Rock Slope Stability Analysis in Melasti Beach Area – Ungasan, Bali

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Abstract

Melasti Beach is one of the main tourist attractions developed by the Bali Government. This beach is located in the southern area of Bali, precisely in Ungasan village, Badung Regency, Bali. At the moment, the region administrator is constructing a tourism facility by excavating a rock mass near the beach. Therefore, to avoid damage to nearby shops and beach facilities, a study is needed to be conducted about the safety of the rock mass that is being excavated. Direct observation of the rock mass and rock mass classification is conducted to obtain the physic and mechanical characteristics of the rock. To do the stability analysis of the slope, Geo-Studio 2012 software is used by inputting the data obtained from the field and laboratory data. The result of this study is a mass rock in Melasti Beach is classified as limestone which has a Fair rock classification and the factor of the safety of the rock slope/cliff is 1.631 which means the cliff is safe and is no need to build an extra reinforcement on the slope/cliff.

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1 Introduction

Melasti Beach is one of the main tourist attractions which is currently being developed by the Bali Government. This beach is located in the southern of Bali, precisely in Ungasan Village, Badung Regency, Bali. The number of tourists is increasing every year because of its beautiful scenery and is supported by a complete tourism facility.
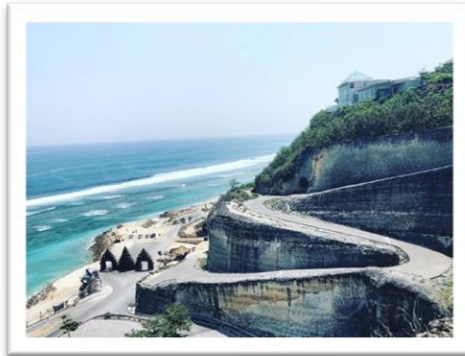

Figure 1. Melasti Beach area

At this moment, to develop the area, the region administrator is constructing a tourism facility by excavating a rock mass near the beach. The rock Slope which is resulted from excavation activities can be unstable because of the activating moment of the rock mass is greater than the resisting moment (Sivakugan et al., 2013). Therefore, to avoid damage to nearby areas due to excavation activity, a study is needed to be conducted about the rock mass that is being excavated.
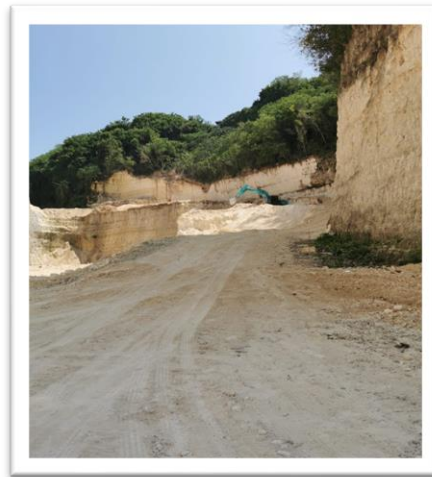

Figure 2. Excavation process in the Melasti Beach area

In order to do the slope stability analysis, firstly, the rock mass classification analysis is conducted to obtain the physical and mechanical characteristics of the rock mass. Those characteristics determine the rock mass's shear strength. Shear strength is the internal resistance per unit area that the rock mass can offer to resist failure and sliding along any plane inside it (Das, 2021). To determine the rock mass characteristic in Melasti Beach Area, in this study uses RMR (Rock Mass Rating) method by Bieniawski (1989). In RMR method, field and laboratory test is performed. Field tests consist of: direct observation of the rock mass condition, observation of cracks (discontinuities) that occur in the rock mass, rock coring, and observation of the water table. Laboratory tests consist of: Uniaxial Compression Test and Unit Weight Test. Studies about rock mass characteristics have been conducted

previously by some other researcher. (Ardana & Aribudiman, 2019), have studied rock mass in Pecatu Area, which is nearby the Melasti Area and has a similar geological condition. Therefore, the result of the previous study can be used for controlling and comparison of the result in this study (Pantelidis, 2009; Liu & Chen, 2007; Basahel & Mitri, 2017; Abbas & Konietzky, 2015).

2   Materials and Methods

Location and Time of the Study

This study is located in the Melasti Beach Area in southern of Bali Province. Field observation and sampling is done on April 17, 2020. A laboratory test is conducted on April 20 – 30, 2020. The location of this study is shown in the figure below:
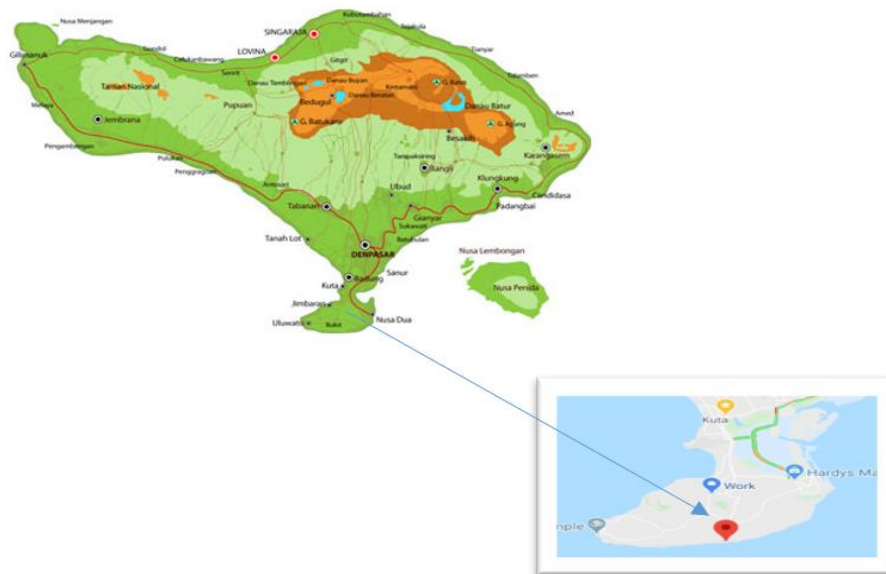

Figure 3. Location of the study

Type of data and data collection technique

Data obtained in this study consist of primary and secondary data. Primary data in this study are field observation results, laboratory tests and discontinuity measurements. Secondary data are previous studies and literature,

Data analysis and calculation technique

This study is quantitative and applied studies because it can solve a problem that can occur in the field (Yusuf, 2016). This study consists of field tests of the rock mass, rock core sampling, laboratory tests, and slope stability analyses. This study is conducted as follows:

1) Direct observation of the rock mass, analyze and measure the crack discontinuities which occur on the rock mass.
2) Rock core sampling. This sampling is used to obtain an undisturbed sample of the rock core and the RQD (Rock Quality Designation) value of the rock mass. Sampling is performed is 4 different point to obtain a representative result.
3) Unit weight and Uniaxial Compression Test (UCT). The rock core obtained from the field is tested with Unit weight and UCS test. Both of those tests are done in the laboratory.

4) Rock mass classification analysis. The data obtained from the previous step is used to determine the characteristic of the rock mass. The RMR method is used in this study. RMR method gives a rating from 1 to 100; according to some rock mass properties such as: RQD value, UCS value, crack spacing, condition of crack, water condition.

5) Rock slope stability analysis. The slope stability analysis is done by using GeoStudio 2012. The rock's physical and mechanical properties is obtained from the previous analysis. The geometry of the slope are right angle slope with a height of 100 m. This height is the highest excavation plan on the Melasti Area (Daftaribesheli et al., 2011; Das et al., 2010; McQuillan et al., 2018).
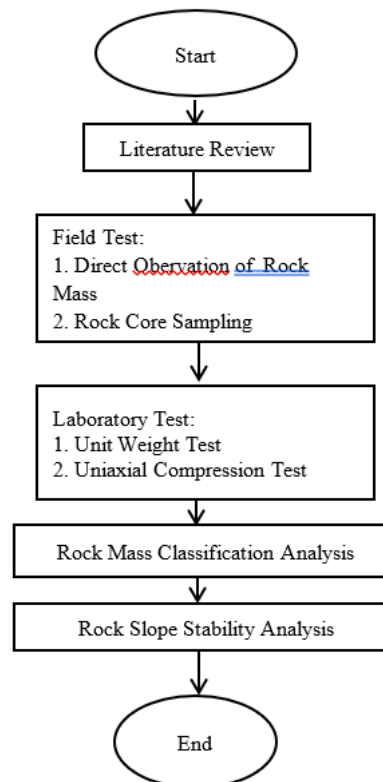

Figure 4. Rock slope stability analysis flowchart

3 Results and Discussions

Rock mass observation

Observation of rock mass type is conducted by using direct visual observation and measuring the crack on the rock mass (Sapigni et al., 2002; Şen & Sadagah, 2003; Tzamos & Sofianos, 2007). The result of rock mass observation are: rock mass is formed by million years-sedimentation of sea organisms; has a rough surface and spacing between crack (discontinuities) is 6 cm – 20 cm.

Figure 5. Crack or discontinuities condition on the rock mass in the Melasti Beach area

Rock core sampling

Rock core sampling is done to obtain an undisturbed sample of the rock core and determine the RQD value of the rock mass. Coring is done in 4 point; 2 in the top of the slope and 2 on the bottom of the slope. RQD value is determined by:

$$RQD = \frac{length\ of\ the\ obtained\ rock\ core}{total\ coring\ length} \ x100\% \qquad (1)$$

The result of the rock core sampling is shown in the table as follows:

Table 1
Rock core sampling result

Number	Total Length (cm)	Rock Core Length (cm)
1	35	20
2	26	7
3	30	28
4	27	26

$$RQD = \frac{20 + 7 + 28 + 26}{35 + 26 + 30 + 27} \ x100\%$$
$$RQD = 68\ \%$$

Thus, the RQD of the rock mass in the Melasti Beach area is 68%.

Laboratory test

The sample obtained from rock core sampling is tested in the laboratory. The result of the laboratory test is shown in the table below:

Table 2
Laboratory test result

No Sample	Specific Gravity	Unit Weight (kg/m3)	UCS (MPa)
1	2.67	2140	16
2	2.68	2396	31
3	2.69	2512	59
Average	2.68	2349	35

the equation as a graphic and insert it into the text after your paper is styled. In this study, rock mass classification is determined by the RMR method. RMR method gives a rating from 1 to 100; according to some rock mass properties such as: RQD value, UCS value, crack spacing, condition of crack, and water condition (Khatik & Nandi, 2018; Wesnawa, 2017; Amerta et al., 2018). The data result from field and laboratory test is used to give the rock mass its rating. RMR value of rock mass in the Melasti Beach area is shown in the table below:

Table 3
Rock mass rating result

Parameter	Description	Rating
Nilai UCS	35 MPa	4
RQD	68 %	13
Discontinuity Spacing	0.06 – 0.2 m	10
Discontinuity condition	Rough Surface, weathered, separation 1 – 5 mm	10
Water condition	dry	15
Total Rating		52

Rock mass in the Melasti Beach area obtained a total rating of 52 and was categorized as a fair rock. Mechanical parameter suitable for fair rock are: (ϕ) : 25° - 35° and cohesion : 200 KPa – 300 KPa[6].

Slope Stability Analysis

Rock slope stability analysis in this study uses GeoStudio 2012 software and uses Morgenstern – Prince calculation method. The height of the slope is 100 m, which is the highest excavation plan in the Melasti beach area. Input geometry on Geostudio is shown in the figure below:
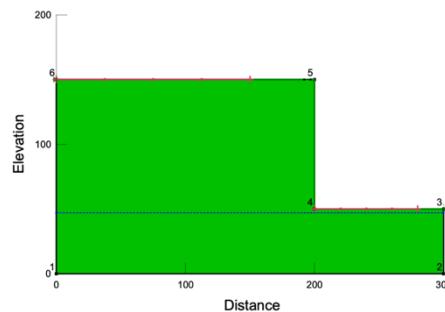

Figure 6. Geometry input on GeoStudio

The input of the rock's mechanical and physical properties is obtained from previous analysis on this study. The input parameter is shown in the table and figure below:

Arya, I. W., Wiraga, I. W., Negara, I. G. A. G. S., Ramia, I. N., & Premana, I. M. W. (2023). Rock slope stability analysis in Melasti Beach area – Ungasan, Bali. International Research Journal of Engineering, IT & Scientific Research, 9(3), 82–90. https://doi.org/10.21744/irjeis.v9n3.2319

Table 4
Rock parameter

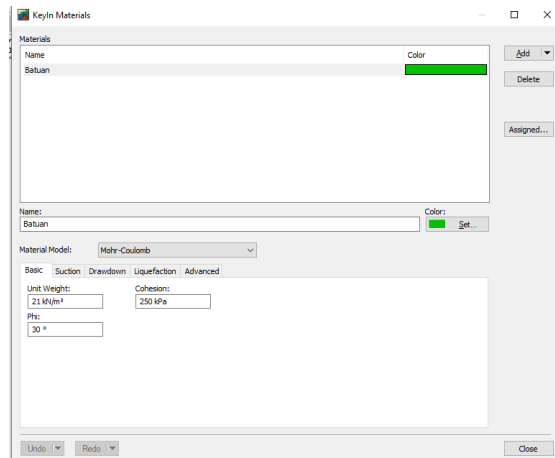| Parameter	Description
Unit Weight	2349 kg/m3
Phi	30
Cohesion	250 KPa

Figure 7. Rock parameter input on Geoslope

The selection of phi and cohesion value is based on range values that correspond with the type of rock in the Melasti Beach area. The result of the calculation shows that the slope has a factor safety (FS) of 1.63. FS >1 value means that the slope resulting from the excavation of the rock mass is stable and don't need any stabilization or external support. The results of the calculation are shown in the figure below:
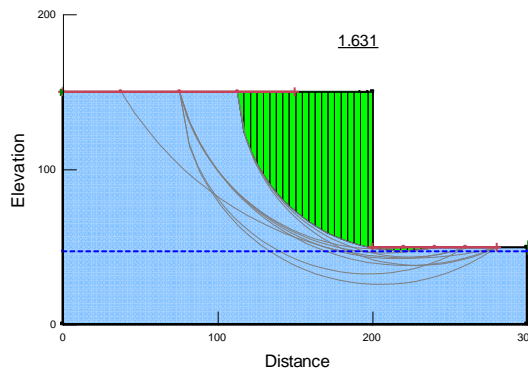

Figure 8. Slope stability analysis output on GeoStudio

Table 5
Tabulation of slope stability calculation

Item	Data
Slip Surface	90
Factor of Safety	1.63
Volume	6,571 m³
Weight	137,997kN
Resisting Moment	12,254 kN-m
Activating Moment	7,515,343. kN-m

Resisting Force	91,282 kN
Activating Force	[a.] 55,980 kN
Exit	[b.] (240.144, 50) m
Entry	(112.5, 150) m
Radius	106.38839 m
Center	[c.] (218.80441, 154.22625) m

4 Conclusion

Field tests, laboratory tests, and analysis that have been conducted in this study can be summarized as follows:

a) The type of rock in the Melasti Beach area is a sedimentary rock formed by sea organisms with the classification of fair rock.
b) The physical and mechanical properties of rock mass are:
   - Internal angle of friction (ϕ) : 30
   - Cohesion (c)   : 250 Kpa
   - Unit Weight (γ)   : 2349 kg/m3
c) The factor of safety of the excavation plan is 1.63 (FS = 1.631)
d) The rock slope doesn't need any stabilization or external support.

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