Analysis Slope Stability And Seepage Logung Dam – Kudus Central Java

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Abstract - Logung Dam is located in Dukuh Slalang, Tanjungrejo Village, Jekulo District and Dukuh Sintru, Kandangmas Village, Dawe District. Logung Dam has an area of inundation of 144.06 ha and a normal catch of 20,150,000 m3. This analysis is to know the safety of the slope and seepage with the result of the approaching analysis so that it can give it to the dam. Zone analysis conducted with the location of the dam, physical testing of the material in the clay laboratory (zone 1), sand (zone 2), random (zone 4), show the results indicating the soil as the analysis material meets the dam requirements. Analyze the data required by the planner's consultant in the laboratory. Soil parameter data used in PLAXIS 8.6 and Geostudio 2007 programs: cohesion, c; Sliding angle in soil, φ; Slope angle, α; And the weight of the volume of land, γ; Modulus of elasticity, E; Permeability, k; And poisson ratio, From soil parameter data can be found nialai cohesion (c) = 0.457, shear force (φ) = 15° 02 '38 ", slope angle (α) = 1:30 upstream, 1:35 downstream and volume weight Soil (γ) = 32.56 from PLAXIS data at the value of deformation = 26.46 m, active pore pressure = -927.61 m, effective soil voltage -2.70x10-3 kN / m2; down slope safety = 1, 26 and seepage = 46,41x10-3 From geostudio program can obtain upstream slope safety factor = 1.41, downhill slope security = 1.23 and seepage = 63.30x 10-3.Air dam safety analysis to normal safe, For seepage safety by grouting or injection of cement on the ground beneath the foundation along the dam.
***Keywords*:** Analysis, Security Factor, Plaxis and Geostudio

1. Introduction

Kudus Regency is a regency in Central Java province, most of its people work in agriculture sector which is in need of air for agricultural purposes and raw water for drinking water. Dry season in this district often experience drought and during the rainy season is always flooded due to overflow of rivers in the mountains of Muria. Based on the above, then one alternative that can be done is the construction of a dam as an air container in the rainy season and can be used efficiently in the dry season.

Kudus District through the Ministry of Public Works and People's Housing builds Logung Dam in Dukuh Slalang, Tanjungrejo Village, Jekulo Sub-District and Dukuh Sintru, Kandangmas Village, Dawe District. Logung Dam is planned to have an area of inundation of 144.06 ha and a normal catch of 20,150,000 m3. The availability of Dam Logung building is expected to reduce the flood disaster in Kudus and surrounding areas, and will directly improve the living standards of local communities.

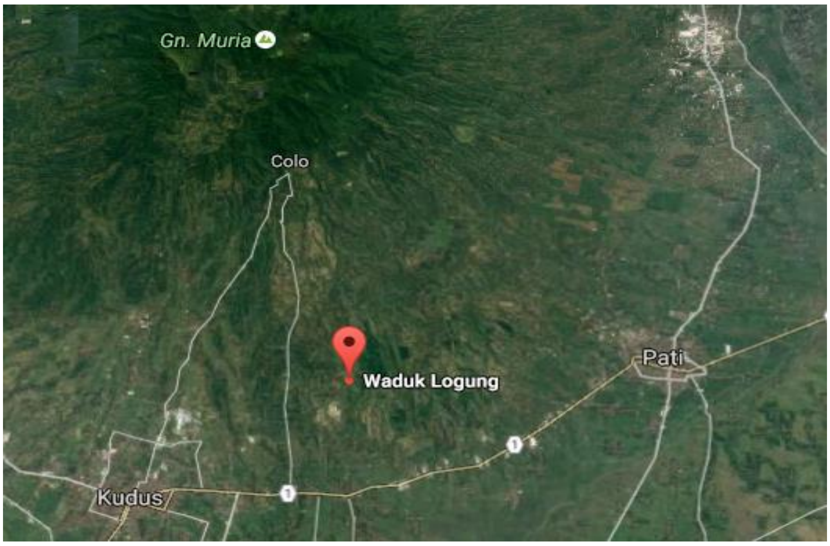

Figure 1. Location of Logung Dam (Google Earth)

The location of the work is at the downstream of the River Logung encounter with the Gajah River in Dukuh Slalang, Tanjungrejo Village, Jekulo District with the position of 06o 45 '28.38 "LS and 110o 55' 20.27" BT. While the inundation area into the area Hamlet Sintru, Village Kandang Mas, Dawe District and Dukuh Slalang and Village Tanjungrejo, District Jekulo all of which entered in the area of Kudus District. To go to the project location can be reached by landline. It takes about 2 hours from Semarang City to get to the project location with 2 or 4 wheeled vehicles. Whereas from Kudus City can be reached for 30 minutes as far as + 15 km or from the Kudus - Pati Highway entering as far as + 5.5 km towards north up to Dukuh Slalang Desa Tanjungrejo

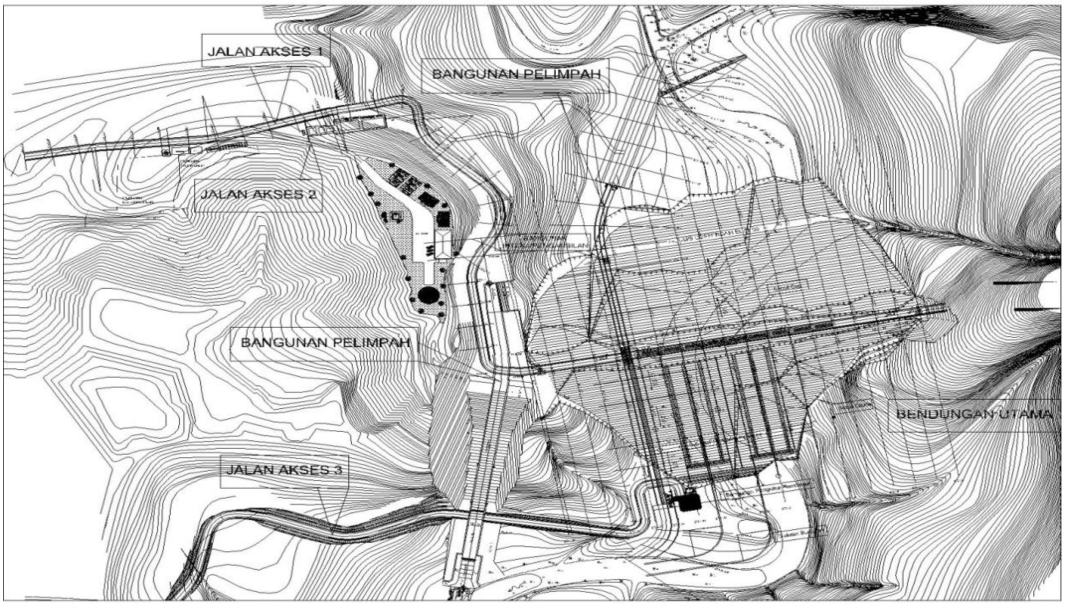

Figure 2. Lay Out Bendungan Logung

With the analysis of the slope and seepage to determine the security obtained by the dam in order to find the field conditions with the results of the analysis approaching in order to provide. In order for the age of the dam plan to be met, then the dam that is built must have a high durability as well. Therefore, in the planning, the dam must be tested for its strength and power in the presence of danger of slope collapse, piping, earthquake, and other factors capable of threatening the stability and durability of the dam. The data in Table 2.2. shows the percentage of causes of failure at the dam from before and after 1950 to 1986.

Tabel 1. Statistics of dam failures type urugan 1986

(Foster et al., 1998, 2000)

NO	Penyebab Kegagalan	Total Kegagalan (%)	Kegagalan Sebelum 1950 (%)	Kegagalan Sesudah 1950 (%)
1	*Overtopping*	34,2	36,2	32,2
2	Kerusakan *Spillway*	12,8	17,2	8,5
3	*Piping* pada timbunan	32,5	29,3	35,5
4	*Piping* pada fondasi	1,7	0	3,4
5	*Piping* dari tubuh ke fondasi	15,4	15,5	15,3
6	*Down stream slide*	3,4	6,9	0
7	*Upstream slide*	0,9	0	1,7
8	Gempa	1,7	0	3,4
	Total overtopping dan kerusakan *spillway*	48,4	53,4	40,7
	Total *Piping*	46,9	43,1	54,2
	Total *sliding*	5,5	6,9	1,6
	Total seluruh kegagalan	124	61	63

From the data in Table 2.2, it can be concluded that the biggest cause of dam failure is piping events, namely the presence of water seepage that passes both the dam body and the foundation so as to carry the fine materials continuously and result in the porous filler material which eventually causes the dam to fail. Based on the urgency of the dam role and the above failure problem, the writer has the ability to do geotechnical analysis to the stability of the slope and seepage security.

2. Problem Formulation

Based on the description above, then the problem studied in this research is as follows:

a. Conservation of the Environment and Society how to safeguard Log dams on slope stability and seepage, in an effort to protect and preserve society. Therefore, with the dams Logung is expected to reduce floods and drought and the safety justification of the dam meets the expected safety criteria.

b. Justification of Dams, Materials used for pile of dams logung bodies must meet the criteria of planned receipts. Moreover, the security justification on log dam to slope stability due to normal load in 3 conditions is stady state, rapid drawn, after contruction, and logging safety justification. Logung against seepage hazard in 3 conditions ie safety boling, phreatic analisysis, seepage quantity using program aid Plaxis version 8. 6 and Geostudio 2007.

3. Research Objectives

a. Encourage all relevant stakeholders (SKPD) / stakeholders to synergize their respective functions and roles in flood control for success.
b. Availability of a safe dam building against the stability of the slope and seepage, located on the slopes of the muria that can reduce the flood disaster in the area of the holy district and surrounding areas.

4. Research Methodology

Study will use several methods to answer all the sub-question is needed. These methods include:

The approach used is qualitative approach with research data collecting stage through observation, in-depth interview to BBWS agency (Balai Besar Wilaayah Sungai Pemali Juana, Indra Karya Planning Consultant, Consultant of Virama Karya Inspector, Wijaya Karya Contractor and Nindya Karya) and direct observation and testing while on duty in the dam field Logung Kudus Central Java.

5. Result and Discussion

5.1. Dam Requirements

In this discussion for the requirements used as the reference material acceptance criterion literature using united state bureau reclamation (USBR), calculation of slope stability (RSNI-M-03-2003), seep stability calculation (Look, 2005) and various other related literature. From the results of the study, the dimensions of the log dams shown in Figure 4.2 and the dam of the dam are shown in Table 4.1.

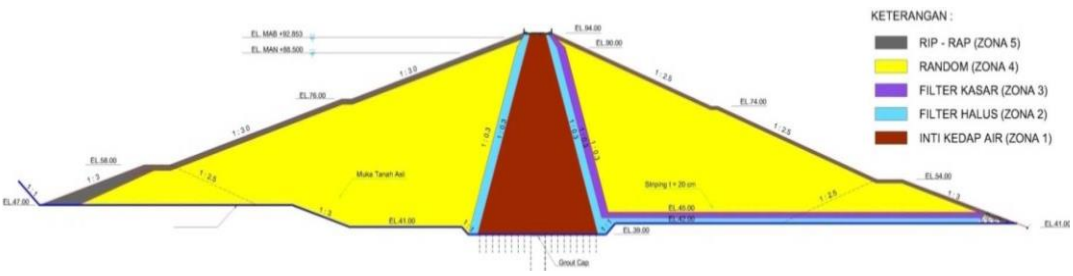

Figure 3. A typical cross section of a logging dam

Furthermore, a slope dam analysis is mounted against the slope according to the USBR standard.

Tabel 2. Analysis of the slope of the dam to the slope of the standard USBR

Zona		Dipasang	USBR	Komentar
Luar	Hulu	1:3	1:2	Lebih landai
	Hilir	1:2,5	1:2	Lebih landai
Inti	Hulu	1:0,3	1:2	Lebih curam
	Hilir	1:0,3	1:2	Lebih curam

Seen from Table 4.1. core zone is designed with a steeper slope than the standard USBR. To check whether the dam has adequate security associated with slopes that are steeper than the standard then be modeled by using plaxis and geostudio 2007 software. In analyzing the stability of the slope and seepage of logs Logs used the parameters listed in tabel 3 and tabel 4.

Table 3. Parameters of embankment and foundation of Logung dam

Material	Zona	k (m/dt)	γ_{sat} (kN/m^3)	γ_{unsat} (kN/m^3)	c (kN/m^2)	Φ (°)
Inti (core)	1	6.253E-06	18,200	16,670	45,7	25
Filter Halus	2	7.703E-03	18,00	15,00	0	40
Filter Kasar	3	0.508	21,00	16,00	0	40
Random	4	2.501E-04	19,550	15,800	18	20
Rip Rap	5	6,38E-01	21,00	17,00	0	40
Sandstone	-	1.000E-04	21,00	17,00	20	33
Tuff lapli	-	1.000E-05	17,670	12,050	72,92	26,67

Table 4. Selection of material behavior type (Duncan,1992)

	End of construction	Condition rapid draw-down and stage construction	Normal operating ("steady seepage")
Analysis prosedureand shear strength for free draining zones – filters, rockfill, sand/gravel in foundation	Effective streaa analysis using c', φ'	Effective stress analysis using c', φ'	Effective stress analysis using c', φ'
Analysis procedure and shear strength for low permebility zones	Total stress analysis using S_u and φ_u (1) or effective stress analysis modelling partially saturated conditions	Total stress analysis using S_u and φ_u (1) for the dam prior to draw down or construction of the second state	Effective stress analysis using c', φ', unless soils are constractive(2) in which case use Su measured in the dam
Internal pore pressures	No internal pore pressure (u) for total stress analysis; set u equal to zero in these zones. Pore pressures determined from laboratory tests for effective stress analysis	No internal pore pressures (u) for total stress analysis; set u equal to zero in these zones. Pore pressures from seepage analysis for effective stress analysis	Pore pressures from seepage analysis and/or from piezometer readings for effective stress analysis
Reservior water	Include (usually as a zone with c' = 0, φ' = 0. γ = 9,8 kN/m^3)	Include (usually as a zone with c' = 0, φ' = 0. γ = 9,8 kN/m^3)	Include (usually as a zone with c' = 0, φ' = 0. γ = 9,8 kN/m^3)
Unit weights (3)	Total	Total	Total

Notes:

(1) S_u and φ_u describe the undrained strength envelope, so the variation in undrained strength, with increase in total stress, can be modelled in the anallysis.
(2) Contiguous soils include the compacting of a highly uncompacted saturated clay, normally consolidated clay and light, effective stressanalysis which ignores the pore pressures generated at the cut exceeds the estimated safety factor
(3) For free draining zones γ_{dry} or γ_{moist} for zones above water, γ_{sat} below. For low permeability zones, use γ_{dry} or γ_{moist}

5.2. Output and Security Justification

Justification of dam security is done after the obtained modeling output is the slope stability from normal and seepage analysis. So in doing the security justification of some related literature. The following is a description of the logging dam security justification:

- **Slope Stability Against Normal Load**
  Justifying the safety of the slope of the dam is done by comparing the value of the security factor of the modeling to the requirements security factor. The dam is said to be safe if the SF modeling value is greater than SF requirements (SF modeling> SF requirements). It appears that in Table 4.12 for all loading conditions SF modeling, both with plaxis 8.6 and with geostudio 2007, is always greater in SF requirements (RSNI M-3-2003 and Lambe, 1969; sherard et al., 1963) so it can be concluded that the safety of the dam slope is stable against various loading conditions.

Table 5. Justifying the safety of the dam slope to normal load

No	Kondisi	SF pemodelan		SF persyaratan		Aman/ Tidak
		Plaxis 8.6	Geostudio 2007	RSNI M-03-2002	Lambe, 1969 ; sherard et al.,1963	
1	After construction					
A	Hulu	-	1.410	1,3	1,4	Aman
B	Hilir	1.26	1.299	1,3	1,4	Aman
2	Steady state					
A	Hulu	-	3.174	1,5	1,5	Aman
B	Hilir	1.2144	1.045	1,5	1,5	Tidak Aman
3	Rapid draw down					
A	Hulu	-	1.267	1,2	1,2	Aman
B	Hilir	1.2071	1.174	1,2	1,2	Aman

- **Seepage Safety**
  The safety of the dam against the danger of seepage is seen based on several factors Debit seepage.
  Based on the model, the seepage discharge at the lower end of the foot is obtained as follows:
  Plaxis 8.2: 0.04641 m3 / days = 46,410 liters / days
  Geostudio: 0.063054 m3 / days = 63,054 liters / days
  While the following is a security requirement of seepage discharge in table 6.

Table 6. Security seepage discharge (look, 2005)

Dam height (m)	Seepage,litres/day/metre,(Litres/minute/metre)	
	O.K	Not O.K
< 5	<25 (0.02)	>50 (0.03)
5-10	<50 (0.03)	>100 (0.07)
10-20	<100 (0.07)	>200 (0.14)
20-40	<200 (0.14)	>400 (0.28)
>40	<400 (0.28)	>800 (0.56)

Based on the above requirements table with high dam> 40 m permit discharge is 400-800 liters / days while the modeling results show that the seepage discharge that occurs greater than the permit discharge. So it can be concluded that securely discharge seepage, the dam is safe.

- Influence of Phreatic Lines

A dam is said to have safety against seepage, if the phreatic line formed is captured by the vertical drain and is ejected through the horizontal drain. The form of line phreatic line itself can be observed by doing modeling. In this analysis, the result of phreatic line modeling with geostudio 2007 and plaxis 8.6, the phreatic form obtained is the same. The line runs straight through rock fill and filter, then down periodically on clay, then captured by vertical drain (sand) to be removed through the horizontal drain. From the phreatic line behavior above, it can be concluded that the outward phreatic line does not cut the body of the dam but through the horizotal drain. So the dam is safe by phreatic line analysis.

- Security Against Boiling Events

The boilling event is the inability of the gravity (overburden) to withstand lift (up lift) due to seepage. This event took place in a long time, and the location of occurrence around the foot of the dam downstream. If this event occurs then it will lead to a sufosi or internal erosion of material that impact on the dam instability. Dam safety against boilling events can be seen from the results of seepage modeling with Gestudio 2007 and plaxis 8.6 by removing the maximum gradient (Imax) information from the stain located around the downstream heel of the dam. Security analysis of boilling events is given in Table 7.

Table 7. Dam security analysis of boiling events (Christady, 2010: 220)

Nodal	X-Gradient	Y-Gradient	XY Gradient	I max	Icr	FS bolling	FS syarat	OK/ not OK
(1)	(2)	(3)	(4)	(6)	(7)	(8)=(7/6)	(9)	(10)
539	0,043705	1,800050	1,800050	1,800050	1	0,56	4	Not Ok
557	0,603454	3,698458	3,747366	3,747366	1	0,267	4	Not OK
574	0,015452	0,055856	0,057954	0,057954	1	17,24	4	OK
575	0,060480	2,757539	2,758202	2,758202	1	0,362	4	Not OK
595	0,006338	0,058239	0,058583	0,058583	1	17,24	4	OK
635	0,066016	3,865494	3,866058	3,866058	1	0,26	4	Not OK
636	0	3,757576	3,757576	3,757576	1	0,266	4	Not OK
637	0	-0,042485	0,042485	0,04248	1	25	4	OK
638	-0,001945	-0,053476	0,053511	0,053511	1	18,87	4	OK
648	-1,754557	3,757576	4,147029	4,147029	1	0,241	4	Not OK
657	-0,195249	0,401365	0,446336	0,44633	1	2,22	4	Not OK
667	-0,022551	0,046052	0,051277	0,051277	1	20	4	OK

➢ **Repair Dam**

Due to the dam safety requirements are not achieved, then the dam is done by grouting. Grouting is to inject the cement into the foundation rock in order to cover the cracks and joints between the podation rock structures so that the strength and pallidity of the rocks can increase. At logging dam is done cementation or grouting with a depth of 10-30 m and the distance between the cementation holes is 1.5-3 meters. Based on modeling after grouting, the seepage discharge at the bottom of the foot downstream is obtained as follows Q seepage: 0.168 m / days = 168 liters / days. Semtara based on the above requirements table with high dam> 40 m permit seepage permit plan is 400-800 liters / days while the model results show that the seepage discharge that occurs is in the range of requirements. So it can be concluded that securely discharge seepage, the dam is safe. Based on the results of the dam improvement analysis of the boiling hazard that has been done, it can be said that the dam Logung safe against various conditions due nilia Fs arithmetic ≥ Fs permit.

6. Conclusion

Here is the conclusion of geotechnical analysis of logging bridge to seepage security and slope stability, including:

a. Laboratory testing and comparative study with secondary data for clay soil material (moisture material), sand and gravel slag (filter zone filler), and random soil material (zone 4) material as feasibility analysis material spec and filter zone filler requirements and waterproof.
b. From the secondary data study, the feasibility analysis of rip-rap materials and foundation rocks, as filler of dam structure components, obtained the result that both materials are feasible to be used based on requirement and related literature study.
c. With plaxis 8.6 and seep / w (geostudio), a safety analysis of dams on seepage hazard has been carried out, including seepage discharge, phreatic line observation, and boiling hazard, showing mixed results. The dam is declared safe on phreatic and unsafe analyzes on seepage discharge and boiler hazard analysis.
d. With plaxis 8.6 and slope / w (geostudio), stability of the slope of the dam has been carried out against the normal loads in three conditions: steady state, after contruction, and rapid draw down which shows that the dam is declared safe in all three conditions

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