The investigation of avalanche patterns on railroad tracks with steep slopes

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The investigation of avalanche patterns on railroad tracks with steep slopes

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Abstract. This study aims to investigate the pattern of landslides on the cliffs forming the railway with steep slopes. This research was conducted at Rejosari Natar Station, South Lampung Regency, Lampung Province. The point of observation is at STA 30 + 250. The data in this study were divided into primary and secondary data. Primary data is the data that is directly obtained in the field by taking soil samples which are then processed in the laboratory. The secondary data is the soil characteristics data of the railroad structure starting from the rail load, rail bearings, ballast layers, sub-ballast layers, and sub-grade. These will be used as input in conducting railroad analysis using Plaxis modelling. Plaxis modeling requires these variables and parameters to be analyzed based on the amount of vertical settlement, total stress, and safety factor values that occur due to rail loads. Reserach found that the value of the soil safety factor was <1.25. This means that the soil condition is in a critical condition for collapse and the ground will experience landslides which can endanger the safety of the passing trains. For this reason, improvements are needed in the soil that will experience landslides.

Keywords: Avalance, pattern, railroad, track

1. Introduction

Train is a vehicle or means of transportation that can transport goods and people in large quantities. A train consists of a locomotive as the driving force and carriages as a place to transport people or goods. The carriages are stretched lengthwise and pulled by the locomotive to move. Trains run on specific roads which are called rails. Throughout the world, trains are used as a means of transporting goods or human transportation. Mass human transportation by rail means dealing with the transportation of large numbers of people from one city to another. For freight transport, trains can be a long series involving more than 50 cars. The longest train in the world is The Kansas City Southern de Mexico with a length of 5166 m. This train is operated between United States and Mexico [1]. The longest train in the world for passenger is in Australia (The Ghan) with a length of about 1696 m with a maximum series of 44 cars [2]. Other countries with the largest number of carriages and the longest trains are Canada, the United States, the United Kingdom and China. In Indonesia, the transportation

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of goods and people using trains is organized by PT. Kereta Api Indonesia, a government-owned company appointed to manage rail transport services in Indonesia [3]. The length of railroads in Indonesia is 6,790 km. Of that number, only two thirds are active and still in use. Railroads in Indonesia are spread across Java as much as 71% and in Sumatra as much as 29%. By 2030, the government targets to increase the length of the railroad so that its length is twice the length of the current rail. The plan for this long train network will be spread across the islands of Java, Bali, Sumatra, Kalimantan, Sulawesi and Papua [4]. Increasing the length of railways to twofold by 2030 inevitably requires expertise to better organize and maintain this infrastructure to ensure the smooth operation of railways.

Due to its operation, railroads that are used as roads for trains will experience quality degradation in some of their components [5][6] including in railroad structures such as fractures in rail weld joints, damage to rail fasteners, wear on rails and cracks in concrete bearings. The dominant incidence of train accidents in Indonesia is the collapse of the carriages caused by the spread of cracks in rail fractures, cracks in concrete pads, loose fastening of rails, failure of railroad structures, land subsidence, and human error. One of the most dominant causes of accidents is cracks in concrete bearings. The cracks in the concrete bearings are caused by the concrete bearings that are not able to withstand the loads given by the railroad cars, causing cracks on various sides of the concrete bearings. Cracked concrete bearings can also occur due to land subsidence due to decreased soil bearing capacity due to non-standard soil compaction. In addition, the railroad structure on sloping ground contours can trigger landslides and cause fractures to concrete bearings, rails and damage to the railroad structure.

This study aims to investigate the pattern of landslides on the cliffs forming the railway with steep slopes. This research was conducted at Rejosari Natar Station, South Lampung Regency, Lampung Province. The point of observation is at STA 30 + 250. The laboratory work is carried out at the Laboratory of Soil Mechanics, University of Lampung. The visualization of the collapse of the cliffs forming the railroad will be carried out with the help of the Plaxis method.

2. Research methodology

2.1. Study location

This research was conducted at Rejosari Natar Station at the observation point of STA 30 + 250. Rejosari Station is a train station located in Natar District, South Lampung Regency. The distance is approximately 19 km from Tanjung Karang Central Station, Lampung. Rejosari Station is a Class II train station located at an altitude of +104 meters above sea level. Administratively, this station is under Regional Division IV Tanjungkarang.

Figure 1. Study location

This station has four railway lines with line 3 being a straight line plus eight special lines in the workshop area. At this station, there is a coal train maintenance workshop that sends coal from the Bukit Asam coal mine, South Sumatra Province, to the Tarahan power plant in Lampung Province. This coal carrier train is the longest train in Indonesia, which is approximately 600 m long with a maximum series of 50 carriages. This train is capable of making 50 trips from Bukit Asam to Tarahan every day and supplies several hydropower plants in Java Island apart from PLTA Tarahan in Lampung Province.

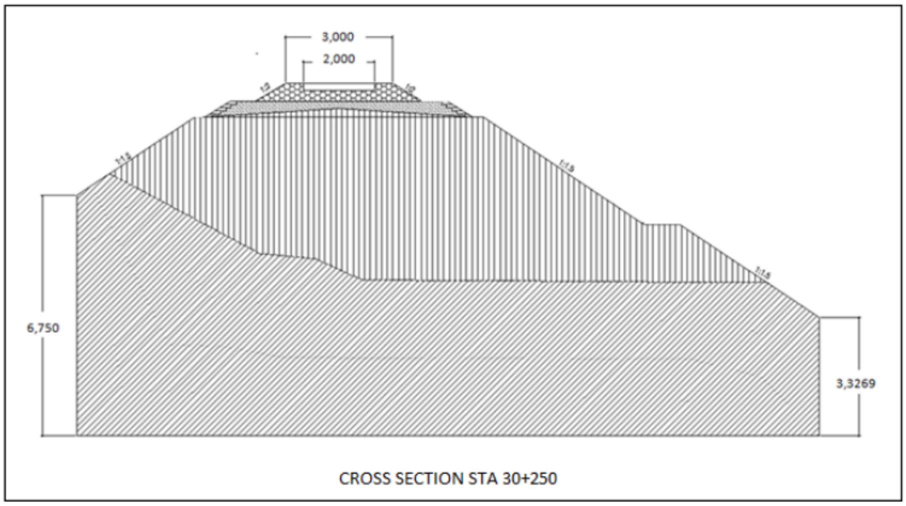

Figure 2. Cross section in the location of study

2.2. Data and research procedures

The data in this study were divided into primary and secondary data. Primary data is data that is directly obtained in the field by taking soil samples which are then processed in the laboratory. Meanwhile, secondary data is data obtained from the results of previous research which can be accounted for its accuracy. Primary data obtained from this study is the data on the characteristics of landfills [7] which are the results of tests at the Laboratory of Soil Mechanics, University of Lampung. These data are:

- Water content (%)
- Specific gravity (%)
- Sieve analysis (%)
- Atterberg Limit (%)
- Max. dry density (%)
- CBR soaked and unsoaked (%)

The secondary data is the soil characteristics data of the railroad structure starting from the rail load, rail bearings, ballast layers, sub-ballast layers, and sub-grade layer [8]. The characteristics of the railroad include the modulus of soil elasticity (E), subgrade modulus (Ks), poisson ratio, soil permeability, soil cohesion and soil shear angle. These characteristics will be used as input in conducting railroad analysis using Plaxis.

3. Result and Discussion

Plaxis modeling requires variables and parameters to be analyzed based on the amount of vertical settlement, total stress, and safety factor values that occur due to rail loads. The following are the

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characteristics of the primary data and the parameters that will be used in the Plaxis program input in the form of cross sections and tables.

Table 1. Original soil characteristics data from the field (primary data)

No.	Description	Unit	Value
1.	Water content	(%)	12.3
2.	Specific gravity	(%)	2.562
3.	Sieve analysis	(%)	36.82
4.	Atterberg Limit	(%)	LL = 37.92, PL = 25.33, IP = 12.59
5.	Max. dry density	(gr/cm^3)	1.531
6.	Opt. moisture content	(%)	23.70
7.	CBR soaked and unsoaked	(%)	Soaked = 13.60 Unoaked = 7.33

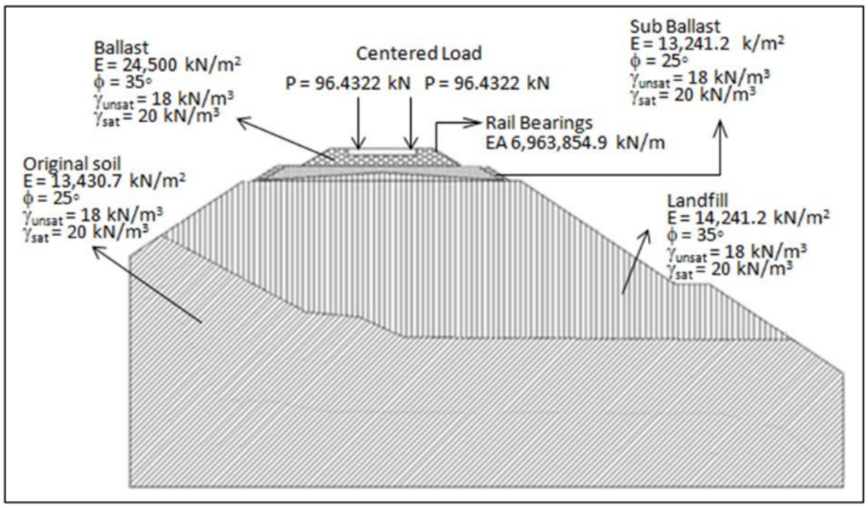

Figure 3. Force distribution in the cross section studied

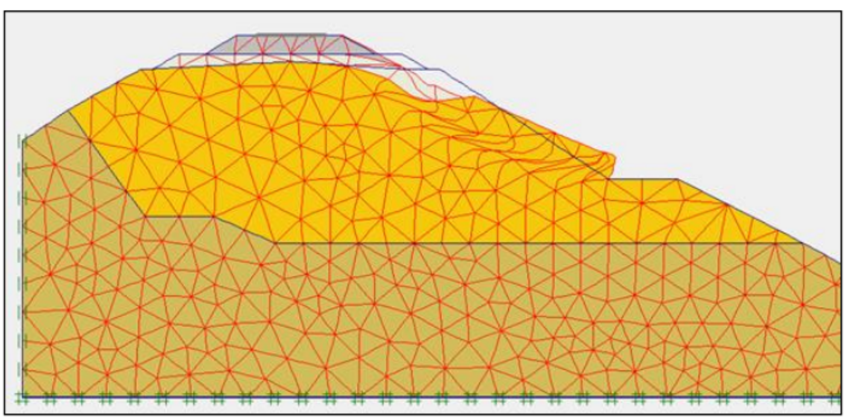

Figure 4. Figure network of deformed elements in the unsaturated condition of the railroad structure which is located at STA 30 + 250

Table 2. Input data for Plaxis analysis (secondary data)

Zone	Parameter	Symbol	Value	Unit
Centralized load	-	-	96.4322	kN
Concrete rail bearing	Elastic Axial Stiffness	EA	6,963,854.9	kN/m
	Flexural ridigity	EI	141.4812	$kN.m^2/m$
	Weight	W	0.2246	kN/m/m
	Poisson Ratio	V	0.2	-
Ballast	Fill weight above the phreatic level	γ_{unsat}	20	kN/m^3
	Fill weight below the phreatic level	γ_{sat}	22	kN/m^3
	Permeability in the hor. direction	Kx	0.0011574	m/day
	Permeability in the vertical direction	Ky	0.0011574	m/day
	Modulus Young	E	24,500	kN/m^2
	Poisson Ratio	V	0.4	-
	Sliding angel	Ø (phi)	40	°
	Angel of dilation	φ (psi)	10	°
Sub-ballast	Fill weight above the phreatic level	γ_{unsat}	18	kN/m^3
	Fill weight below the phreatic level	γ_{sat}	20	kN/m^3
	Permeability in the hor. direction	Kx	0.000011574	m/day
	Permeability in the vertical direction	Ky	0.000011574	m/day
	Modulus Young	E	12,250	kN/m^2
	Poisson Ratio	V	0.15	-
	Sliding angel	Ø (phi)	35	°
	Angel of dilation	φ (psi)	5	°
Landfill	Fill weight above the phreatic level	γ_{unsat}	18	kN/m^3
	Fill weight below the phreatic level	γ_{sat}	20	kN/m^3
	Permeability in the hor. direction	Kx	1.1574E-09	m/day
	Permeability in the vertical direction	Ky	1.1574E-09	m/day
	Modulus Young	E	14,241.2	kN/m^2
	Poisson Ratio	V	0.3	-
	Sliding angel	Ø (phi)	25	°
	Angel of dilation	φ (psi)	0	°
Original soil	Fill weight above the phreatic level	γ_{unsat}	18	kN/m^3
	Fill weight below the phreatic level	γ_{sat}	20	kN/m^3
	Permeability in the horizontal direction	Kx	1.1574E-09	m/day
	Permeability in the vertical direction	Ky	1.1574E-09	m/day
	Modulus Young	E	13,430.7	kN/m^2
	Poisson Ratio	V	0.3	-
	Sliding angel	Ø (phi)	25	°
	Angel of dilation	φ (psi)	0	°

Figure 4 is a display of the results of the deformed element network in the unsaturated condition of the railroad structure which is located at STA 30 + 250. The red grid color is the element distribution that occurs after a stretching analysis of the element density due to the effect of sloping soil displacement on the embankment soil. There was a change in the shape of the sloping soil position on the right side of the embankment in the conditions after analysis, on the sloping part of the embankment there was a temporary settlement. In the cross section of STA 30 + 250 there is a deformation of 1.25 m. The greater the deformation value, the greater the likelihood of landslides due to soil deformation occurring on sloping land, both vertically and horizontally. The amount of deformation is influenced by the magnitude of the slope angle of the embankment soil and the height of the soil slope itself.

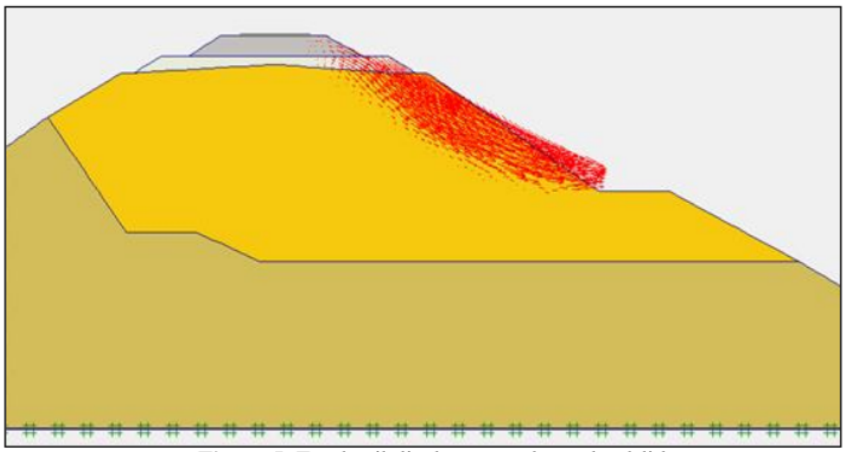

Figure 5. Total soil displacement due to landslides

The illustration of total soil displacement shows the effect of two directions of soil displacement, both horizontally and vertically. There are two directions of arrows that move vertically and horizontally. Soil displacement that occurs is indicated by the largest arrow and the direction as shown. The total soil extreme displacement value at STA 30 + 125 is $1.25.10^3$. The total soil displacement is obtained at 1.25 m.

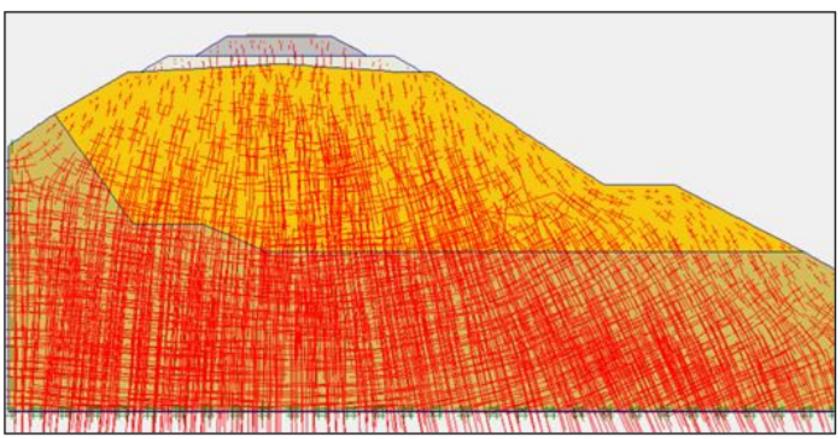

Figure 6. Effective stress illustration

The illustration of the effective stress shows the amount of effective earth stress that occurs at the cross section of STA 30 + 250. Effective stress affects shear strength and changes in volume or soil subsidence that occurs on sloping soil. The deeper the soil, the greater the effective soil stress that occurs. This is indicated by the red density element. The denser the elements, the greater the effective soil stress that occurs. In this condition, the maximum effective stress value is -156.97 kN / m^2. The negative sign at the maximum value indicates the pressure on the soil particles. The greater the value of the effective soil stress that occurs, the better the condition of the soil particles in providing bearing capacity for sloping soil landslides on the landfill. From the calculation results, the unsaturated sloping soil conditions studied had a safe factor (Fk) value of 1.19, or were in a critical condition (Fk <1.25) for collapsed. Therefore, retaining walls for supporting soil must be installed on steep soils so that the safety factor value reaches a value of more than 1.25 and the construction is safe against landslides.

4. Conclussion

In overall, in the analysis for STA 30 + 250, it was found that the value of the soil safety factor was <1.25. This means that the soil condition is in a critical condition for collapse. This situation states that the ground will experience landslides which can endanger the safety of the passing trains. For this reason, improvements are needed in the soil that will experience landslides such as the installation of retaining walls, flat sheet piles, steel sheet piles and soil geometric changes on steep slopes.

5. Acknowledgements

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