Tri Datu Model Slope Stability in Collaboration with Community Based Hydroseeding (Case Study: Songan Villages A and B Kintamani)

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Abstract. Landslide disaster is one of the events that often occurs in northern and eastern Bali, especially in Songan A and B Kintamani villages as happened on February 9, 2017 which claimed lives. Landslide consists of two parts, namely the slip plane soil and the transition layer soil. One way to characterize soil properties is to use geotechnical methods. Five slopes that have the potential for landslides in Songan A Village (dsa1, dsa2) and Songan B Village (dsb1, dsb2, dsb3), Kintamani District, Bangli Regency, and were characterized using geotechnical methods to identify the physical magnitude of slip plane soil and transition soil layers. The results of the characterization of soil physical properties such as cohesion, shear angle, density and slope geometry were analyzed for slope stability using the Fellenius method manually. This study uses a quantitative approach, in collecting data using survey methods and sampling. To determine the value of the factor of safety (FK) using the manual Fellenius method. The existing data is processed and analyzed so that the value of the recommended safety factor is obtained. Based on the safety factor research for existing slopes by reducing the soil mass of each slope sequentially, the results are 1.45 and 5.02 m^3, 1.35 and 4.49 m^3, 1.36 and 1.68 m^3, 1, 13 and 3 79 m^3, 1.20 and 7.54 m^3 on the five slopes (FK <1.5) if a landslide occurs, the landslide will cover roads and houses. From the results of the characterization, mitigation is carried out in the form of slope arrangement of the Tri Datu Model in collaboration with community-based Hydroseeding. .93 and 16.40 m^3, 2.34 and 3.18 m^3, 1.65 and 9.19 m^3, 1.52 and 9.8 m^3 all values of the factor of safety of the slopes (FK >1.5).
Keywords: Characterization of slope stability, run-out, Tri Datu, Hydroseeding.

INTRODUCTION

Kintamani District is one of the sub-districts in Bangli Regency which has an area of 366.92 km2, or about 70.45% of the Bangli Regency area and is even the largest sub-district in Bali Province (6.51% of the total area of Bali Province). The uniqueness of the sub-district is that it has a Batur caldera geopark measuring about 13.8 × 10 km, and other caldera structures formed in the middle with a diameter of 7.5 km and the tributary of Mount Batur with the highest peak of +1,717 m (Bemmelen, 1949). Based on data from the Bali Province BPBD Pusdalop in 2014, in Bangli Regency there have been 14 landslides or about 7.33% of all ground movement events on the island of Bali (Bali Province BPBD Pusdalop, 2014). Most of these incidents occurred in Kintamani District and occurred in early January to March, which are the months with the highest rainfall intensity in the area. The threat of soil movement in the Gunung Batur geopark area in [1] shows that the Mount Batur caldera is at 500 – 2000 mdpl, with a high threat percentage of 11% and very high 9%. A high threat level of 5232 ha is located around the slopes of Mount Batur, especially in Songan Villages A and B with landslide types in the form of falling rocks, this area is a tracking route and excavation area-C. The location of the sand mining is in Songan A Village. On the one hand this activity will be able to increase people's income but from an environmental perspective it is very damaging to the landscape, especially the mining system which is not planned/regulated properly, so it is easy to cause landslides as happened on 9 February 2017 which claimed lives or gave rise to new inundated areas with the level of erosion classified as mild to severe. Landslides are movements of soil mass (including rock), layers of unconsolidated sediment or soil layers on slopes with a gentle to very steep slope towards the foot of the slope as a result of exceeding the balance of slope resistance [2]. Adam (2008) stated that the prediction of run-out on the flow of soil debris is an important element in reducing the potential for damage and is used as disaster mitigation [3]. One way to predict is to use a simple Coulomb model as stated by [4]. Based on this, this study proposes to predict run-out using a simple Coulomb model. From the results of these characterizations, landslide mitigation efforts were then derived by structuring the slopes of the Tri Datu model in collaboration with community-based hydroseeding using slope stability analysis.

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RESEARCH METHODS AND LIBRARY

Broadly speaking, this research consists of sampling slip plane soil and transition layer soil from five different landslide locations (dsa1, dsa2, etc.1, etc.2, etc.3). Soil samples taken were then tested for physical properties of the soil in the laboratory. Then the parameters obtained from the results of the physical test are also used to model the unstable soil volume. From the results of slope characterization, disaster mitigation efforts are made based on increasing the Safety Factor (FK). The following is the flow of research that has been carried out which can be seen in Figure 1.

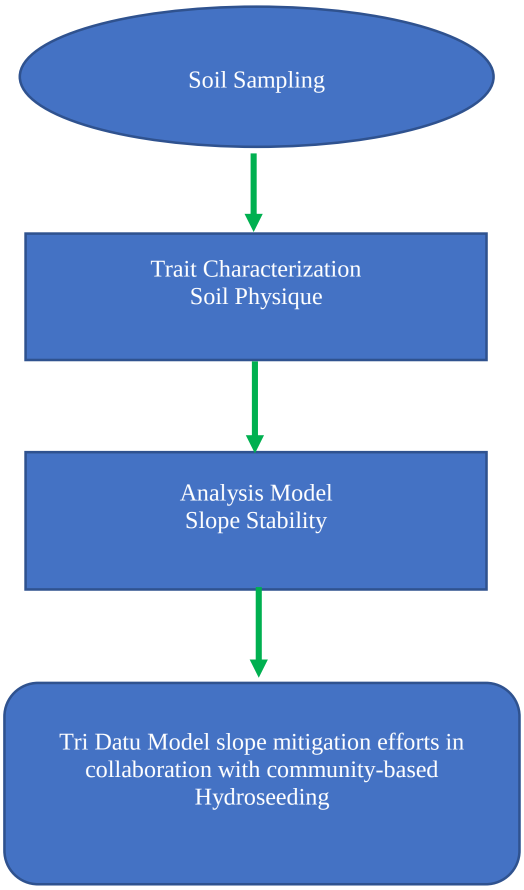

Figure 1. Research flow chart.

There were five places where the landslide occurred which soil samples were taken for research. Each soil sample was characterized using geotechnical methods. The parameters needed for slope stability analysis are shear strength and bulk density which have been obtained from geotechnical tests. According to Terzaghi (1996), shear strength is also influenced by effective stress as the effect of pore water stress so that the equation becomes (1):

$$t = c' + (\sigma - \square)tan\emptyset' \quad (1)$$

Where:
t = shear strength (kg/cm^2)
c' = effective soil cohesion (kg/cm^2)
$\square$ = pore water pressure (kg/cm^2)
σ = effective normal stress (kg/cm^2)

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Slope stability consider the safety factor that will be faced, load conditions and parameters used to analyze slope stability are as follows:

$$FK = \frac{\tau_f}{\tau_d} \quad (2)$$

Where:
$FK =$ Safety factor against ground shock
τ_f = The average shear strength of the soil
τ_d = The average shear stress acting along the sliding plane.

The shear strength of the soil has two components, namely friction and cohesion, which are formulated. As follows:

$$\tau_f = c + \sigma \tan \emptyset \quad (3)$$

Where:
c = Retaining soil cohesion
$\emptyset$ = Holding shear angle
σ = The average normal stress on the surface of the avalanche plane

$$\tau_d = C_d + \sigma \tan \emptyset_d \quad (4)$$

Where:
C_d = Cohesion
$\emptyset_d$ = The shear angle acting along the sliding plane.

By substituting, we get the equation:

$$\text{FK} = \frac{c + \sigma \tan \emptyset}{C_d + \sigma \tan \emptyset_d} \quad (5)$$

To determine the stability or stability of a slope, known as the safety factor, the forces that resist compared to the forces that move the soil will be considered stable, if it is formulated:

$$\text{Safety Factor (FK)} = \frac{holding\ moment}{driving\ moment} \quad (6)$$

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RESULTS AND DISCUSSION

Rainfall

The Kedisan Rain Station and the Kintamani Rain Station are recording rains that affect the rain in the areas of Songan A and Songan B Villages, where the average rainfall is 2.17 mm/day and the maximum rain that has ever occurred until 2013 is 2.97 mm/day. days (BWS, 2015). The following are the results of recording the Kedisan Rain Station and Kintamani Rain Station on a monthly average scale from 2003 to 2013
Table 1.

TABLE 1. Average Daily Rainfall Patterns for Kedisan Stations and Stations Kintamani (mm/day)(BWS,2015)

Bulan / Tahun	JAN	FEB	MAR	APR	MEI	JUN	JUL	AGS	SEP	OKT	NOV	DES
2003	7.06	9.37	2.18	0.22	0.81	0.00	0.07	0.00	1.97	4.34	1.24	0.05
2004	1.94	4.59	3.67	0.67	0.53	0.03	0.09	0.02	0.08	0.00	2.50	2.52
2005	0.69	3.20	6.79	2.54	0.00	0.26	0.13	0.11	0.00	0.77	3.87	5.53
2006	2.54	5.44	5.87	6.76	2.44	4.65	3.40	2.57	1.43	3.54	4.30	3.55
2007	3.44	9.65	3.68	5.54	9.3	7.55	4.22	3.65	1.54	3.99	5.32	6.43
2008	2.45	6.43	7.81	8.77	3.79	4.34	6.54	3.20	3.45	5.4	3.44	4.59
2009	8.38	7.78	2.55	0.91	0.52	0.44	0.00	0.00	0.03	0.00	0.40	2.57
2010	4.15	6.09	2.87	1.33	1.97	0.00	0.45	0.00	1.12	2.13	4.93	2.77
2011	5.29	4.28	12.16	1.30	1.15	0.09	0.03	0.00	0.00	0.02	1.10	1.14
2012	6.19	4.25	10.70	0.30	0.62	0.00	0.00	0.00	0.00	0.00	0.53	3.82
2013	9.43	9.32	5.65	1.94	1.63	1.54	0.32	0.00	0.00	0.02	1.08	4.75

LABORATORY TEST RESULTS

Moisture Check

Sampling of water content was carried out at three locations in Songan Village with laboratory test results as shown in Table 2.

TABLE 2. Results of Examination of Moisture Content

No	Description	Songan (Df = 1,00 m)		
		1	2	3
1	Heavy container Wc (gr)	9,90	9,80	9,78
2	Heavy cont + wet sample W1 (gr)	44,20	41,92	36,65
3	Heavy cont + dry sample W2 (gr)	37,30	33,40	31,70
4	Heavy air W1 – W2 (gr)	6,90	8,52	4,95
5	Dry sample weight W2 - Wc	23,4	23,60	21,59
6	Water content w = 4/5 x 100%	29,49	36,10	22,93
7	W average (%)		29,51	

Filling Weight Check

Sampling of bulk density was carried out at three locations in Songan Village with laboratory test results as shown in Table 3.

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TABLE 3. Results of Filling Weight Inspection

No	Description	Songan (Df = 3,00 m)		
		1	2	3
1	Volume ring ∅ = 6,35 cm, t = 2 cm (cm^3)	63,34	63,34	63,34
2	Heavy mould W_1 (gr)	81,80	79,70	57,40
3	Heavy mould + sample W_2 (gr)	176,50	178,20	160,40
4	Sample weight $W_2 – W_1$ (gr)	94,70	98,50	103
5	Volume weight (gr/cm^3)	1,50	1,56	1,60
6	Average volume weight (gr/cm^3)		1,55	

Specific Gravity Check

Sampling of bulk density was carried out at two locations in Songan Village with laboratory test results as shown in Table 4.

TABLE 4. Specific Gravity Examination Results

No	Description	Songan	
		1 (1,00 m)	2 (2,00 m)
1	Heavy Piknometer (gr)	39,10	37,40
2	Heavy Piknometer + dry sample (gr)	48,40	47,50
3	Piknometer + water + sample W_1 (gr)	144,30	143,70
4	Heavy Piknometer + water W_2 (gr)	139,00	137,50
5	Temperature (o^c)	29	29
6	Temperature correction (k)	0,99	0,99
7	Dry sample weight Ws (gr)	9,30	10,10
8	Specific gravity $Gs = Ws/(W_2.k – W_1 + Ws)$	2,50	2,80

Shear Strength (Direct Shear Test)

The results of the shear strength test with the provisions of depth of sampling (Df = 1.50 m), proving calibration = 0.6 and wide of sample = 31.621 cm^2 with shear test results as shown in Figure 2.

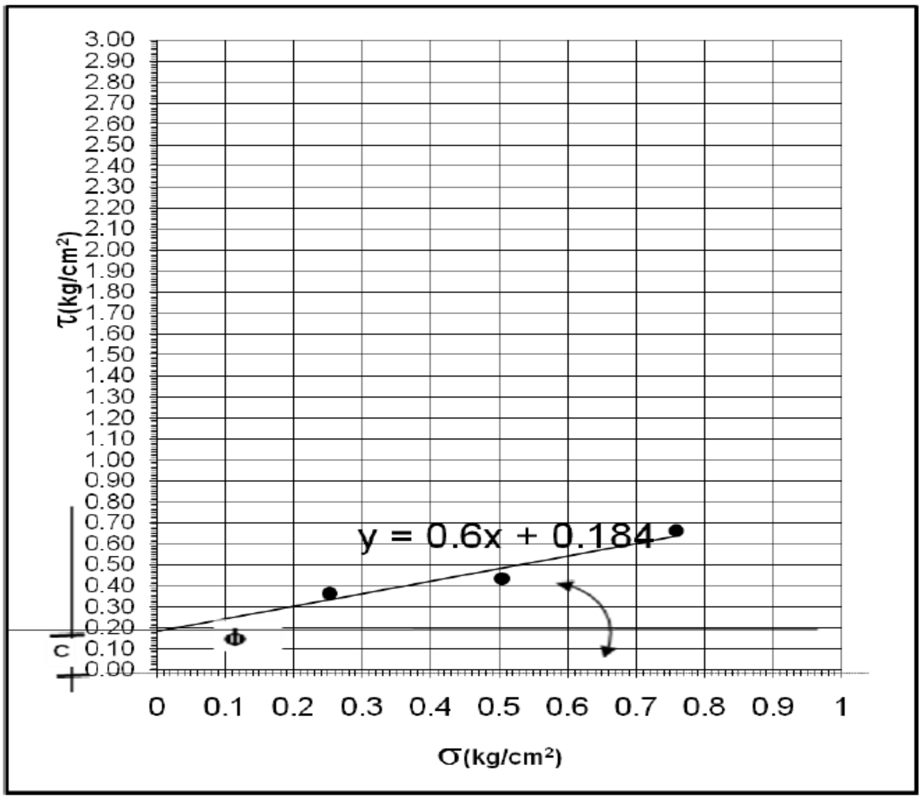

FIGURE 2. Direct shear test with the results of cohesion (c) = 0.18 kg/cm^2 and angle of friction (Ø) = 55^0

Tri Datu Test Results Collaboration with Hydroseeding

Reduction of soil mass and the Tri Datu Safety Factor in collaboration with Hydroseeding as shown in Table 5 and Table 6.

TABLE 5. Reduction of soil massa

(H : V)	Reduction of Soil Massa (m^3)				
	dsa1	dsa2	dsb1	dsb2	dsb3
Existing 2 : 3	5,02	4,49	1,68	3,79	7,54
Tri Datu collaboration Hydroseeding 2 : 3	8,61	16,40	3,18	9,19	9,8

TABLE 6. FK values based on soil massa reduction

(H : V)	FK					Deseription
	dsa1	dsa2	dsb1	dsb2	dsb3	
Existing	1,45	1,35	1,36	1,13	1,2	All FK < 1,5

2 : 3						
Tri Datu collaboration Hydroseeding 2 : 3	1,95	1,93	2,34	1,65	1,52	All FK >1.5

From Table 5 and Table 6, each sample was reduced to soil mass with a slope ratio of (H: V) 2: 3, the test results were obtained, the greater the reduction in soil mass, the greater the Safety Factor (FK) obtained. The factor of safety greater than 1.5 (FK > 1.5) was obtained from the results of the mitigation of the slope ratio (H : V) 2: 3 Tri Datu model in collaboration with Hydroseeding.

CONCLUSION

From the results of this study, it can be concluded:

1. The slope of the slope is arranged with a ratio of (H: V) 2:3
2. From the results of slope stability analysis modeling, it was found that the reduction of soil mass in a ratio of 2: 3 (slope height: slope length) with the Tri Datu Collaborative Model arrangement with Hydroseeding has increased the FK value so that the slope becomes more stable (FK> 1.5).

THANK-YOU NOTE

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