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Analysis of Ground Movement Using Inclinometer At Power House 2 Peusangan Hydroelectric Power Plant Takengon, Central Aceh

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Abstract - This study aims to analyze land movement in the Power house 2 area of Peusangan Hydroelectric Power Plant in Takengon, Central Aceh by using inclinometer tool. Ground movement monitoring is very important to ensure the stability and safety of structures, especialply in critical hydropower project such as the Peusangan Hydropower Plant. Peusangan Hydroelectric Power Plant. The research methodology includes periodic data collection over a certain period. Results of this analysis indicate the presence of significant lateral soil movement at several monitoring points,identified through changes in slope detected by inclinometer. The data obtained were processed and analyzed to identify movement patterns and contributing factors, such as changes in soil conditions and the influence of contruction activities. The findings provide important information on the geotechnical condition in the study area and help in decision-making for mitigation messures. This study underscores the importance of continuous monitoring of slope arears using inclinometers to detect and anticipate potentially hazardous soil movements. Recommendations for continued monitoring and mitigation strategies are presented based on the results of this study, with the aim of improving the stability and safety of operational operations at Peusangan Hydroelectric Power Plant.

Keywords : Power House, Hydroelectric, Inclinometer, Monitoring

1. INTRODUCTION

Land movement is a geological phenomenon that can have a significant impact on infrastructure,especially on buildings located in landslide-prone areas. The peusangan hydroelectric power plant, located in the mountainous region of Aceh, precisely in Takengon, Central Aceh, is one of the hydroelectric power plant projects that has the potential to experience land movement problems. The complex geological conditions and high rainfall in this area increase the risk of landslides and land shifts which could threaten the stability of building structures, including powerhouse 2. To monitor and analyze ground movement around Powerhouse 2, a measuring instrument known as an inclinometer is used. An inclinometer is a device designed to measure the slope and changes in position of the ground over a certain time. It is hoped that the use of and inclinometer at the Peusangan hydropower plant will provide accurate data regarding ground movement so that prevention and mitigation measures can be carried out effectively. This research aims to analyze ground movement data obtained from the inclinometer installed in Powerhouse 2 at the Peusangan hydroelectric power plant. Through this analysis, it is hoped that the results of this research can become a reference in planning and implementing landslide risk mitigation efforts, so that the sustainability of the Peusangan hydroelectric power plant operation can be guaranteed.

2. LITERATURE REVIEW

Soil movement is an important aspect of geotechnics that has been widely researched. According to Turner and Schuster (1996), land movement can be caused by various factors such as seismic activity, rainfall and changes in soil conditions. In disaster-prone areas such as the mountains of Aceh, monitoring ground movements is crucial to prevent infrastructure damage. One method that is often used to monitor ground movement is to use an inclinometer. An inclinometer is a tool designed to measure slope angles and changes in position in the ground. According to Dunnicliff (1988), the use of an inclinometer allows accurate and continuous measurements of ground movements, making it easier to identify potential landslides early on. Research conducted by Sakurai (2005) shows that the use of inclinometers in monitoring ground movements and the use of inclinometers is still limited. However, a study conducted by Wijaya (2012) regarding monitoring ground movements in landslide-prone areas in West Java shows that inclinometers can provide significant data in understanding soil dynamics in these areas. This research also underscores the importance of long-term monitoring to identify ground movement patterns that can vary temporally. Various methods have been developed to monitor ground movements ranging from geophysical techniques to the use of mechanical measuring instruments. One tool that is widely used is an inclinometer. According to Mikkelsen (2003), an inclinometer is a tool that is able to measure changes in the angle of slope of the land accurately. So it can detect soil deformation at a certain depth. The accuracy and consistency of data obtained from inclinometers makes them the tool of choice in geotechnical studies. Peusangan Hydroelectric Power Plant, as a hydroelectric power plant

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project located in a mountainous area, has a high risk of ground movement. According to Ranchman (2016), soil structure and geology require special attention in planning and implementing infrastructure projects. In this context, the use of an inclinometer becomes very relevant to monitor ground movements around Powerhouse 2, so that preventive measures can be taken in a timely manner. By referring to previous research, this research will analyze ground movement data obtained from the inclinometer installed in powerhouse 2 at the Peusangan Hydroelectric Power Plant. It is hoped that the results of this research can contribute to the development of more effective land movement monitoring methods in Indonesia. Especially for infrastructure projects located in landslide-prone areas.

1. **Land movement and the factors that cause it**
   Land movement is a geological phenomenon caused by various natural and human factors. According to Smith (2015), high rainfall can cause a decrease in slope stability which can trigger landslides. Seismic activity, as explained by Jones and Brown (2017), can also accelerate ground movement, especially in areas with a history of earthquakes. Apart from that, changes in ground water levels and soil physical properties, such as density and cohesion also play a role in soil movement (Terzhagi, 1950)
2. **Methods for monitoring ground movements**
   Various methods have been developed to monitor ground movements ranging from geophysical techniques to the use of mechanical measuring instruments. One tool that is widely used is an inclinometer. According to Mikkelsen (2003), an inclinometer is a tool that is able to measure changes in the angle of slope of the land accurately. So it can detect soil deformation at a certain depth. The accuracy and consistency of data obtained from inclinometers makes them the tool of choice in geotechnical studies.
3. **Inclinometer application in infrastructure monitoring**
   The use of inclinometers in infrastructure monitoring has proven effective in various large projects.Lee and Kim (2010) explained the application of an inclinometer in monitoring slope stability in dam areas. The data obtained helps in planning structural strengthening and making decisions related to risk mitigation. In Indonesia, research by Sutrisno (2018) shows that inclinometers are used to monitor ground movements in hydropower projects and help in making decisions regarding disaster risk mitigation.
4. **Case study of the use of an inclinommeter in hydropower**
   Several case studies show the success of using inclinometers in monitoring ground movements in hydropower projects. In Japan, the Nagashima dam project used an inclinometer to monitor ground movements and the results showed an increase in slope stability after interventions were carried out based on inclinometer data (Yoshida, 2012). In Indonesia, the Cirata hydropower plant also uses an inclinometer to monitor soil movements around the dam, which helps maintain structural stability and operational safety (Rahardjo, 2016).
5. **Peusangan hydropower plant and geotechnical challenges**
   The Peusangan Hydroelectric Power Plant is located in a mountainous area that has complex geological conditions and high rainfall. According to Nasution (2020), the area around Powerhouse 2 has the potential for high ground movement and even landslides have occurred in the area around the Penstock. Data from the inclinometer is expected to provide important information regarding ground movement patterns and the factors that influence them, so that preventive measures can be taken appropriately.

3. RESEARCH METHODOLOGY

3.1 Research location

This research was conducted in the area around Power house 2 at the Peusangan Hydroelectric Power Plant which is located in the mountainous region of Aceh. This location was chosen because it has the potential for high ground movement due to geological conditions and significant rainfall.

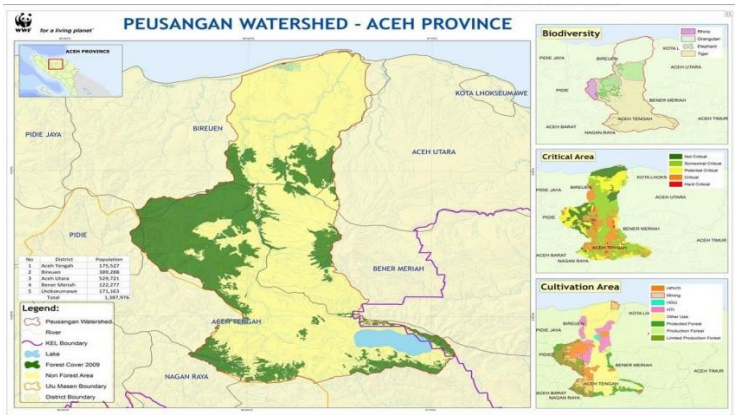

Figure 1. M*ap of the Peusangan river flow boundaries*

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3.2 Tools and Materials

The main tool used in this research is an inclinometer. Inclinometers are used to measure changes in the angle of slope of the ground at various depths. Apart from that, this research also uses other supporting tools such as geotechnical analysis software and pipe inclinometers.

Figure 2**.** *inclinometer*

Figure 3. *Inclinometer measurements*

3.3 Preparation and Installation of the Inclinometer

The steps taken are as follows:

- Selection of measurement points: measurement points are selected based on initial analysis of areas that have the potential to experience ground movement. These points are determined by considering factors such as slope slope, soil type and history of land movement in the past.
- Drilling and installation of the inclinometer sleeve: at the selected point, drilling is carried out to install the inclinometer sleeve. This sleeve functions as a place to insert the inclinometer probe which will be used for measurements.
- Initial calibration and testing: after installation, initial calibration and testing is carried out to ensure that the inclinometer functions properly and provides accurate measurement results.

3.4 Periodic Data Collection

Data collection is carried out periodically to monitor changes in ground movements over time. The data collection stages are as follows:

- Frequency of measurements: measurements are carried out every month during the project period.This frequency was chosen because ground movement in the slope area is no longer too dangerous so the data needed is sufficient for monitoring.
- Measurement procedure: at each measurement session, the inclinometer probe is inserted into the sleeve and slope data is measured at certain depth intervals. The data obtained is recorded and stored for further analysis.

3.5 Data Analysis

Data obtained from inclinometer measurements are analyzed to determine ground movement patterns.
Analysis steps include:

- Data processing: raw data from the inclinometer is processed using geotechnical analysis software. This processing includes data correction and calculation of slope changes at various depths.
- Movement pattern analysis: ground movement patterns are analyzed byidentifying trends and anomalies in slope data. This analysis helps in understanding the mechanisms of soil movement at the research location.

3.6 Interpretation of Results

The results of data analysis are interpreted to provide an understanding of the ground movement around Powerhouse 2 at the Peusangan Hydroelectric Power Plant. This interpretation includes:

- Identification of vulnerable areas: areas that show significant ground movement are identifiedas a vulnerable area
- Mitigation recommendations: based on the results of the interpretation, recommendations for land movement risk mitigation measures are prepared to reduce the negative impact on the Peusangan hydropower infrastructure.

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4. RESULTS AND DISCUSSION

Inclinometer Measurement Results

Measurements of ground movements in the Powerhouse 2 area of the Peusangan Hydroelectric Power Plant are carried out periodically Every month, the total number of inclinometers that must be calculated is 9 inclinometers. However, there are inclinometers that are a priority for each measurement because these inclinometers are areas prone to landslides such as inclinometer 1 (IC1), inclinometer 2 (IC2), inclinometer 8 (IC8) and inclinometer 9 (IC9).

The following data was obtained in 2022. To be precise, at the initial installation of the inclinometer.

Table 1. Measurement control value proposed in inclinometer

Caution level	Vigilance level	Remarks
$3*10^{-5}$ rad/hari (0.0015) mm/hari	$9*10^{-5}$ rad/hari (0.045 mm/hari	Inclinometer prioritas (IC1,IC2,IC8 dan IC9)

Table 2**.** Times the caution and vigilance levels of the borehole inclinometer padaJuni 2022

Item	Symbol	Timeof Caution Level	Time of Vigilance Level	Remarks
Inclinometer	IC1	292	283	**See on Table 3**
	IC2	**331**	**156**	
	IC8	488	123	
	IC9	603	199	

Table 3**.** inclinometer data based on soil depth in June 2022

Depth	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5
CL*1	10	11	10	9	9	9	8	8	4	9	8	12	7	10	9
VL*2	2	2	3	2	2	2	2	2	4	2	3	1	1	1	1
Depth	8.0	8.5	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0	13.5	14.0	14.5	15.0
CL*1	11	8	10	9	9	13	7	7	9	13	7	10	10	8	8
VL*2	1	7	3	3	2	3	2	4	2	2	2	4	4	3	3
Depth	15.5	16.0	16.5	17.0	17.5	18.0	18.5	19.0	19.5	20.0	20.5	21.0	21.5	22.0	22.5
CL*1	7	10	14	9	12	15	14	9	10	10	9	13	14	12	10
VL*2	5	4	5	4	5	5	5	7	5	5	7	2	2	4	4
Depth	23	23.5	24	24.5	25	-	-	-	-	-	-	-	-	-	-
CL*1	11	10	13	13	11	-	-	-	-	-	-	-	-	-	-

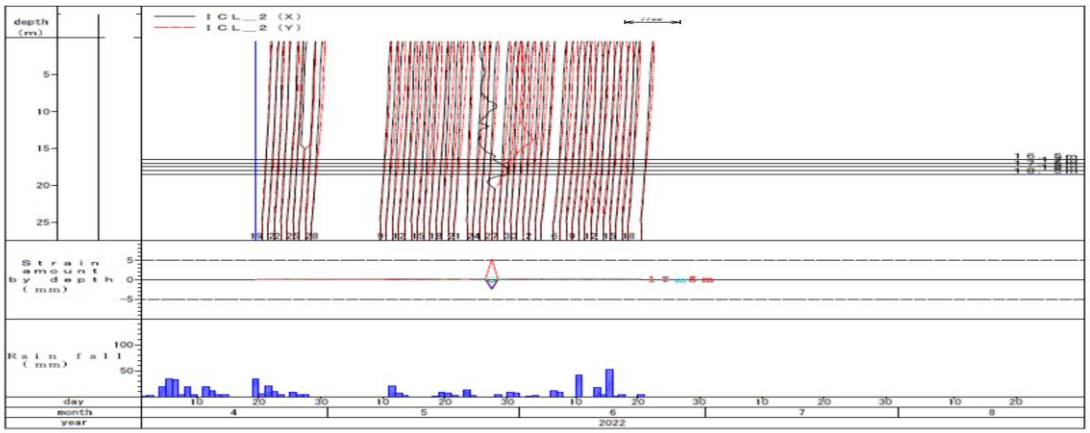

Figure 4. Inclinometer graph June *2, 2022*

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5. CONCLUSION

Based on the analysis of slope changes at power house 2 at the Peusangan Hydroelectric Power Plant, there are 9 inclinometers planted at different points with different priority levels. In 2022 until now there are 4 priority inclinometers. Based on the data shown on the 4 inclinometers, ground movements often occur, which as a reference, the times of caution levels and times of vigilance levels can help in monitoring ground movements. In fact, based on the latest data, precisely in May 2024 at inclinometer 2 there has been significant ground movement at a certain depth so that mitigation or countermeasures are needed in this area so that disasters or undesirable things do not occur.

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