p–ISSN: 2723 - 6609 e-ISSN: 2745-5254
Vol. 5, No. 4 April 2024 http://jist.publikasiindonesia.id/

Seepage handling using a secant pile as a solution to replace curtain grouting and dam stability evaluation to optimize work on the Margatiga Dam construction project.

Ahmad Sidik
Institut Teknologi Sepuluh November Surabaya, Indonesia
Email: ahmad.sidik@waskita.co.id
*Correspondence

Keywords: Seepage Management; Secant pile; Stability; Margtaiga Dam.

ABSTRACT

Based on the results of a soil investigation using the bore log method carried out by the Consultant, it was found that the foundations of the spillway building and intake building are in a geological condition that is composed predominantly of sand and porous deposits or quickly absorbs water, as well as rocks with the characteristics of OK tuff rock, indicating that the foundation The building is prone to seepage. The seepage treatment contained in the contract is the curtain grouting method 20 meters deep with a distance of 2 meters between points. To be sure, it is necessary to carry out trial grouting in 3 location zones. Therefore, it is necessary to analyze the second pile design. In filling the dam body on the left and right sides, a review needs to be carried out to optimize the implementation of the work because it has a safety factor that is too high than the required safety factor. Secant pile design planning and cross-section evaluation calculations use software to help calculate seepage and stability analysis. Based on the results of modeling analysis calculations and evaluation of cost and implementation time calculations that meet the criteria, it is recommended to handle seepage using secant piles, namely with dimensions of 80 cm, overlap of 15 cm, and a depth of up to -10 elevation and recommendations for the cross-section of the dam body, namely by modifying the slope of the section.

Introduction

Margatiga Dam Construction Work is in Jemanten State Village, Margatiga District, East Lampung Regency, Lampung Province (Saidillah & Artati, 2022). The river used to construct the Margatiga Dam is the Way Sekampung River (Yulikasari, Utama, & Purwanto, 2017). The Way Sekampung River has the potential to meet the needs of irrigation water, raw water, and electricity. For the construction of the Margatiga Dam itself that has benefits for meeting the irrigation water needs of the Jabung area, reducing flooding, and tourism (Azizah, 2022). The map of the Margatiga Dam project location can be seen in Figure 1.

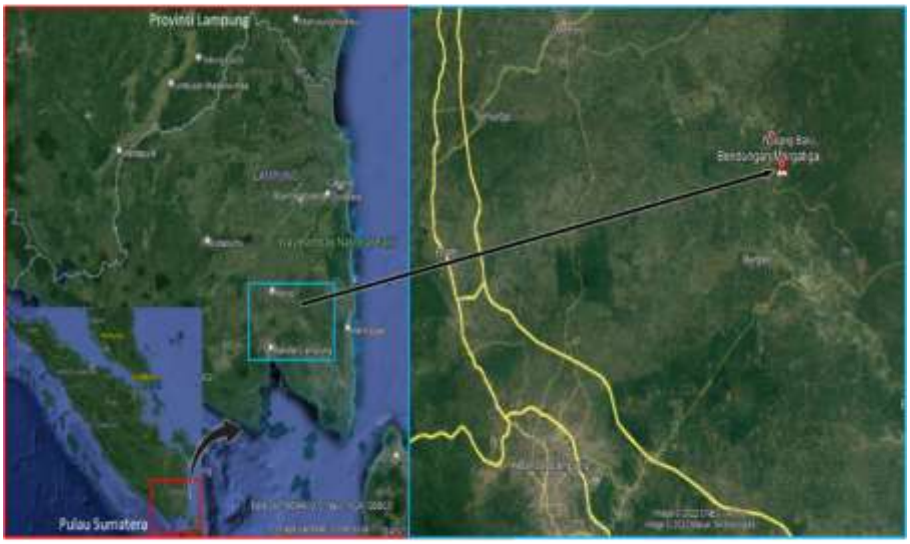


Figure 1 Location of Margatiga Dam (Google Earth, 2022)

Dam construction on the Way Sekampung River applies a casecade system or a serial or multilevel construction system along the river with a certain distance, or often (Pitaloka, Khamim, & Lydianingtias, 2021). Margatiga Dam is fourth in the series of schemes for the utilization of the Way Sekampung river seen in Figure 2.

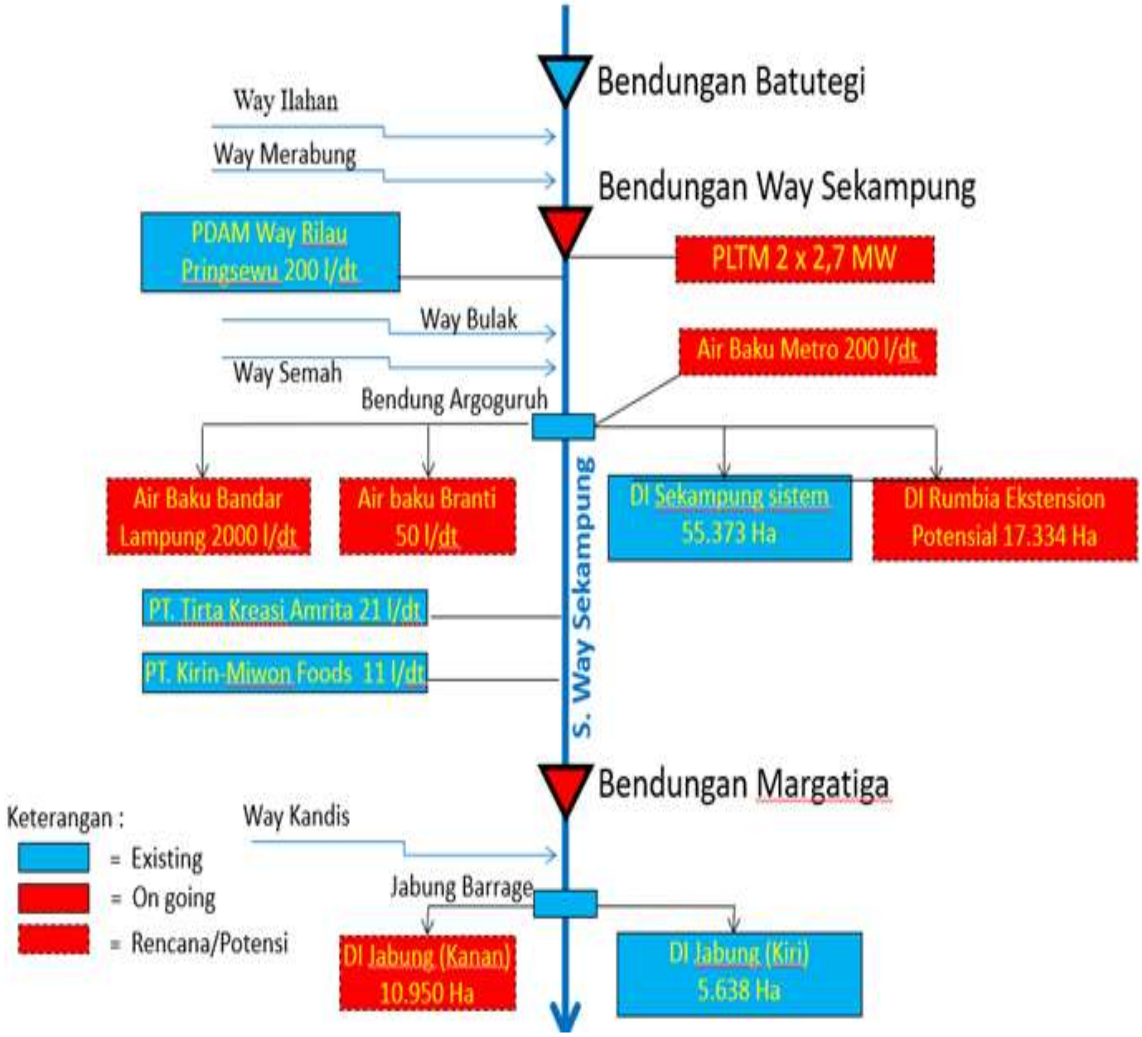


Figure 2
Way Sekampung River Management Scheme (Waskita - Adhi KSO Margatiga Dam Project, 2022)

Margatiga Dam has a dam design type, namely a composite type dam with a combination of a gravity type concrete dam (concrete gravity dam) and a rock dam with an upright core (Sidik, 2024). Margatiga Dam will have a water storage capacity of 29.96 million m3 for normal conditions or NWL (Normal Water Level) and 42.31 million m3 for flood conditions or HWL (High Water Level). Margatiga Dam has a length of 321.76 m, with the right and left parts being the type of Arakan dam with an upright core, while in the middle of the dam is a type of concrete dam with spillway building types and retrieval buildings (Azizah, 2022). The spillway building is of the ogee spillway type, and in the retrieval building, there are 2 types of doors: radial doors totaling 3 units and funnel doors totaling 1 unit.

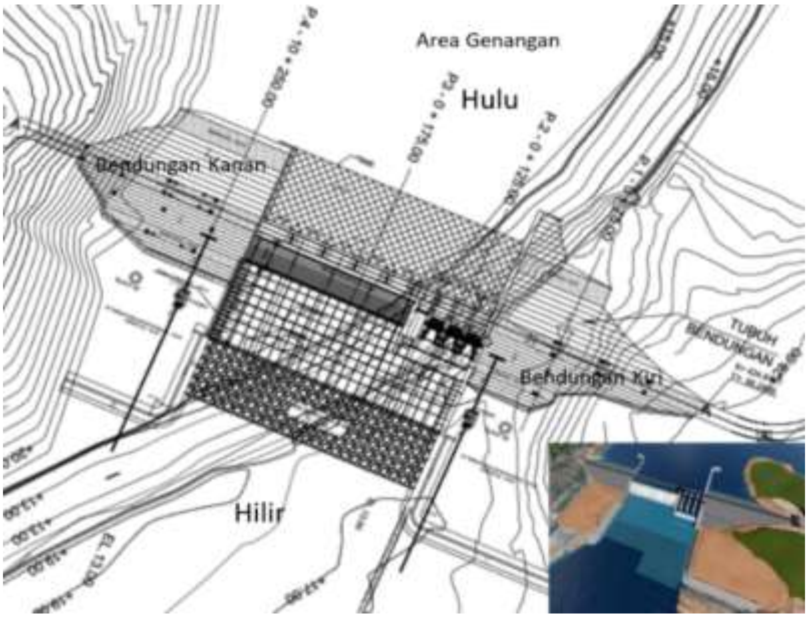


Figure 3
Layout and 3D Model of Margatiga Dam (Waskita - Adhi KSO Margatiga Dam Project, 2022)

From the results of geological mapping or interpretation of the correlation of engineering geological cross-sections that have been seen in the condition of the layout and subsurface of the dam axle, it can be seen that the rock units contained in the cross-section are as follows:

1. Alluvial deposits: Found along the Way Sekampung River, which dominates 35% of the employment area. Dominates the cross-sectional surface of the river before excavation. It is a loose material of silt, sand, and kerakal clay. It is part of the Holocene Alluvium Unit.
2. Basalt lava unit: Found on the dam body of the left side of the work area. It dominates 20% of the employment area. Blackish-gray, very hard, vesicular / hollow structure due to the release of gases at the time of rock formation. It is part of the Pleistocene Sukadana Basalt Formation.
3. Sandstone unit: Found on the dam body of the right and left sides of the work area. It dominates 45% of employment areas and is the most dominant at job sites. In the form of smooth and rough tuffs interspersed:

1. Coarse Tuff: Brownish-gray/white to grey in color. Medium-coarse sand, there are lapili pebbles measuring 0.5 – 1 cm with sub-angular – angular grain shapes, low – high, rather dense – solid, layered structures ranging from 2 m – 12 m thick. It is thought to be part of the Plio-Pleistocene Lampung Formation.
2. Fine Tuff: Yellowish-gray/white to gray-sized clay-silt, there is a small amount of gravel measuring 0.5 cm -1 cm with a subangular-angular grain shape, weathered low – high, rather soft – hard, layered structure, has a thickness ranging from 2 m -15 m. It is thought to be part of the Plio-Pleistocene Lampung Formation.

Based on the formulation of the problem above, the following are the objectives of this study:

1. Get an effective secant pile design to substitute curtain grouting in overcoming seepage.
2. Know how to compare secant piles and curtain grouting to overcome seepage in terms of cost and implementation time.
3. Obtain the results of design stability analysis based on a cross-sectional review of the weir backfill.
4. Know how to calculate the implementation cost analysis of the design based on a review of the cross-section of the stockpile.
5. Get the recommended shape of secant pile design and the most optimal cross-section of the dam pile.

Research Methods

Research Method Flow

Research method is a way, step, or method that will be used to work on a research so that the thesis can be prepared in a structured, systematic, and also effective and efficient.

Student Literature

This study was conducted to obtain theories, previous studies, and various literature that support the research. Literature study is carried out by reading, researching and understanding all information both written and images so that it can help the process of preparing this research.

Data Collection

After identifying the problems in the field, the next step is to find supporting data to solve these problems. The data in question is secondary data. Secondary data is supporting data obtained indirectly in the form of records or research results from other parties. The secondary data includes:

1. Contract Drawings
2. Peta Geologi
3. Data Hasil Trial Grouting
4. PMT (Pressure Meter Test) test result data
5. SPT (Standard Penetration Test) test result data
6. Technical justification data of soil investigation

The other data and data were obtained from Waskita – Adhi KSO Margatiga Lampung Dam Project, BBWS Mesuji Sekampung, and Supervision Consultant PT. Yodya -Wiratman KSO.

Analysis and Discussion

This stage is the stage of data analysis/calculation process that will determine the selection of design reviews; the planned stages are as follows:

Seepage Analysis of Concrete Building Foundations

The seepage analysis of the concrete building foundation of Margatiga Dam was calculated with SEEP/W (Geoslope International, Canada) software based on Finite Element. Analysis calculations with SEEP / W software are carried out calculation analysis during normal conditions because concrete buildings have 3 radial doors as water table control so that elevation will be maintained in normal conditions (Widodo, 2023).

Dam Body Stabilization Analysis

Slope stability analysis is used to determine safety factors. For the calculation of safety factors, the SLOPE / W auxiliary program will be used. Analysis of the calculation of the stability of the dam body to ensure that it meets the requirements or design criteria of the dam body (Takwin, Turangan, & Rondonuwu, 2017). In the analysis of the dam body stability model, it is divided into three geometric models, which are as follows:

a. Model 1: Geometry according to the Contract design (Upstream slope 1:3 and downstream 1:2)
b. Model 2: Modifying the geometry of rock deposits and rip-rap piles (Upstream slope 1:2 and downstream slope 1:1.5)
c. Model 3: Modifying the geometry of rock deposits and rip-rap piles (Upstream slope 1:1.5 and downstream 1:1)
d. Model 4: Modifying the geometry of rock deposits and rip-rap piles (Upstream slope 1:2.5 and downstream slope 1:1.75)

Results and Discussion

Lithological Characteristics of Research Areas

In general, based on the Geological Map of Tanjung Karang Sheet (Sukarna, Mangga, & Brata, 1993), the construction site of the Margatiga Dam is dominated by Quaternary aged rocks, consisting of Plistocene Lava, Breccia and Tuff with andesite-basalt constituents, Sukadana Basalt, Reef limestone and Holocene Alluvium Sediments. The regional stratigraphic arrangement of the Margatiga Dam area is sorted from the youngest formation to the oldest formation based on geological age as follows:

1. Alluvium (Qa)

In this formation is composed of grained deposits, gravel, sand, loam, and peat. This formation is Holocene aged.

2. Basal Sugadana (KBS)

In this formation it is composed of hollow basalt. This formation is Holocene – Plistocene in age.

3. Lampung Formation (QTl)

The formation is composed of pumice tuff, rhyolitic tuff, tufaan clay, and tufaan sandstone. This formation is Plistocene – Pliocene in age.

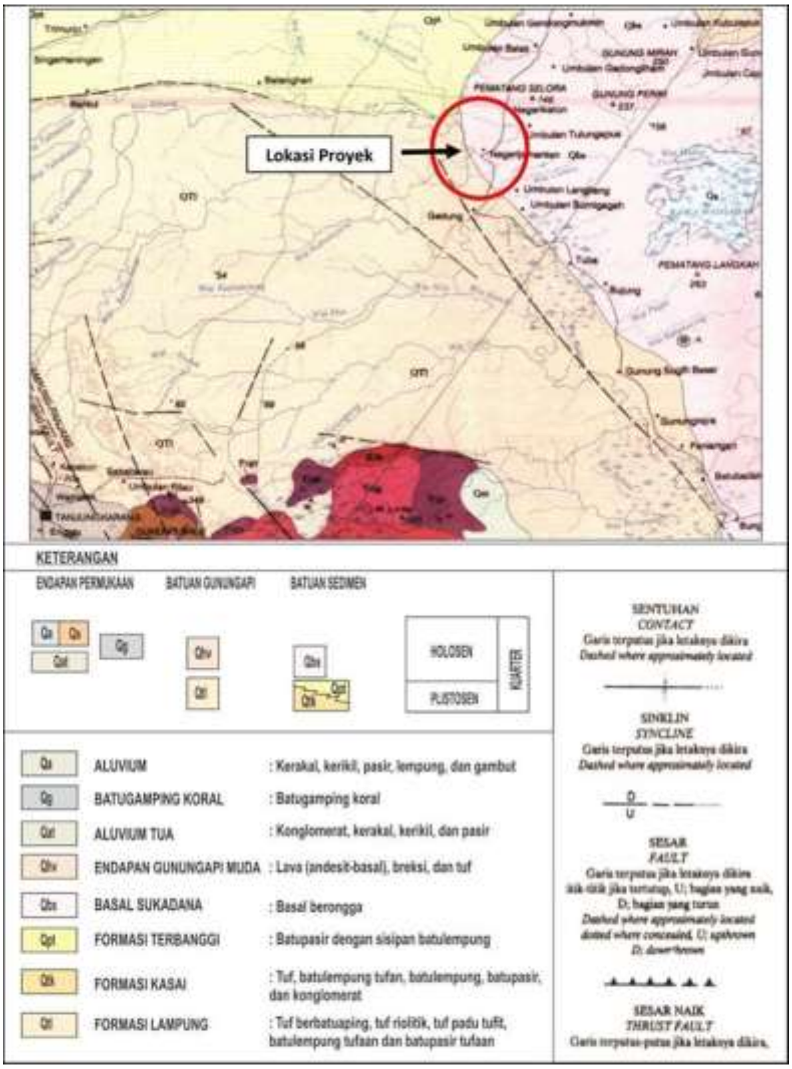


Figure 4
Part of the Regional Geologic Map of Tanjung Karang Sheet (Mangga, S., et al, 1993)

The lithological condition of the research area can be known by conducting surface and subsurface investigations. The purpose of the investigation is to determine the type of lithology that makes up the research area so that it can help analyze the type of handling needed in dam buildings to be built on the lithology (Pangemanan, Turangan, & Sompie, 2014).

Surface Investigation

Surface investigations are carried out by surface geological mapping. Geological mapping was carried out at the work site to determine the distribution of rock units at the Margatiga Dam. Surface geological mapping is carried out directly in the field by taking rock samples and describing these rock types (FERLI BUDI, 2023). The results of geological mapping that have been carried out are known that the location of the Margatiga Dam is composed of 3 rock units sorted from youngest to oldest are as follows:

a) Endapan Aluvial

This lithology is found along the Way Sekampung river which dominates 35% of the Margatiga Dam area. Composed of loose material has not undergone compaction of silt to kerakal clay grains (Figure 4.2). This lithology is part of the Holocene Alluvium Unit.

b) Satuan Lava Basalt

This lithology is found in the left abutment of the Margatiga Dam area (Fig.4.3). It dominates 20% of the employment area. Blackish-gray, very hard, vesicular / hollow structure due to the release of gases at the time of rock formation. It is part of the Pleistocene Sukadana Basalt Formation.

c) Sandstone Unit

This lithology is found on the right and left abutments of the Margatiga Dam area. Dominating 45% of the work area is composed by interspersed fine and rough tuffs. Light – dark grey (Figure 4.4). It is thought to be part of the Plio-Pleistocene Lampung Formation.

The following are field photos based on geological observations made at the location of the Margariga Dam.

Figure 5
Lithology of alluvial deposits found in the main dam area of the Margatiga Dam (Margatiga Dam Work Observation, 2021)

Figure 6
The condition of vesicular basalt lithological outcrops in the left main dam area of the Margatiga Dam (Margatiga Dam Work Observation, 2021)

Figure 7
Unit outcrop conditions per interlude of fine tuff and coarse tuff (Observation of Margatiga Dam Work, 2021)

Results of Subsurface Investigations

Subsurface investigations are carried out to obtain data and information on the types of constituent rocks and rock conditions including the level of weathering, rock structure, and rock hardness. This investigation was carried out with 2 types of methods, namely Pressure Meter Test (PMT) and Standard Penetration Test (SPT).

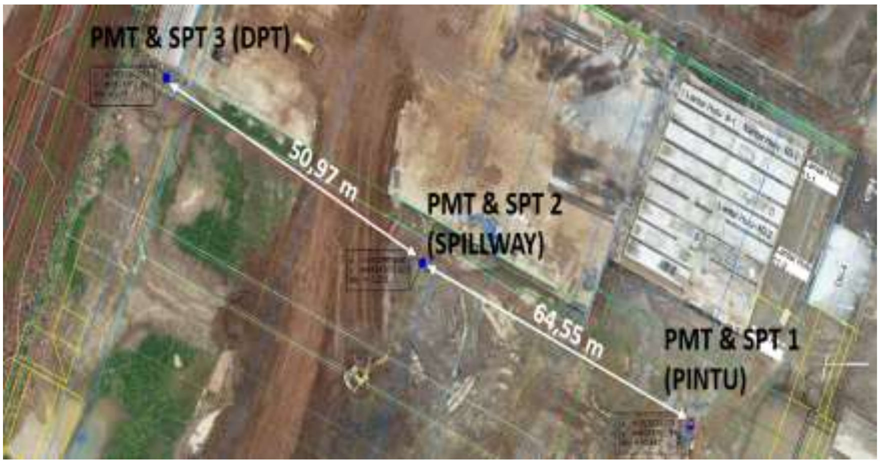


Figure 8
PMT & SPT test point layout (Geological Investigation Data, 2021)

Subsurface investigations carried out provide a picture of subsurface conditions that can be observed through coring results or rock cores taken as deep as 20 meters. Based on core rock observations, the location of PMT & SPT 1 or the door area is predominantly composed of tuff layers with fine sand constituent fragments or 1/16 - 1/4 mm (fine tuff) and coarse sand or 1/4 - 2 mm (coarse tuff) and loose river / alluvial deposits. At elevations +10 to +8 it is composed of OK tuff rock, with intermediate weathering levels, compact rock structures, and very soft hardness, as well as sand-sized to kerakal river/alluvial deposits, loose structures and intermediate weathering levels. At elevations +5 to -1 it is composed of tuff rocks with constituent fragments of fine sand - kerakal, compact rock structures, weathered weathering windows low - medium and soft - hard hardness. At elevations -2 to - 8, it is composed of tuff rock with constituent fragments of fine-coarse sand, compact rock structure, low weathering rate, and medium-hard hardness levels are seen in the drill log data below.

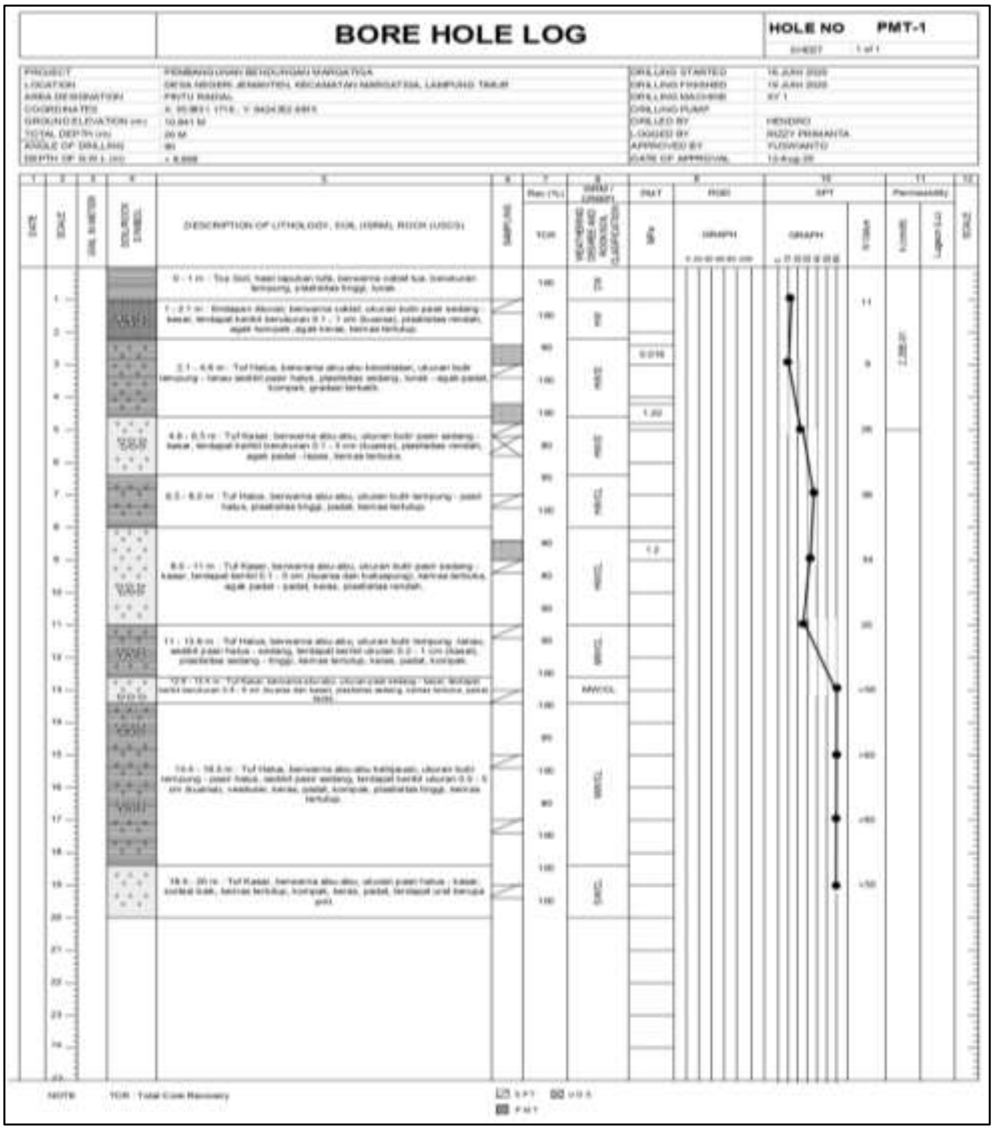


Figure 9
Description of drill log point PMT &; SPT 1 (Geological Investigation Data, 2021)

Figure 10
Core box testing point PMT &; SPT 1g (Geological Investigation Data, 2021)

At PMT & SPT 2 points or spillway areas are composed of loose sand deposits / aluviall, layers of fine tuff and coarse tuff. At elevation +13 to elevation +6 predominantly composed of brown to black sand deposits, conditions are very loose, medium weathered and still interleaved at an elevation of +3 about 1 meter, tuff rocks begin to appear at elevation +5 with fine sand-coarse sand-sized fragments, compact, medium-hard hardness, low-medium weathering. At the PMT & SPT 3 points or the Right DPT area is composed of heap soil, black mud, loose sand deposits and fine tuff rocks and coarse tuff. The heap soil of the actual elevation is about 4 m, the elevation +8 - +3 is composed of river deposits in the form of black clay, at elevation +2 is composed of sand-kerakal river deposits, and at elevations +1 to -8 is composed of tuff rocks with fine sand-sized fragments - coarse, compact, medium - hard hardness, low-medium weathering.

Based on core samples obtained from coring activity and further analysis, rock masses are categorized into three according to their degree of weathering (Kikuchi et all, 1982) (Table 4.1). The upper layer of elevation +12.00 - +05.00 consists of alluvial or river sand deposits categorized as Class D with loose material characteristics with stocky tensile strength and almost no fracturing. The middle layer of elevation +05.00 - +1.00 is categorized as Class CL consisting of tufaan sandstones with characteristic weathered rocks and soft rocks. And the last layer tested from elevation +01.00 - -02.00 is categorized as Grade CM consisting of tufaan sandstones with medium rock classification.

Foundation Geotechnical Parameters

Based on the results of geological observations and the results of geotechnical investigations are correlated so that the parameters used in stability analysis are obtained. Here are the geotechnical parameters of the foundation.

Table 1
Margatiga Dam Foundation Material Parameters

Zone	Material	cwet	c	φ	Permeability towards	
		(kN/m3)	(kN/m3)	(°)	cm/s	m/s
1	Agglomerate Foundation	18,64	0	39,29	2.00 E-04	2.00 E-06
2	Foundation of Tufaan sand butu	18,64	0	39,29	2.00 E-04	2.00 E-06
3	Smooth Tuff Foundation	18,64	0	44,49	2.00 E-04	2.00 E-06

Geotechnical Parameters of Dam Body Material

The body material of the Margatiga Dam is obtained from the results of laboratory and field tests where the results of these tests are correlated to obtain conclusions about the parameters used in the analysis. The tests carried out are as follows.

1. Inti Zone

Laboratory and field tests conducted on core zone materials consist of testing soil shear strength, permeability, dry density, moisture content, and *property index.*

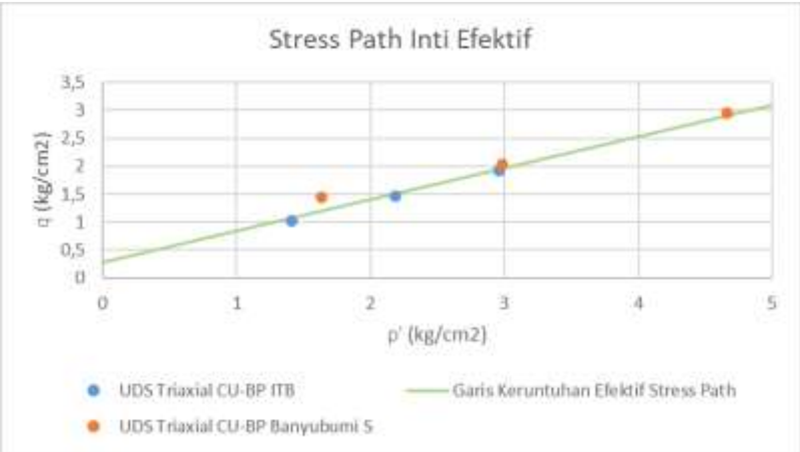
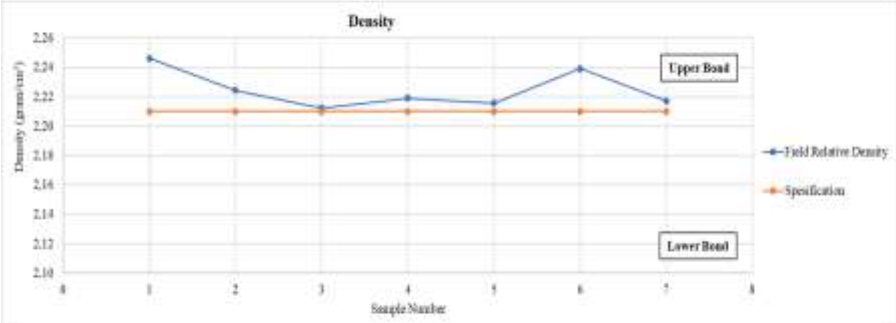


Figure 11 Triaxial Core Shear Strength (Effective) CU-BP c' = 0.33 kg/cm2 and f' = 34.33o (Model Analysis, 2023)

2. Rockfill

Laboratory and field tests performed on rockfill zone materials consist of density testing. For other parameters, correlation is used to get it.



Gambar 12 Density Rockfill

Based on the results of laboratory testing of dam body material in the field, it can be concluded using average calculations and correlation of geotechnical parameters of dam body material are as follows.

Table 2
Margatiga Dam Body Material Parameters

ccc	Material	cwet	c	φ	Permeability towards	
		(kN/m3)	(kN/m3)	(°)	cm/s	m/s
1	Inti	16,70	34	34,33	6.56 E-06	6.56 E-08
2	Fine Filter	16,50	3	33,69	1.04 E-03	1.04 E-05
3	Filter Kasar	19,20	5	31,93	1.05 E-03	1.05 E-05
4	*Rockfill*	22,20	3	40,53	1.00 E-02	1.00 E-04

Reed erosion calculation

Piping and boiling can occur when reservoir water flows through the soil pores and causes attractive forces on the soil grains that are strong enough to carry the soil grains to an unprotected output site. The process of carrying soil grains occurs progressively downstream to form a channel. Piping can also occur when seepage pressure on the foundation produces lifting pressure in the depressed layer of the downstream soil layer which has lower permeability resulting in blowout or heave.

Dam Safety Analysis Dam Body

In conducting stability calculation analysis, determination of geotechnical parameters is important in modeling. The geotechnical parameters used in this analysis are as follows.

Table 3
Parameters of Landfill Material and Foundation Material of Margatiga Dam

c	Material	cwet	c	φ	Permeability towards	
		(kN/m3)	(kN/m3)	(°)	cm/s	m/s
1	Inti	16,70	34	34,33	6.56 E-06	6.56 E-08
2	Fine Filter	16,50	3	33,69	1.04 E-03	1.04 E-05

c	Material	cwet	c	φ	Permeability towards	
		(kN/m3)	(kN/m3)	(°)	cm/s	m/s
3	Filter Kasar	19,20	5	31,93	1.05 E-03	1.05 E-05
4	*Rockfill*	22,20	3	40,53	1.00 E-02	1.00 E-04
5	Agglomerate Foundation	18,64	0	39,29	2.00 E-04	2.00 E-06
6	Tufaan Sandstone Foundation	18,64	0	39,29	2.00 E-04	2.00 E-06
7	Smooth Tuff Foundation	18,64	0	44,49	2.00 E-04	2.00 E-06
8	*Grouting*	18,63	9	28,23	6.00 E-05	6.00 E-07

The results of the stability analysis of the Margatiga Dam type consist of two conditions, namely after construction and steady state where each condition is reviewed based on the static loading mechanism, pseudostatic operated based earthquake (OBE) loading, and maximum design earthquake (MDE) pseudostatic loading.

The model used in the analysis consists of 3 models with different slope types.

Results of Stability Analysis of Margatiga Dam Type Urugan Steady State Conditions

The stability analysis of the Margatiga Dam type of steady state condition will be reviewed based on the static loading mechanism with normal water table conditions and flooding, pseudostatic operated based earthquake (OBE) loading with normal water table conditions, and pseudostatic maximum design earthquake (MDE) loading with normal water table conditions. The earthquake load coefficient used for stability analysis of the Margatiga Dam type of steady state condition uses the value of the earthquake load coefficient.

Flood water table conditions are not subjected to pseudostatic loading because of the very small level of probability.

Results of Stability Analysis of Margatiga Dam Urugan Type Steady State Conditions Static Loading Mechanism

The following is data from the stability analysis of the Margatiga Dam type of steady state condition of the static loading mechanism based on the planned model design.

Results of Seepage Discharge Analysis of Margatiga Dam Urugan Type

The evaluation of seepage in the dam body refers to the book "Grouting Guidelines for Dams" issued by the Department of Public Works of the Ministry of PUPR that the amount of permissible dam seepage discharge is no more than 1% of the river water discharge entering the dam, so that it meets the requirements if the seepage discharge is less than 1% of the river discharge inflow. Here is each seepage calculation analysis for the dam body.

Conclusion

Based on the results of modeling evaluation and analysis of cost calculations and time of work implementation for the design of seepage handling in buildings and the cross-sectional stability of the Margatiga dam body, it can be concluded that:

1. The secant pile design with a diameter of 80 cm, overlap of 15 cm and a depth of up to an elevation of -10 or mode1 according to the modeling results is safe and meets the design criteria, so this design can be used as a seepage handling design on the foundation of the spillway and retrieval building.
2. Secant pile model 1 (depth up to -10) has a cheaper cost of Rp. 3.321.199.000,- and 27 weeks faster than using curtain grouting.
3. Dam stability analysis based on Model 1 according to the contract design has safe results or meets the design criteria of the dam body, for model 2 design by changing the slope of upstream 1: 2 and downstream 1: 1.5 and model 3 design with upstream slope 1: 1.5 and downstream 1: 1 there are results that are unsafe or do not meet the design criteria of dam stability, As for the design of Model 4 with an upstream slope of 1:2.5 and downstream of 1:1.75, there are results that are safe or meet the design criteria for dam stability.
4. The cross-sectional design of the dam body in accordance with the contract (model 1) has an implementation cost of Rp. 25,172,526,000,-, for model 2 (upstream slope 1: 2 and downstream 1: 1.5) has an implementation cost of Rp. 18,278,906,000,-, for model 3 (upstream slope 1: 1.5 and downstream 1: 1) has an implementation cost of Rp. 18,233,144,000,-, and for model 4 (upstream slope 1: 2.5 and downstream 1: 1.75) has an implementation cost of Rp. 22,893,695,000,-, . As well as for the calculation of the time for the implementation of work in accordance with the contract (model 1) has a work execution time of 30 weeks, for model 2 (upstream slope 1: 2 and downstream 1: 1.5) has a work execution time of 27 weeks, for model 3 (upstream slope 1: 1.5 and downstream 1: 1) has a work execution time of 27 weeks, and for model 4 (upstream slope 1: 2.5 and downstream 1: 1.75) has a work implementation time of 28 weeks.

Bibliography

Azizah, Nur. (2022). Comparisonal Analysis Of D35 Bulldozer And GD300A-1 Motor Grader As A Grade Tool Reviewing From Time. *Journal of Science Nusantara*, *2*(3), 109–117.

FERLI BUDI, IRAWAN. (2023). *Analisis Cadangan Air Tanah Dan Tata Guna Air Tanah Untuk Kebutuhan Domestik Menggunakan Metode Geolistrik Di Kecamatan Jati Agung Lampung Selatan*. Universitas Lampung.

Pangemanan, Violetta Gabriella Margaretha, Turangan, Arens E., & Sompie, Oktovian B. A. (2014). Analisis kestabilan lereng dengan metode Fellenius (Studi kasus: Kawasan Citraland). *Jurnal Sipil Statik*, *2*(1).

Pitaloka, Adhelia Diah, Khamim, Moch, & Lydianingtias, Diah. (2021). Analisa Perbandingan Pelaksanaan Secant Pile Dengan Diaphragm Wall Sebagai Perbaikan Pondasi Bendungan Semantok. *Jurnal Online Skripsi Manajemen Rekayasa Konstruksi (JOS-MRK)*, *2*(3), 298–303.

Saidillah, Muhammad, & Artati, Hanindya Kusuma. (2022). Analisis Rembesan Dan Stabilitas Bendungan Saradan. *Jurnal Teknik Sipil Cendekia (Jtsc)*, *3*(2), 316–330. https://doi.org/10.51988/jtsc.v3i2.43

Sidik, Ahmad. (2024). *Penanganan Rembesan Menggunakan Secant pile Sebagai Solusi Pengganti Curtain Grouting dan Evaluasi Stabilitas Bendungan Untuk Optimalisasi Pekerjaan Pada Proyek Pembangunan Bendungan Margatiga*. Institut Teknologi Sepuluh Nopember.

Sukarna, D., Mangga, S. Andi, & Brata, K. (1993). *Geology of the Bayah area: implications for the Cenozoic evolution of West Java, Indonesia*.

Takwin, Gideon Allan, Turangan, Arens Emilie, & Rondonuwu, Steeva Gaily. (2017). Analisis Kestabilan Lereng Metode Morgenstern-Price (Studi Kasus: Diamond Hill Citraland). *Tekno*, *15*(67).

Widodo, Edi. (2023). *Analisis Efektivitas Pengurangan Rembesan Pada Perbaikan Tanah Ditinjau Dari Posisi Titik Grouting dan Penggunaan Material Semen di Proyek Bendungan Jlantah Kabupaten Karanganyar*. ITS.

Yulikasari, Andriyan, Utama, Widya, & Purwanto, Singgih. (2017). Analisis Faktor Keamanan Lereng Tanah Menggunakan Metode Geolistrik Resistivitas Dan LEM Di Daerah Olak Alen, Selorejo, Blitar. *Jurnal Geosaintek*, *3*(3), 143–148.