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Comparison of Landslide Disaster Risk Assessment Standards: A Study of Indonesia's Ministry of Public Works Regulations and Malaysia's Slope Assessment System

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Abstract

Semarang City is an area prone to landslides, especially areas with hilly morphology. The landslide incident certainly brought losses in both lives and material. Seeing that there are landslides in several areas of Semarang City, an assessment is needed so that landslide disasters can be anticipated. This research is located on the slope of Building E10, Faculty of Engineering, Semarang State University. This research aims to determine the level of risk of vulnerability to landslides using the Regulation of the Minister of Public Works of the Republic of Indonesia Number 22 of 2007 and the Slope Assessment Systems Method. The results of the two methods were compared with the finite element method using the Plaxis 8.6 program. The vulnerability level value based on Minister of Public Works Republic of Indonesia Regulation Number 22 of 2007 on slope 1 is 2.44, which is included in the category of a high level of landslide vulnerability, while the value for slope 2 is 2.156, which is included in the moderate level of landslide vulnerability. The assessment results using the Slope Assessment System (Slope Management and Risk Tracking System) method for Slope 1 were 0.957, which was included in the very high level of vulnerability category, while for Slope 2, it was 0.8926, which was included in the very high level of landslide vulnerability category. The results of the finite element method with the Plaxis 8.6 program show that the value of the safety factor on the slope of Building E10, Faculty of Engineering, Semarang State University, is 0.604 and is included in unstable soil conditions.

1. Introduction

Indonesia is an area prone to natural disasters [1]-[5]. Natural disasters that frequently occur in Indonesia include landslides. Landslides are movements of land masses in potential landslide areas. Indonesian disaster statistics as of 2023 show a total of 591, with 149 people dead and missing, 767 people suffering and displaced, and 2,054 residential units damaged [6]. The statistics also show that from 2015 to 2024, the total number of landslides happened to reached 7,098 incidents. This indicates that landslides have become a real threat to people.

To reduce the risk of landslides, an assessment is needed [7],[8]. This assessment is used to estimate the possibility of landslides. This landslide assessment can be carried out using several methods, including statistical methods, landslide inventories, heuristic approaches, and deterministic approaches [9]. Tangestani (2004) describes landslide assessment using the fuzzy approach of gamma operations. Factor maps are incorporated into the GIS factor assessment and landslide hazard assessment. Fuzzy membership functions are assessed for each class of factor maps. The weighting factors are then considered for each factor map and multiplied by the fuzzy membership function to justify the influence of each data layer on the fuzzy membership function [10].

Each country has its own landslide disaster risk assessment standards [11],[12]. In Indonesia, landslide risk assessment uses the Minister of Public Works RI Regulation 22 of 2007 concerning Guidelines for Spatial Planning in Landslide Prone Areas. The guidelines contain a classification of potential landslide zones based on their level of vulnerability, including classification of the level of vulnerability and determining the class of each type of potential landslide zone based on criteria and indicators of the level of vulnerability. The classification of potential landslide zone types based on the level of vulnerability is divided into 3 zone types, namely zone A, zone B, and zone C. Determining the zone type depends on the condition of the slope, the rock or soil that makes up it, geological structure, slope water system, rainfall, type, and land use that exceeds carrying capacity, as well as impacts resulting from human activities according to the type of business, as well as facilities and infrastructure. Meanwhile, to determine the class of potential landslide zones based on the level of vulnerability, 2 (two) groups of criteria are defined, namely a group of criteria based on natural physical aspects and a group of criteria based on aspects of human activity.

In Malaysia, landslide risk assessment uses the Slope Assessment Systems (SAS) method, which consists of five large-scale assessments, namely Slope Maintenance System (SMS), Slope Priority Ranking System (SPRS), Slope Information Management System (SIMS), and Slope Management and Risk Tracking System (SMART), and Landslide Hazard and Risk Assessment (LHRA). Four SAS, namely SMS, SPRS, SIMS, and SMART, were developed by the Public Works Department (PWD) Malaysia [13],[14], while the fifth SAS, namely LHRA, was developed by Fiener [15]. The SAS method continues to be developed, so it is hoped that one of these SAS will be highly accurate in predicting the possibility of landslides. The accuracy in predicting future landslides determines the effectiveness of any SAS. Incorrect predictions can create hazards and cause economic losses if slopes or areas with high hazards are incorrectly classified or estimated as having low hazards. Of the five SAS developments, the one most frequently used in landslide risk assessment is SMART.

The city of Semarang, Central Java Province, is an area prone to landslides. The geographical conditions of Semarang City consist of coastal regions, flat lands, and hills with land slopes ranging from 0% to 45%. In areas with hilly morphology, this often has the potential for landslides. The landslide incident certainly brought losses in both lives and material. Research regarding landslide disaster assessment in Indonesia is still relatively small. This research compares the standardisation of landslide assessment based on Indonesia's Republic of Indonesia Minister of Public Works Regulation Number 22 of 2007 with Malaysia's Slope Assessment Systems (SAS) method.

The location that will be studied in this research is Semarang State University, Building E10, Faculty of Engineering, located to the south of the city of Semarang and has a morphology in the form of hills. The steep topography predicts that this area has an enormous potential for landslides. This research is expected to produce a more appropriate method for determining the potential level of landslide vulnerability to minimise the impact.

2. Methodology

2.1 Research Location

The research location is in Building E10, Faculty of Engineering, Semarang State University with coordinates 7003'07.48" South Latitude and 1100 24' 14.07" East Longitude. The research location can be seen in Fig. 1 and Fig. 2.

2.2 Regulation in Indonesia

The Indonesian regulation used for this research was the Regulation of the Minister of Public Works of the Republic of Indonesia Number 22 Year 2007. This regulation regulates two things. First, it regulates the typology of potential landslide zones based on the results of hydrogeomorphological studies. Based on data and observations in the field, the zone type on the slope of Building E10, Faculty of Engineering, Semarang State

University, is Type C. Second is the assessment of the potential landslide zone type C, which is divided into landslide assessment based on natural and human aspects.

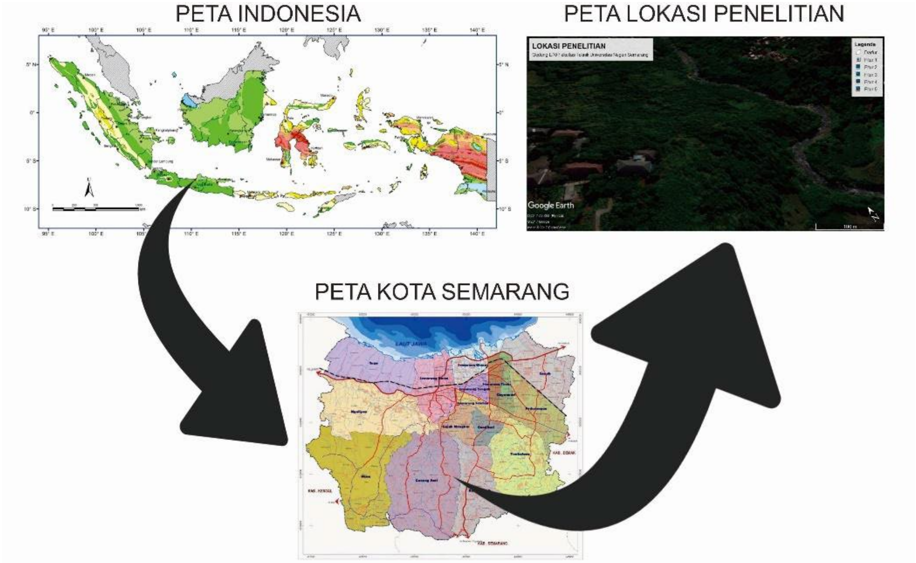


Fig. 1 *Research area in Semarang State University, Semarang City, Indonesia*

Fig. 2 *Selected slopes – slope 1 and slope 2*

2.3 Regulation in Malaysia: Slope Assessment System (Smart Management and Risk Tracking System)

The Slope Management and Risk Tracking System (SMART) is the latest slope management system developed by the Public Works Department. It was based on data from the Tamparuli-Sandakan Road in Sabah, East Malaysia, where many slope failures occur.

2.4 Finite Element Method with Program Plaxis 8.2

Plaxis (Finite Element Code for Soil and Rock Analyses) is a finite element program developed to analyse deformation and geotechnical stabilisation in civil planning. Simple data input can create complex finite element models and provide detailed output in the form of calculation results. This program's calculations are automatic and based on precise number writing procedures.

In general, the stages of the calculation methodology using the Plaxis 8.6 application consist of 3 stages, namely the data input stage (Input), the calculation stage (Calculation), and the calculation results (Output). The data needed to use Plaxis is soil parameter data obtained from the results of investigations. This data is used as input. The procedures for using the Plaxis program started by determining the title, model, and elements in the box and writing the command or purpose used. Second, enter the dimensions of the land from the case to be studied, namely, along to right, from right, up and down. Next, the dimensional shape of the land is assembled. Afterwards, input soil parameter values by pressing the Material Sets button, including γ_{dry}, γ_{wet}, cohesion, Poisson's ratio, etc. The literature obtained from the Plaxis program explains the following procedure more clearly. After getting the Safety Factor (FK) value obtained from the Plaxis 8.6 output, the next step is to find the level of the Safety Factor value in practice.

3. Results and Discussion

These results are based on the regulations from Indonesia and Malaysia, as mentioned in the Methodology section.

3.1 Landslide Assessment Method Based on the Minister of Public Works, Republic of Indonesia Regulation Number 22 of 2007 from Indonesia

Based on the typology of potential landslide zones above, we can conclude that Building E10, Faculty of Engineering, Semarang State University, is at an altitude of 196 meters above sea level (source: Google Earth 2017), so it is included in the lowland category or Type C Zone. The determination of landslide level susceptibility based on criteria and indicators of type C vulnerability based on natural aspects, based on slope, is shown in Fig. 3 and Fig. 4.

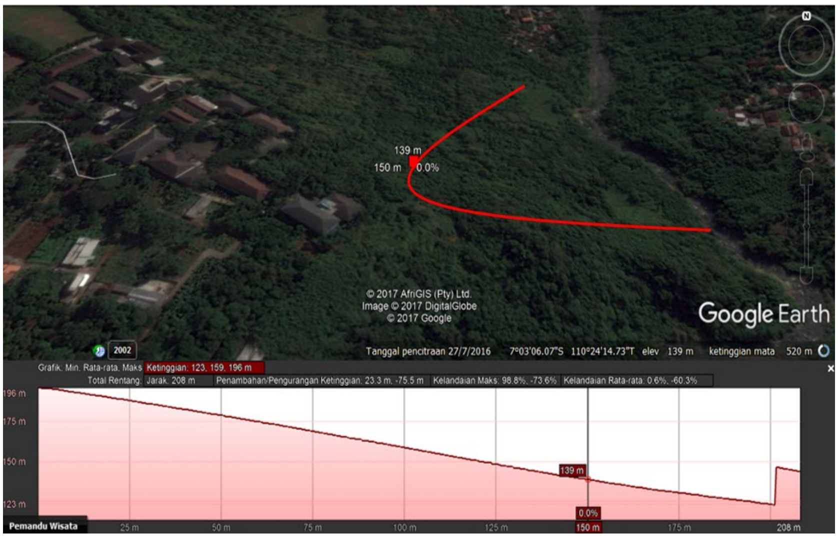


Fig. 3 *Slope 1 top view*

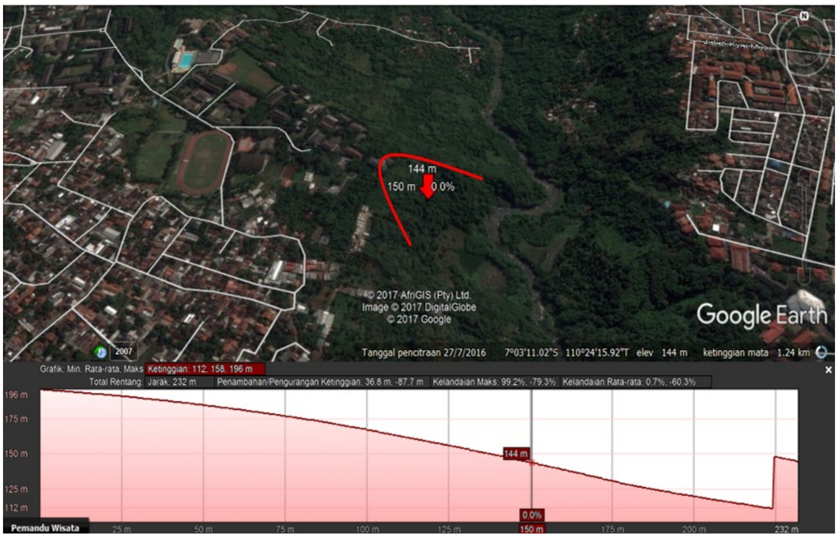


Fig. 4 *Slope 2 top view*

Slope 1 has a 38% slope, and slope 2 has a 34% slope. On slope 1, the hill is composed of rocks, and many crack structures are visible; the rock layers tilt towards the outside of the mountain. River cliffs are rocks easily eroded by river flows, with cracks/joints in the rocks. Slope 2 is composed of rocks with a visible crack structure, but the rock layers do not slope toward the outside of the hill. River cliffs are rocks easily eroded by river flows, but the stones have no cracks/joints.

The rocks that make up the slope are one of the determinants of landslides [16], [17]. In general, volcanic sedimentary rock, sand-sized sedimentary rock, gravel, sand, and clay are less robust. These rocks will quickly become soil if they undergo a weathering process and are generally susceptible to landslides on steep slopes. On slope 1, there is a slope made of rock, and many cracks are visible. Slope 2 comprises stones and visible crack structures, but the rock layers do not slope toward the outside of the hill.

High-intensity rainfall is one of the causes of landslides [18],[19]. During the dry season, cracks occur in the soil. When it rains, rainwater will enter the open pores of the soil. Rainwater that has filled the pores in the soil causes the soil to shift and eventually experience landslides. Based on the analysis, it can be concluded that the rainfall data in Building E10, Faculty of Engineering, UNNES (Semarang State University), both slope 1 and slope 2, shows moderate rainfall (range 30-70 mm/hour), lasts no more than 2 hours and does not rain every day (100-2500mm).

Water system conditions such as blocked drainage, deep erosion, mass accumulation of water, and hydrostatic pressure are causes of landslides. Slope water management is crucial so that water can be channelled properly [20],[21]. At slope 1, no water seepage, springs on slopes, or contact areas between impermeable rocks and permeable soil layers exist. At slope 2, no water seepage, springs on slopes, or contact areas between impermeable rocks and permeable soil layers exist.

The next thing that causes landslides is earthquakes. Earthquakes are vibrations in the Earth or soil. Vibrations originating from earthquakes can be strong, moderate, or light. However, vibrations emanating from within the ground can cause pressure on mineral particles and weak areas in rock and soil masses, which can cause landslides on these slopes [22],[23]. Meanwhile, Semarang City has a low earthquake risk [24],[25].

Vegetation is significant in overcoming landslides. Vegetation on slopes is a reservoir for rainwater, so that water does not flow directly to the ground. The denser the vegetation, the more effective it is at preventing erosion. Based on observations in the field, the vegetation on slopes 1 and 2 consists of grasses, shrubs, and trees. Table 1 shows the results of recapitulating criteria and indicators for landslide vulnerability levels based on human aspects.

Criteria for the level of vulnerability based on human aspects for type C zones are categorised as follows: High if the result is 2.40 - 3.00, Medium if the result is 1.70 - 2.39, and Low if the result is 1.00 - 1.69. The criteria for the level of vulnerability of the type C zone are categorised as High if the result is 2.40 - 3.00, Medium if the result is 1.70 - 2.39, and Low if the result is 1.00 - 1.69. According to the calculation of Landslide Potential Zone Susceptibility Level, it is found that slope 1 is included in the category of potential landslide zone with a high level of vulnerability (2.44) at slope 1 and 2.165 at slope 2, categorised as medium. Meanwhile, Table 2 summarises the results of the landslide risk assessment using the Slope Assessment Systems (SAS) method.

Table 1 *Results based on human aspects*

No.	Indicator	Level	Verifier	Weighted Value	Slope 1	Slope 2
1	Planting pattern	High	Slopes are planted with inappropriate and very sensitive planting patterns; for example, they are planted with fibre-rooted plants and used as paddy fields and pine forests.	0.3	0.2	0.2
		Medium	Slopes are planted with appropriate and very intensive planting patterns, for example, fibrous root crops are planted and used as paddy fields and/or fields.	0.2		
		Low	Slopes are planted with appropriate and non-intensive planting patterns, for example, planted with tap-rooted wood trees	0.1		
2	Excavation & Cutting Slope	High	High intensity of excavation/cutting of slopes, for example, for roads or buildings and mining, without paying attention to the structure of the	0.6	0.4	0.4

			soil/rock layer on the slope and without calculating slope stability analysis			
		Medium	Intensity of excavation/cutting of low slopes (roads, buildings, mining) and paying attention to the structure of soil/rock layers on slopes and calculating slope stability analysis	0.4		
		Low	Do not dig/cut slopes	0.2		
3	Pond Printing	High	Pool moulding is carried out, which can result in pool water seeping into the slope	0.3	0.1	0.1
		Medium	Pool moulding was carried out, but there was water seepage, and pool water into the slope	0.2		
		Low	Does not perform pool printing	0.1		
4	Drainage	High	Inadequate drainage system	0.3	0.2	0.2
		Medium	The drainage system is somewhat adequate, and there are efforts to improve the drainage	0.2		
		Low	The drainage system is adequate, and there are efforts to maintain drainage channels	0.1		
5	Construction Development	High	Construction is carried out with too large a load	0.6	0.6	0.4
		Medium	Construction is carried out, and the load is too large, but does not exceed the carrying capacity of the soil	0.4		
		Low	Construction is being carried out, and the load is still not small and has not exceeded the land's carrying capacity, or there is no construction.	0.2		
6	Population density	High	High population density (>50 people/ha)	0.6	0.6	0.6
		Medium	Medium population density (20-50 people/ha).	0.4		
		Low	Low population density (<20 people/ha)	0.2		
7	Mitigation Efforts	High	There are no disaster mitigation efforts by the government or society	0.3	0.3	0.3
		Medium	There are disaster mitigation efforts by the government or community, but they are not yet coordinated and institutionalised well	0.2		
		Low	There are natural disaster mitigation efforts by the government or community, which are well-organised and coordinated	0.1		
	Total			0.96 – 2.88 (1.00 – 3.00)	2.4	2.2

Table 2 *Summary of SAS SMART assessment results*

No.	Slope	Interval	Class	Slope 1	Slope 2
1	Height	Height value from 0 to 200 meters	0 - 200	57	52
2	Tilt angle	Each value is from 0 to 90 meters	0 - 90	20	18
3	Slope shape	Simple	1	3	3
		Planar	2		
		Asymmetric	3		
		Compound	4		
4	Profile plan	Convex	1	2	2
		Sunken	2		
		Straight	3		
5	Topographic cutting	On	1	1	1
		Middle	2		
		Base	3		
		Basin/ Flat land	4		
		Embankment thickness	5		
6	Structure	None	1	8	8
		Water tunnel	2		
		terraced walls	3		
		Surface net	4		
		Soil sediment	5		
		Gabion walls	6		
		Repair	7		
		Concrete wall	8		
		Masonry walls	9		
		Etc	10		
7	Main Cover Types	Grass	1	4	4
		Bush	2		
		Fern	3		
		Forest	4		
		Plantation	5		
		Agriculture	6		
		Etc	7		
8	Slope cover	Good (100%)	1	2	1
		Average (80 - 100%)	2		
		Poor (<80%)	3		
9	Percentage of rock exposure	Each value from 0 to 100 %	0 - 100%	30	30
10	Core rock	No	0	0	0
		Yes	-1		
11	Rock condition profile	The majority < class III	1	1	1
		Some < Class III & Some > class IV	2		
		Mostly class IV to VI	3		
		Mostly class IV to VI but with rocks	4		
		Mostly Colluvium	5		
12	Measure of soil saturation	Lowest	0	3	3
		Medium	1		
		High	2		
		Very high	3		

The instability slope is known from the value of P, which is the probability of the landslide vulnerability level. The value of P is obtained when the value of Y is achieved. Y is the value of the slope variable, calculated using the parameters in Table 2, i.e., height, tilt angle, slope shape, profile plan, topographic cutting, structure, main cover types, slope cover, percentage of rock exposure, core rock, rock condition profile and the measure of soil saturation as shown in Eq. (1).

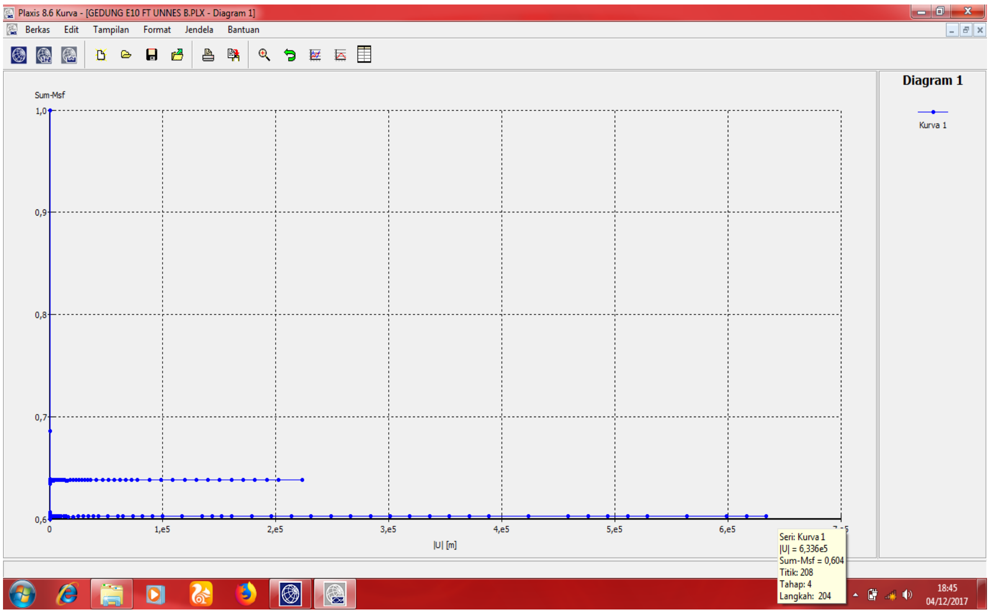
The calculation of the Y value in slope 1 obtained Y = 2.595, and for slope 2, the value of Y = 1.948. The following probability calculation from Y to P shows slope 1, P = 0.957, and slope 2 = 0.892. The category of instability shown by the P value is as follows: very low (0.0 – 0.2), low (0.2 – 0.4), medium (0.4 – 0.6), high (0.6 – 0.8), and very high (0.8 – 1). At slope 1, the calculation result of Y = 2.595 means the calculated probability P is 0.957, so it can be concluded that slope 1 has a very high vulnerability risk. At slope 2, the calculation result of Y = 1.948 means the probability calculation value P is 0.8926, so it can be concluded that slope 2 has a very high vulnerability risk. The results of the Finite Element Method using Plaxis 8.6 with the input parameters are shown in Table 3.

$$\begin{gathered}Y = 0.027(\text{height}) + 0.02(\text{tilt angle}) + 0.163(\text{slope shape}) + 0.354(\text{profile plan}) + \\ 0.278(\text{topographic cutting}) + 0.202(\text{structure}) - 0.172(\text{main cover types}) + 0.472(\text{slope cover}) + \\ 0.017(\%\ \text{rock exposure}) - 1.266(\text{core rock}) + 0.249(\text{rock condition profile}) + 0.281(\text{soil} \\ \text{saturation}) - 4.293\end{gathered} \tag{1}$$

Table 3 *Input parameters of the research location*

Parameter	Symbol	Value	Unit
Model material	Model	Morh-Coulomb	-
Material behavior	Type	Undrained	-
Dry volume weight	γ_{dry}	14	kN/m³
Wet volume weight	γ_{wet}	16/20	kN/m³
Permeability in the horizontal direction	Kx	0	m/day
Vertical direction permeability	Ky	0	m/day
Modulus of elasticity	E_{ref}	15000	kN/m²
Poisson's ratio	v	0.300	-
Cohesion	c	20	kN/m²
Shear angle	φ	17.486	°
Dilation angle	ψ	-	°

Calculations were performed computationally using the Plaxis 8.6 program in the slope stability analysis. The safety factor (FK) value was obtained as 0.604 based on the calculation output results. The safety factor value graph is shown in Fig. 5. The results of the Plaxis calculation show a safety factor value of 0.604. Thus, it can be concluded that the slopes in Building E10, Faculty of Engineering, Semarang State University, are unstable. The results of the landslide disaster risk assessment are shown in Table 4.



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Seri: Kurva 1
|U| = 6,336e5
Sum-Msf = 0,604
Titik: 208
Tahap: 4
Langkah:  204
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Fig. 5 *Output Plaxis 8.6*

Table 4 *Results of the landslide risk assessment*

	Permen PU RI No. 22 Year 2007		SAS (SMART)		Finite Element	
	Score	Remark	Score	Remark		
Slope 1	2.44	High level of vulnerability	0.95	High level of vulnerability	0.604	Unstable
Slope 2	2.16	Medium level of vulnerability	0.89	High level of vulnerability		

The results of the risk assessment of the level of landslide vulnerability show that the two methods on slope 1 both have a high level of vulnerability. In contrast, on slope 2, there are differences. The RI PU Ministerial Decree Number 22 of 2007 on slope 2 shows a medium level of vulnerability, while the Slope Assessment System (SAS) method shows a high level of vulnerability. According to the Minister of Public Works Republic of Indonesia Regulation Number 22 of 2007, for slope 1 and slope 2, the difference lies in the indicators of soil conditions, rocks that make up the slope, and construction. Building construction on slopes has an impact on landslides or cracks. Field observations concluded that most cracks occurred on slope 1, especially in the lower structure of the building and retaining walls. On the other hand, the verifiers in the PU Ministerial Decree assessment indicators are too specific, so some do not match the conditions in the field. Using the SAS Method for both slope 1 and slope 2, the differences lie in the height of the slope, the slope angle, and the slope cover condition. Differences in height and slope angle affect the risk of landslides. The observations and data analysis results show that the slope angle of slope 1 is steeper than slope 2. Apart from forests, the vegetation on slope 1 also contains agricultural land. Land use on slopes is prohibited for agricultural land because it can cause landslides. Meanwhile, according to the finite element method using the Plaxis 8.6 program, the safety factor (FK) value was 0.604 and included in the unstable or critical slope conditions category.

4. Conclusion

Landslides have become a disaster that is still among the disasters that regularly happen in Indonesia, with damages resulting in victims and other material and immaterial losses. Therefore, the assessment of landslides is needed. This research has proven the calculation of landslide assessment using methods used in Indonesia and Malaysia. The landslide vulnerability level value based on Minister of Public Works, Republic of Indonesia Regulation Number 22 of 2007 for slope 1 is 2.44, including the high landslide vulnerability level category, while for slope 2 it is 2.165, including the moderate landslide vulnerability level. The landslide vulnerability level value based on the Slope Assessment Systems Slope 1 Method is 0.957, which is included in the very high landslide vulnerability level category. In contrast, 0.89 is included in the category of very high landslide vulnerability level. The safety factor value based on Plaxis 8.6 calculations is 0.604 and is included in unstable soil conditions. So, based on the different regulation methods used, the regulation found quite the same results.

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Conflict of Interest

The authors declare no conflict of interest regarding the paper's publication.

Author Contribution

The authors confirm contribution to the paper as follows: ***Study conception and design:*** *Muhammad Mukhlisin, Rini Kusumawardani;* ***Data collection:*** *Iwanudin, Rini Kusumawardani;* ***Analysis and interpretation of results:*** *Muhammad Mukhlisin, Iwanudin, Rini Kusumawardani;* ***Draft manuscript preparation:*** *Hany Windri Astuti, Roni Apriantoro, Amin Suharjono. All authors reviewed the results and approved the final version of the manuscript.*

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