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Testing Soil Properties and The Stability of Sedimentation Retaining Wall in Tondano Lake - Minahasa

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ABSTRACT

Analysis of technical soil properties in terms of size, type, and pressure is needed for the proper development plan. Building plans, which include Sedimentation Retaining Wall, need to be able to create buildings that are safe, stable, and resistant to both vertical and horizontal forces. It requires shear resistance analysis (Pα), which is carried out through laboratory tests by estimating the value of cohesion, shear angle, soil fill weight, and density. When the shear resistance analysis has a value greater than 1.5, it means that the building is resistant to force.

Keywords — Soil, sediment, containment

INTRODUCTION

Proper stability analysis is very important in creating a safe building that needs to be resistant to vertical and horizontal forces. Planning for sedimentation retaining wall requires soil analysis, due to the mixtures of mineral grains with or without the content of organic matter derived from rock weathering physically or chemically. The technical properties of the soil such as its grain size, type, and pressure, are used to determine the vertical and horizontal forces.

Analysis of sedimentation retaining wall stability requires shear resistance to determine the active force of the soil/thrust (Pα), which was performed by estimating the value of cohesion, angle, and soil density, through laboratory testing.

This study aims to 1) obtain the values of soil shear angle (φ), soil cohesion (c) soil density (ɤ) and soil fill weight, and 2) know the resistance ability of Sedimentation Retaining Wall to shear force.

The method used is field study, with tests carried out in the Soil Test Laboratory, Department of Civil Engineering, State Polytechnic of Manado. Data were taken from the Tondano River and the Balai Wilayah Sungai Sulawesi 1, while the research was conducted from April to November 2019. Furthermore, the results of this study are published and reported.

LITERATURE REVIEW

Retaining Wall

Retaining walls are artificial and natural slanted walls used to hold water, soil, and sediments made of concrete and soil.

Soil

Soil consists of mineral grains with or without organic material content derived from weathering rocks physically or chemically.

Cohesive soil

Cohesive soils such as clay, silt, sandy or gravel consist of fine grains. The shear strength of this type of soil is determined primarily by its cohesion, which is generally low.

Silt and loess soils

The material in silt soil escapes the No. 200 filter and was further divided into plastic as well as non-plastic silts (Peck et al.) with the technical properties close to fine sand. Loess is defined as a silt material deposited by the wind with a grain diameter of approximately 0.06 mm, and adhesives particles due to the presence of calcium carbonate. This soil type has a moderate to high bearing capacity under dry conditions and the content of the binding material (clay or lime) and decreases or loses its stickiness due to saturation. It is generally a non-dense deposit with a volume weight of approximately 10 kN / m3 and found on almost all vertical cliffs.

Organic Soil

Organic soil contains organic matter, which affects its technical properties. Its amount is the comparative value between the weight and the soil dried by the oven.

Non-cohesive Soil

Contains very little or no attachment between the grains, for example, sand.

Forces in Sedimentation Retaining Wall

The forces in the construction of the sedimentation retaining wall need to be planned to avoid exceeding the allowable stress. The magnitude and direction of the soil pressure tend to overthrow or shear the embankment construction. The forces which affect the stability of the Sedimentation Retaining Wall :

a. Active soil pressure; Groundwater changes the characteristics of the soil behind the embankment.
b. Hydrostatic force; Hydrostatic force is the horizontal force due to water contained in the up and downstream. Hydrostatic pressure is a function of the depth below the water surface and works perpendicular to the face of the building. Its pressure is influenced by gravity and depth, with the entire inner surface of the dike affected.
c. Passive soil pressure

Stability against Shear

Active soil force (Pα) not only creates moments but also thrust against the dike, with the soil barrier stability used to determine the force balance (ΣF = 0 and ΣM = 0). The resistance occurs in the contact area between the soil at the base of the dike and the foundation.

Formula:

$$SF = \frac{F.\sum(V)}{\sum H} \geq 1{,}5 \quad \text{(Required safety factor)}$$

Where:

Σ (H) = Overall horizontal force on the construction (kN)
Σ (V) = Overall vertical force (kN)
F = Friction Coefficient
SF = Safety factor

METHODOLOGY

This research began with a literature review on technical soil properties, stability, and testing methods based on applicable standards. The samples were tested and analyzed at the Soil Test Laboratory of the Civil Engineering Department of Manado State Polytechnic. The results of this study are presented, publicized, used as Soil Mechanics teaching material and reported in the form of a research report booklet.

RESULT & DISCUSSION

Active soil force (Pα) does not only cause moments but also pushes forces on the walls of dikes, while Dam stability is used to determine the balance of forces (ΣF = 0 and ΣM = 0). Also, resistance occurs in the contact area between the basic soils of construction and foundation.

$$SF = \frac{F.\Sigma(V)}{\Sigma H} \geq 1{,}5\ (Required\ safety\ factor)$$

Where:
Σ (H) = Overall horizontal force on the construction (kN)
Σ (V) = Overall vertical force (kN)
F = Friction Coefficient
SF = safety factor

The existing and non-existent values were analyzed at the Manado State Polytechnic Soil Test Laboratory with data, as shown in table 1.

Table 1. **Examination of Soil Specific Gravity**

LABORATORIUM UJI TANAH
JURUSAN TEKNIK SIPIL – POLITEKNIK NEGERI MANADO
Alamat : Kampus Politeknik Ds. Buha Manado 95252
Telp. (0431) 812988, 811568, Fax. (0431) 811568

PEMERIKSAAN BERAT JENIS (Gs)
(ASTM D 854-83)

Proyek : Praktek – Penelitian	Tanggal :
No. Sampel :	Dikerjakan :
Kedalaman :	Diperiksa :

Flaks No.		1	2
Berat Flaks	W_1 (gram)	30.97	33.97
Berat Flaks + Tanah Kering	W_2 (gram)	76.88	82.74
Berat Tanah Kering	$W_3 = W_2\text{-}W_1$ (gram)	45.91	48.77
Berat Flaks + Tanah Kering + Air	W_3 (gram)	158.73	163.05
Berat Flaks + Air	W_4 (gram)	132.51	134.99
Temperatur	(°c)	29	29
Faktor Koreksi Temperatur	(K)	0.9995	0.9995
Berat Flaks + Air Terkoreksi	(W_5)	132.44	134.92
Berat Jenis Tanah	$W_3/[(W_5\text{-}W_1)\text{-}(W_3\text{-}W_2)$	2.340	2.363
Berat Jenis Tanah rata-rata	(Gs)	2.352	

Source: Laboratory Test Results

Table 2: **Soil volume-weight test**

LABORATORIUM UJI TANAH
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PEMERIKSAAN BERAT ISI TANAH
(ASTM D 2937-83)

Proyek : Praktek – Penelitian	Tanggal :
No. Sampel :	Dikerjakan :
Kedalaman :	Diperiksa :

Ring No.		1	2
Berat Tanah + Ring	(gram)	159.32	158.76
Berat Ring	(gram)	51.36	51.36
Diameter Ring	(cm)	6.30	6.30

Tinggi Ring	(cm)	1.90	1.90
Volume Ring	(cm3)	59.20	59.20
Berat Tanah	(gram)	107.96	107.40
Berat Isi Tanah	(gram/cm3)	1.82	1.81
Berat Isi Tanah Rata-Rata	(gram/cm3)	1.8190	

Source: Laboratory Test Results

Table 3: **Direct Shear test**

LABORATORIUM UJI TANAH
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PERCOBAAN GESER LANGSUNG

(ASTM D 3080)

Proyek : Praktek – Penelitian Tanggal :
No. Sampel : Dikerjakan :
Kedalaman : Diperiksa :

Diameter : 6.3 cm Tinggi : 1,9 cm
Luas : 31.68 cm^2 Kalibrasi : 0.4093

Normal Force		P_1	5	Kg	P_2	10	Kg	P3	15	Kg
Normal Stress		σ_1	0.158	Kg/cm 2	σ_2	0.316	Kg/cm²	σ3	0.473	Kg/cm 2
Time	Δ□	Dial	Shear	Shear	Dial	Shear	Shear	Dial	Shear	Shear
(min)	(mm)	Reading	Force	Stress	Reading	Force	Stress	Reading	Force	Stress
0.00	0.00	0.0	0.000	0.000	0.0	0.000	0.000	0.0	0.000	0.000
0.15	0.25	8.5	3.479	0.110	9.2	3.766	0.119	12.0	4.912	0.155
0.30	0.50	10.0	4.093	0.129	13.5	5.526	0.174	16.2	6.631	0.209
0.45	0.75	10.2	4.175	0.132	16.2	6.631	0.209	19.2	7.859	0.248
1.00	1.00	10.9	4.461	0.141	18.0	7.367	0.233	21.8	8.923	0.282
1.15	1.25	11.6	4.748	0.150	19.8	8.104	0.256	23.5	9.619	0.304
1.30	1.50	11.9	4.871	0.154	19.9	8.145	0.257	24.1	9.864	0.311
1.45	1.75	11.9	4.871	0.154		0.000	0.000	24.1	9.864	0.311
2.00	2.00	12.0	4.912	0.155		0.000	0.000	25.7	10.519	0.332
2.15	2.25	12.3	5.034	0.159		0.000	0.000	25.7	10.519	0.332
2.30	2.50	12.3	5.034	0.159		0.000	0.000	25.7	10.519	0.332
2.45	2.75	12.5	5.11	0.161		0.000	0.00	25.7	10.51	0.332

			6				0		9	
3.00	3.00	12.5	5.116	0.161		0.000	0.000		0.000	0.000
3.15	3.25	12.5	5.116	0.161		0.000	0.000		0.000	0.000
3.30	3.50					0.000	0.000		0.000	0.000
3.45	3.75					0.000	0.000		0.000	0.000
			$T_{1\text{-}max}$	0.161		$T_{2\text{-}max}$	0.257	$T_{3\text{-}max}$	0.332	

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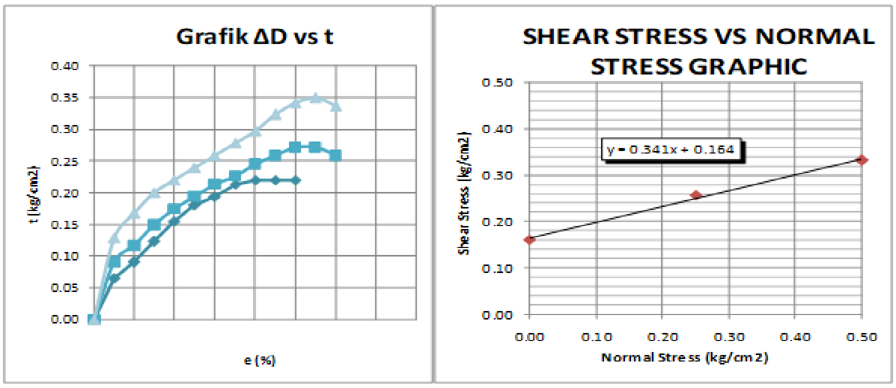

Source: Laboratory Test Results

Calculation of Analysis of Sedimentation Retaining Wall Stability on Shear

1. Calculate the volume weight of dry soil

$$\gamma d = \frac{Gs \times \gamma w}{1+e} \qquad \gamma d = \frac{2.351 \times 1}{1+e} \quad \rightarrow e = \frac{n}{1-n}$$

$$n = \frac{0.003}{0.024} = 0.125 \qquad e = \frac{0.125}{1-0.125} = 0.1428$$

$$\gamma d = \frac{2.351 \times 1}{1+0.1428} = 2.4936 \text{ gr/cm}^3$$

2. Calculate the volume weight of saturated soil γsat

$$\gamma sat = \frac{\gamma w \times (Gs + e)}{1+e} = \frac{1 \times (2.351 + 0.1428)}{1 + 0.1428} = 2.182 \text{ gr/cm}^3$$

3. Calculate the weight of the embankment

This calculation is divided into 4 (four) parts

$$W1 = 2{,}5 \times 1{,}58 \times 1{,}819 = 7{,}185$$

$$W2 = \frac{(2{,}58 + 3{,}58)}{2} \times 2 \times 1{,}819 = 11{,}205$$

$$W3 = 6 \times 3{,}58 \times 1{,}819 = 39{,}072$$

$$W4 = \frac{(3{,}58 + 1{,}58)}{2} \times 4 \times 1{,}819 = 19{,}523$$

t_{otal} = 76,985 gr/m3

4. Calculate the center of gravity

$$x1 = 2{,}5 \times \frac{1}{2} = 1{,}25\text{m}$$

$$x2 = 2{,}5 + \left(\frac{2{,}59 + (2 \times 3{,}58)}{2{,}58 + 3{,}58}\right) \times \frac{2}{1} = 5{,}662M$$

$$x3 = 5{,}662 + \left(\frac{1}{2} \times 6\right) = 8{,}662M$$

$$x4 = 8{,}662 + \left(\frac{1{,}58 + (2 \times 3{,}58)}{1{,}58 + 3{,}58}\right) \times \frac{2}{1} = 12{,}05M$$

5. Active soil pressure

Ka = Tg²(45°- Ø /2) = tg²(45°-18.83/2) = 0,511

Pa = 0,5 x ɣe* x h2² x ka = 0,5 x 0,3116 x 1,58² x 0,511 = 0.198 gr/m

6. Hydrostatic pressure

Pw = 0,5 x ɣw x h1² = 0,5 x 1 x 2,58² = 3,328 gr/m

7. Passive soil pressure

Kp = Tg² (45°+ Ø /2) = tg² (45°+18,83/2) = 1,95

Pp = 0,5 x ɣ* x h2² x kp = 0,5 x 0,3116 x 1,25² x 1,95 = 0,474 gr/cm

8. Shear stability

$$SF = \frac{F.\sum(V)}{\sum H} \geq 1{,}5 \text{ (Required safety factor)}$$

$$SF = \frac{0{,}3 \times (76{,}985)}{(0{,}0198 + 3{,}328) + (-)0{,}474}$$

= 7,569 ≥ 1,5 (safe against shear)

CONCLUSIONS

Based on the results of the study, it is concluded that: The Sedimentation Retaining Wall is declared safe because its value is greater than 1.5 (required safety factor), even without gabion reinforcement. Soil and water pressure are very influential in calculating the stability of the Sedimentation Retaining Wall.

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