameters of the soil namely soil grain size, porosity, and soil permeability. Determination of grain size was done by granulometric analysis method. This method applies the concept of precision or the approach of measuring the actual grain size and distribution. Rock porosity was measured using a gas porosimeter by measuring the length and diameter of each core. Permeability measurements were carried out using a gas permeameter by inserting the core, which has been measured for length and diameter, into the rubber stopper. Based on the explanation above this study aimed was to determine the grain size of the soil, the value of soil permeability, and the distribution characteristics of the soil in landslide-prone areas in Battang Barat Village, Palopo City.

Method

This research was conducted in West Battang Village, Palopo City. Before taken soils sampling, the researcher surveyed the research location by taking into account the geological conditions of the study area. Than soils sampling was taken around the landslide site on the Palopo – North Toraja axis road. The position data of each sampling point are also taken with the GPS (Global Position System) to determine the position of the research site. Sampling procedure, determine the point of sampling i.e. 30 points.

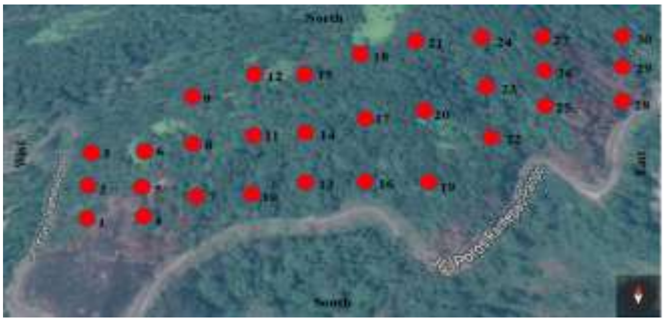

Figure 1. Map of soil sampling points (Google Earth)

And than the soil samples was taken randomly at the bottom, middle, and top part around the landslide site at 30 cm from the surface. Next, the soil samples were put in the plastic clips and taken to the laboratory to be tested of soil physical properties.

Result and Discussion

Grain Size Analysis

The grain sizes of the soil samples were determined with the sieve method. The results of the grain size distribution of the soil samples are shown in Table 1.

Table 1. Grain Size Distribution of Samples Taken from West Battang Village

Sample	Gravel (%)	Coarse Sand (%)	Medium Sand (%)	Fine Sand (%)
Point 1	7.95	4.29	73.21	14.38
Point 2	16.07	41.10	25.06	17.78
Point 3	15.63	8.55	37.28	38.54
Point 4	15.96	33.08	29.39	21.57
Point 5	13.72	33.39	34.84	18.04
Point 6	27.60	21.15	28.70	22.54
Point 7	31.55	33.58	22.40	12.48
Point 8	32.89	29.41	23.72	13.97
Point 9	5.64	19.29	51.27	23.82
Point 10	12.79	6.53	26.07	54.60
Point 11	27.34	23.08	11.24	38.35
Point 12	26.85	25.41	27.15	20.38
Point 13	27.60	21.15	28.70	22.54
Point 14	36.72	37.91	9.43	15.95
Point 15	4.41	11.26	29.53	54.79

Sample	Gravel (%)	Coarse Sand (%)	Medium Sand (%)	Fine Sand (%)
Point 16	27.79	34.90	25.00	12.31
Point 17	35.78	30.77	13.78	19.67
Point 18	30.31	29.00	24.25	16.44
Point 19	33.53	30.73	20.52	15.22
Point 20	32.92	30.07	12.37	24.63
Point 21	31.47	30.96	14.12	23.44
Point 22	30.27	31.84	10.92	26.96
Point 23	32.21	32.18	11.13	24.47
Point 24	32.31	34.07	21.27	12.55
Point 25	29.23	29.89	9.05	31.83
Point 26	26.53	21.09	17.48	34.90
Point 27	29.84	24.39	19.74	26.03
Point 28	29.27	33.38	29.27	8.07
Point 29	30.06	25.02	20.84	24.08
Point 30	27.31	31.05	19.23	22.40

Table 1 shows the soil sample contains gravel, coarse sand, medium sand, and fine sand, with a size of approximately 0.075–4.75 mm. The soil in the West Battang area is dominated by coarse sand grains. Soils dominated by coarse sand will have macro pores that allow water to pass quickly so that no water accumulation occurs. Meanwhile, soil dominated by fine sand has micropores that allow water to pass slowly, resulting in water accumulation (Isra et al., 2019; Kusuma et al., 2016).

Soil Grain Size Distribution

Based on the grain size distribution curve of the soil, the uniformity coefficient (Cu) and curvature coefficient (Cc) was obtained. The uniformity coefficient (Cu) and curvature coefficient (Cc) are the characteristics of the classification of soil physical properties, categorized as good or bad graded. The uniformity coefficient (Cu) and curvature coefficient (Cc) can be calculated using the following equation (Darwis, 2018).

$$Cu = \frac{D60}{D10} \quad (1)$$

$$Cc = \frac{D30^2}{D60 \times D10} \quad (2)$$

where D30 is the size of soil particles that pass 30%, D60 is the size of soil particles that pass 60, and D10 is the size of soil particles that pass 10%.

The distribution curve of the soil distribution of several samples taken from the West Battang Village is given in Figure 2. As seen in Figure 2, the distribution of soil is incomplete at all points. The silt grain size is only found at one point, namely at Point 12, and there are no clay grains. Based on Figure 2, D10, D30, and D60 are obtained. The data will then be used to obtain Cc and Cu values. The Cc and Cu results for all samples are presented in Table 2.

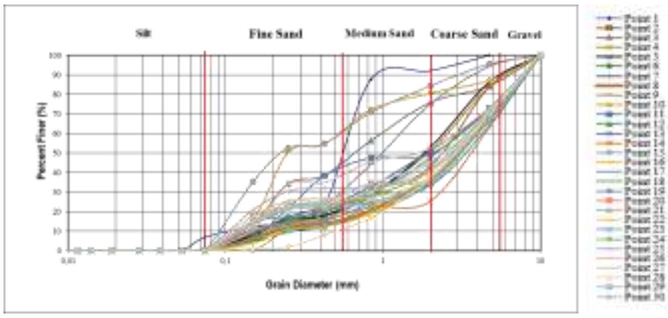

Figure 2. Soil grain size distribution in West Battang Village

Table 2. Uniformity Coefficient (Cu) and Curvature Coefficient (Cc) in Soil Samples Taken from West Battang Village

Sample	D10	D30	D60	Cu	Cc
Point1	0.10	0.45	0.60	6.00	3.38
Point2	0.17	0.80	3.00	17.65	1.25
Point3	0.06	0.12	0.50	8.33	0.48
Point4	0.20	0.80	2.50	12.50	1.28
Point5	0.27	2.10	5.50	20.37	2.97
Point6	0.15	0.70	3.00	20.00	1.09
Point7	0.15	0.70	3.00	20.00	1.09
Point8	0.20	1.50	4.00	20.00	2.81
Point9	0.17	0.55	1.55	9.12	1.15
Point10	0.06	0.09	0.30	5.00	0.45
Point11	0.21	0.60	7.00	33.33	0.24
Point12	0.15	0.90	3.00	20.00	1.80
Point13	0.15	0.70	3.00	20.00	1.09
Point14	0.07	1.00	1.80	25.71	7.94
Point15	0.06	0.07	3.00	50.00	0.03
Point16	0.21	1.50	3.50	16.67	3.06
Point17	0.06	0.50	1.80	30.00	2.31
Point18	0.17	1.00	3.50	20.59	1.68
Point19	0.15	1.50	4.00	26.67	3.75
Point20	0.06	0.35	1.60	26.67	1.28
Point21	0.21	3.00	8.00	38.10	5.36
Point22	0.11	1.10	3.50	31.82	3.14
Point23	0.11	1.50	4.00	36.36	5.11
Point24	0.25	1.80	4.00	16.00	3.24
Point25	0.10	0.25	3.50	35.00	0.18
Point26	0.15	0.21	3.00	20.00	0.10
Point27	0.06	0.31	1.50	25.00	1.07
Point28	0.50	1.50	3.50	7.00	1.29
Point29	0.11	0.85	3.50	31.82	1.88
Point30	0.12	0.85	3.50	6.00	3.38

Figure 2 is the result of the gradation analysis curve for all samples. In the distribution curve, the values of D10, D30, and D60 can be obtained, which are the percentage of soil that passes. From these data, the uniformity coefficient (Cu) and curvature coefficient (Cc) values are obtained, which are the physical characteristics of the soil classified as excellent or bad graded, presented in Table 2. Based on Figure 2 and Table 2, it is found that the soil with good grades is at Point 2, Point 4, Point 5, Point 6, Point 7, Point 8, Point 9, Point 12, Point 13, Point 17, Point 18, Point 20, Point 27, Point 28, and Point 29. The soil is poorly graded at Point 1, Point 3, Point 10, Point 11, Point 14, Point 15, Point 16, Point 19, Point 21, Point 22, Point 23, Point 24, Point 25, Point 26, and Point 30. Based on the uniformity coefficient (Cu) and the curvature coefficient (Cc) obtained show that the soil in the West Battang Village area consists of coarse and fine grains in the form of coarse sand gravel, medium sand, and fine sand with some good and some bad gradations (Darwis, 2018). In addition, the distribution curve of the soil distribution can be seen at all points consisting of incomplete soil grain sizes, namely only gravel, coarse sand, medium sand, and fine sand. The silt grain size is only found at one point, namely at Point 12, and there are no clay grains. Incomplete grain size can cause the existing grains not to fill each other and result in cavities. Therefore the land in West Battang sub-district is categorized as poorly graded soil (Pratama et al., 2017).

Soil Permeability

Soil permeability is a measure of how quickly water passes through a soil. The permeability test results of some soil samples are shown in Table 3.

Table 3. Permeability Value (k) of Soil Samples Taken from West Battang Village

Sample	Permeability (k) (cm/hour)	Category
Point 1	0.56	Moderately slow
Point 2	0.52	Moderately slow
Point 3	0.62	Moderately slow
Point 4	2.95	Moderately rapid
Point 5	0.68	Moderately slow
Point 6	0.68	Moderately slow
Point 7	27.68	Very rapid
Point 8	0.73	Moderately slow
Point 9	0.31	Slow
Point 10	0.26	Slow
Point 11	0.67	Moderately slow
Point 12	4.87	Moderately rapid
Point 13	1.02	Moderately slow
Point 14	0.66	Moderately slow
Point 15	0.73	Moderately slow
Point 16	0.26	Slow
Point 17	0.67	Moderately slow
Point 18	0.24	Slow
Point 19	0.32	Slow
Point 20	0.38	Slow
Point 21	0.40	Slow
Point 22	1.09	Moderately slow
Point 23	0.89	Moderately slow
Point 24	0.44	Slow
Point 25	0.39	Slow
Point 26	0.45	Slow
Point 27	0.56	Moderately slow
Point 28	0.64	Moderately slow
Point 29	0.45	Slow
Point 30	3.26	Moderately rapid

Table 3 shows Permeability Value (k) of soil samples taken from West Battang Village. The different permeability values are influenced by the distribution of different land sizes at each point. Soil with a permeability value between 0.0125–0.5 cm/hour includes soil that can absorb water slowly. Soils in this category are Point 9, Point 10, Point 16, Point 18, Point 19, Point 20, Point 21, Point 24, Point 25, Point 26, and Point 28. Soil samples with permeability values between 0.5 – 2.0 cm/hour, categorized as moderately slow, are Point 1, Point 2, Point 3, Point 5, Point 6, Point 8, Point 11, Point 13, Point 14, Point 15, Point 17, Point 22, Point 23, point 27, and Point 28. Soil with a permeability value of between 2.0 – 6.25 cm/hour is classified as soil with a moderately rapid ability to absorb water. Soils that fall into this category are at Point 4, Point 12, and Point 30. Soil with a permeability value of > 25.5 cm/hour includes soil that can quickly rapid absorb water. Soil sample that belongs to this category is at Point 7. Based on these results, the soil in the West Battang sub-district is dominated by soil types with a permeability of 0.5 – 2.0 cm/hour and can absorb water in category of moderately slow. Moderately slow permeability category can stimulate landslides due to gradually accumulation of water in the soils (Isra et al., 2019; Rusdi et al., 2015).

Conclusion

This work investigates physical properties parameters of the soil in landslide prone areas in West Battang Village, Palopo City. Experimental results showed that the grain size of the soil in the West Battang area consisted of gravel, coarse sand, medium sand, and fine sand, with grain size in the range of 0.075 – 4.75 mm. The grains soil in the West Battang Village is dominated by coarse sand. The physical characteristics of the soil grains in this area are classified as poorly graded due to incomplete grain size. The soil in the West Battang sub-district is dominated by soil types with a permeability of 0.5 – 2.0 cm/hour and can absorb water in category of moderately slow. These values can stimulate landslides due to gradually accumulation of water in the soils.

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