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Design Of Retaining Wall In Landslide Areas

(Case Study: Nagrak Street, Bandung Regency, West Java)

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Abtract---*The rapid development of traffic volume and the presence of natural phenomena can affect the deterioration of the road structure and its complementary buildings. One of the natural phenomena that arise on Jalan Nagrak is landslides, so we need the best and economical treatment by paying attention to the safety and comfort of road users. The purpose of this research is to deal with landslides on Jalan Nagrak by planning the construction of a Soil Retaining Wall in areas with unstable soil conditions and certain slopes. This study refers to data at the location conducted in accordance with American Standard Testing and Material (ASTM) procedures. From the results of the study it was found that the condition of Nagrak road damage in the form of cracks and subsidence in the pavement layer leading to slope collapse, selected Avalanche Handling Technology in the form of Reconstruction of the retaining wall using a masonry retaining wall with a bore pile foundation. The foundation of the retaining wall is placed under the skid plane at least 2 m and the width of the foundation 1.1 m.*

Keywords---*Landslides. Retaining Wall Soil, Bore Pile Foundation*

I. Introduction

Roads are transportation infrastructure that connects one region to another. The rapid development of traffic volume and the presence of natural phenomena can affect the deterioration in the condition of the road structure and its complementary buildings. To be able to improve services and a sense of security for road users, it is necessary to have the best and economical technical planning with due regard to safety and comfort.

One of the natural phenomena that arise on Jalan Nagrak is landslides. To be able to deal with these symptoms by planning the construction of the Soil Retaining Wall in areas with unstable soil conditions with a certain slope. The construction of the Soil Retaining Wall is expected to prevent and reduce landslides, so that it can provide a sense of security and comfort.

II. Literature Review

Landslide

Understanding the motion of the land (mass movement) with an avalanche (Landslide) have in common. Soil movement is the transfer of a mass of soil or rock in an upright, horizontal or sloping direction from its original position, ground motion includes creeping and flow movements and landslides. From the definition of ground motion it can be concluded that landslides are part of ground motion [1].

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Basically landslides occur when the driving force on the slope is greater than the holding force. Retaining forces are generally influenced by rock strength and soil density. While the driving force is influenced by the magnitude of the slope angle, water, load and rock density. The forces acting on the slope are generally grouped into two, namely: the forces that tend to cause the material on the slope to move down and the forces that hold the material on the slope so that there is no movement or avalanche.

Based on the mass movement of the collapse, landslides can be grouped into several, namely:

a. Falling; is the fall of chunks of rock or material apart from steep slopes.

b. Sliding (sliding); is the downward and outward movement of mass caused by the shear stress acting on the collapsed surface in excess of the shear resistance possessed by the material on the collapsing surface.

c. Toppling; is the overthrow of several blocks of rock caused by the rolling moment that works on these rock blocks.

d. Flow (flowing); is a material that moves down the slope like a liquid.

Some Causes of Road Slope Collapse

In general, there are four main causes of slope instability:

• Local soil / rock conditions
- Soft and weak, sensitive and rotten material
- There are cracks and burly
- Variations in physical properties (permeability, plasticity, minerals and so on)

• Morphology
- Movement / removal of the ground surface due to active tectonic or volcanic motion
- Erosion process (lateral crushing)
- Vertical scouring (scouring)
- Addition of soil load / discharge in the peak slope area
- Stripping of vegetation due to drought or fire.

• Physical condition around the slope
- Heavy and long rain
- Fast drawdown
- Earthquake
- Volcanic eruptions
- Fluctuation of marin plate rocks
- Artesian pressure

• Man-made
- Multiplication at the foot of the slope
- Adding weight to the top of the slope
- Deforestation
- The existence of irrigation at the top of the slope (being wet and wet)
- Mining activities
- Water that is trapped and leaks from the utility

Retaining Wall

Retaining wall (Retaining wall) is a building that is built to prevent steep land collapse or slopes built in places where stability cannot be guaranteed by the slope itself, influenced by the topographical conditions of the place, if earthwork is carried out such as embankment or land cutting [2].

In general, the function of a retaining wall is to withstand the amount of soil pressure due to poor soil parameters so that landslides can be prevented, as well as to protect the slope of the soil and complete the slope with a solid foundation.

Broadly speaking, retaining walls are classified into seven types, namely:

a. Gravity Wall (Gravity Wall) is a retaining wall made of reinforced concrete or stone pairs.
b. Semi gravity wall (semi gravity wall) Gravity walls that are rather slender in structure require concrete reinforcement only on the wall only.
c. Cantilever wall (Cantilever wall), in the form of the letter "T" inverted or like the letter "L" and each part is counted as a cantilever.
d. Counter-wall (Counterfort wall), the shape of this wall is the same as the cantilever wall, only between the ground floor and the wall is reinforced with a supporting wall known as counterfort.
e. Butters wall (Butters wall), the shape of the wall butters is the same as the counter wall (Counterfort wall). Only on this wall the support is at the front of the wall (Face) that appears, making it less tidy so it is rarely used.
f. Bridge abutments (Bridge abutments), the shape of this wall sometimes has wings which are also called wing walls, these wings are used to hold the infill soil and prevent erosion. The wing slope towards the abutment face ranges from 0 o - 30o.
g. Cribb wall This wall is made of wood, printed concrete or steel which is then filled with granular soil. This wall is only used for smaller walls and the soil pressure is not too large. This wall cannot withstand surcharge.

Basic Principles of Landslide Control Methods

A good countermeasure is a countermeasure that can solve the problem completely with relatively low cost and easy implementation. Countermeasures depend on the type and nature of landslides, field conditions and geological conditions. Countermeasures that are only based on trial-and-error methods are generally less successful. Less successful because the countermeasures are not appropriate and inadequate. For complex types of avalanches, the response requires more careful analysis based on more complete data.

Mitigation of landslides by reducing the driving force is done by cutting and controlling surface water. While countermeasures by adding restraining forces, among others, by controlling seepage water, tethering and landfill at the foot of the slope.

Avalanche Mitigation Technology Options

In handling landslides, there are 3 types of approaches commonly used to increase the safety factor [3], namely:

a. Increase the resisting forces

Various methods can be applied to increase anchoring forces such as: subdrainage to increase soil shear strength; eliminating weak zones or skidding areas by constructing benching on slippery surfaces; construction of retaining structures such as poles, retaining walls, or embankments on the toe of a slope; and compaction of loose grained material.

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b. Reducing driving forces

Reduction of the driving forces can be achieved by doing the following: removing material from the slope that causes the driving forces to cause movement; and subdrainage to eliminate hydrostatic forces and / or reduce soil mass weight by reducing water content. The latter method is actually more influential in increasing the retaining forces by increasing the shear strength of the soil than reducing the driving forces.

c. Avoid or eliminate avalanches

The methods that can be used for this approach are: relocation of roads or structures to avoid unstable areas, removing the mass of the land that is experiencing landslides as a whole; or make the bridge cross an unstable area.

III. Methodology

General Description

This research refers to the data that the writer got from the field data, namely at the work location in Nagrak street, Pacet Subdistrict, Bandung Regency, West Java Province, Indonesia. Field research is carried out in accordance with laboratory procedures in accordance with with American Standard Testing and Material (ASTM) [4].

Preparation

Activities required at the preparatory stage include:

a. Look for library references from books and the internet
b. Prepare things that are needed when research in the field
c. Following data collection in the field

Data Collection Methods

Conducted by direct observation in the field and data processing which includes:

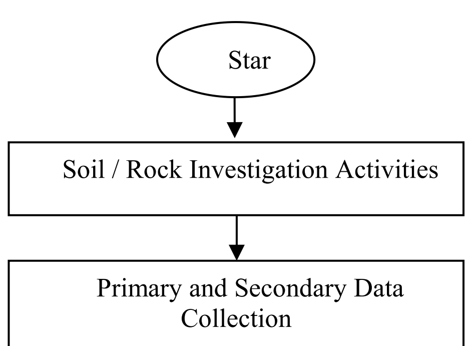

Figure 1. Flowchart of investigations and countermeasures for slope collapse / landslides

IV. Data Processing and Analysis

Data of Sondir Investigation Results

The investigation was carried out as many as 2 (two) points spread over several existing road points. Following are the results of the Sondir test:

Table 1. Resume of Sondir Test Results

No. Sondir	Depth (m)	qc (kg/cm^2)
S-1	5.40	153

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S-2	3.40	153

DUTCH CONE PENETROMETER GRAPH

PROJECT	SID PEMBANGUNAN TPT JL NAGRAK KEC PACET (P.17.01.JKP 23)						Page
SITE	SID TPT						1 of 2
LOCATION	JL NAGRAK - PACET, KAB BANDUNG						
ELEVATION ABOVE MSL(m)			S / E	48 M 801730 9214920			
BORE HOLE NO.	S-2		DEPTH OF GWL (m)			3,00	
Machine Type	Gouda		Date	19-Mei-16			
Max. Capacity	2.5 Tons		Operator	DANI			
Manometer type	0-25,0-60,0-250 kg/cm2		Rate of Penetration(mm/second)			20	
Piston/Cone Area Ratio (A_{pc})		1	Piston/Sleeve Area Ratio (A_{ps})			0,09	
Rod-Weight Corr. Factors	A-Factor	0,138	B-Factor	0,22	C-Factor 0,0124	D-Factor	0,023

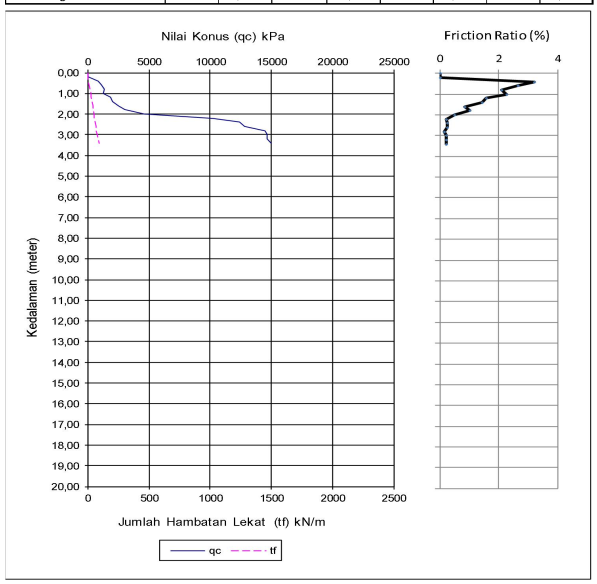


Figure 2. Dutch Cone Penetrometer Graph S-1

DUTCH CONE PENETROMETER GRAPH

PROJECT	SID PEMBANGUNAN TPT JL NAGRAK KEC PACET (P.17.01.JKP 23)							Page
SITE	SID TPT							1 of 3
LOCATION	JL NAGRAK - PACET, KAB BANDUNG							
ELEVATION ABOVE MSL(m)			S / E	48 M 801730 9214920				
BORE HOLE NO.		S-1	DEPTH OF GWL (m)				3,00	
Machine Type	Gouda		Date	19-Mei-16				
Max. Capacity	2.5 Tons		Operator	DANI				
Manometer type	0-25,0-60,0-250 kg/cm2		Rate of Penetration(mm/second)				20	
Piston/Cone Area Ratio (A_{pc})		1	Piston/Sleeve Area Ratio (A_{ps})				0,09	
Rod-Weight Corr. Factors	A-Factor	0,138	B-Factor	0,22	C-Factor	0,0124	D-Factor	0,023

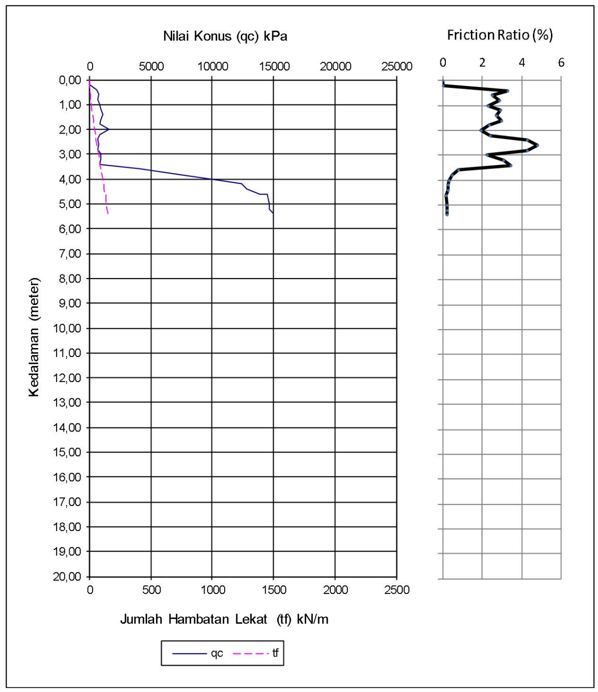


Figure3. Dutch Cone Penetrometer Graph S-2

Foundation Recommendations

Shallow foundation

Based on static cone penetration test data, the carrying capacity of shallow foundation soil is based on static cone penetration testing, where the reduction does not exceed 2.5cm calculated by the Meyerhoff formula [5].

Formula:

a. square foundation or elongated foundation with a width of foundation B ≤ 1.2m

$$q_a = \frac{q_c}{30} \text{ (kg/cm}^2\text{)} \quad \text{.............................(1)}$$

b. For square or elongated foundations with a width of foundation B ≥ 1.2m

$$q_a = \frac{q_c}{50} \times \left(\frac{\text{B+0,30}}{\text{B}} \right)^2 \text{ (kg/cm}^2\text{)} \quad \text{...........(2)}$$

Where:

Qa = carrying capacity of the permit for a 2.54 cm reduction

Qc = cone resistance in kg / cm^2

B = width of foundation (meters)

Table 1. The results of the calculation of carrying capacity shallow foundation

Point number	B (m)	Qc (kg/cm^2)	Carrying Capacity (qa)	
			(kg/cm^2)	(Ton/m^2)
S-1	1	9	0.30	0.04
	1.5	9	0.52	5.20
S-2	1	13	0.44	4.39
	1.5	13	0.75	7.51

For shallow foundations recommended at a depth of 1 meter with a width of shallow foundations of 1 meter and 1.50 meters respectively. Then the carrying capacity of shallow foundation as shown in the table above for S-1 sondir carrying capacity ranges from 3.04 tons / m2 for foundations with a width of 1 meter and 5.20 tons / m2 for foundations with a width of 1.5 meters and for S-2 is 4.39 tons / m2 for foundations with a width of 1 meter and 7.51 tons / m2 for foundations with a width of 1.5 meters.

The foundation design is calculated based on the results of the sondir data that has been done. The carrying capacity analysis uses the approach of Meyerhof (1956) and Beggeman who have issued empirical formulas for calculating the carrying capacity of deep foundations based on Sondir data.

The Beggeman Way

P_{all} = (qc . Ab)/3 + (JHP . As)/5 ....(3)

Where:

qc = ½ (qc-u + qc-b)

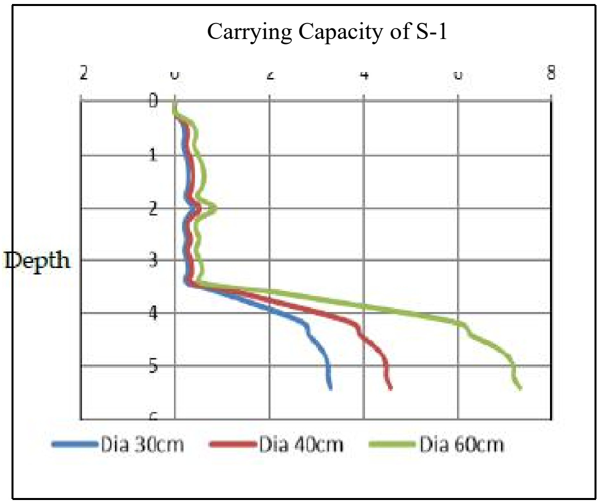
qc-u = qc averaging 8x the diameter of the top of the pole

qc-b = qc on average along the 3.5x diameter of the bottom end of the pole

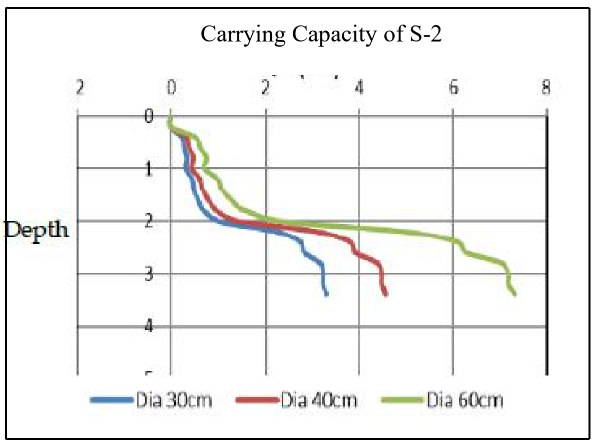
A_b = total area of foundation

A_s = length around the foundation

The results of the bearing capacity of the foundation are based on the results of the sondir compressive test.



Gambar 4a. S-1 Borepile Capacity Chart



Gambar 4b. S-2 Borepile Capacity Chart

Recommended deep foundations used are recommended using data from S-1 and S-2 with depths of 5.40 and 3.40 meters respectively. For use of bored piles (Borepile) it is recommended to use a diameter of 60 cm with better limit capacity limited to a maximum of 7 tons, except if the use of piles is calculated based on the strength of the piling itself.

Analysis of Nagrak Road Damage Conditions

The formation of the sliding plane on a slope is caused by changing conditions of forces that make it unbalanced. The cause of slope imbalance is firstly caused by additional forces from outside such as rising ground water level, earthquake, traffic load etc., Secondly it is caused by weakening of material strength contained on the slope. Specifically on the slope of the shale deposit, the cause that often occurs is due to the weakening process of shear strength which takes place faster than other materials. The main cause of weakening is due to contact with water and air.

The weak layer on the flakes (slickenside) in the direction of the path follows the pattern of hair cracks from the shale material. This is because the flow of water that causes weakening of the flakes tends to follow the pattern of shale cracks. In Figure 5. the following illustrates the process of the occurrence of slickenside. The slickenside line pattern in Stage 1, where the shale is still intact, the slickenside line tends to follow the fissured hairline. In Stage 2, which is the condition of the flakes experiencing weathering in the hair crack area, the slick line pattern still follows the hair crack line but slightly curved. In Stage 3 the slickenside lines are linear or do not follow the hairline cracks, as in Stage 4 the slickenside pattern is similar to Stage 3.

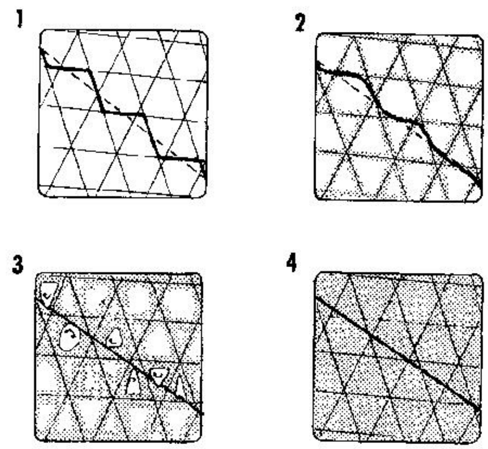


Figure 5. Slickenside patterns at each stage of weathering generally along a segment
(SNI Guidelines for slope engineering, 2004

Nagrak road conditions are often found such as; cracks and sinks in the pavement layers leading to slope collapse, for more details see the sketch in Figure 6.

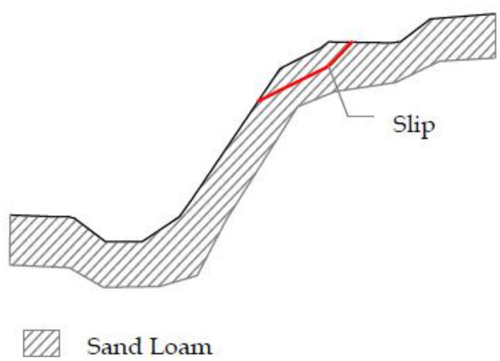
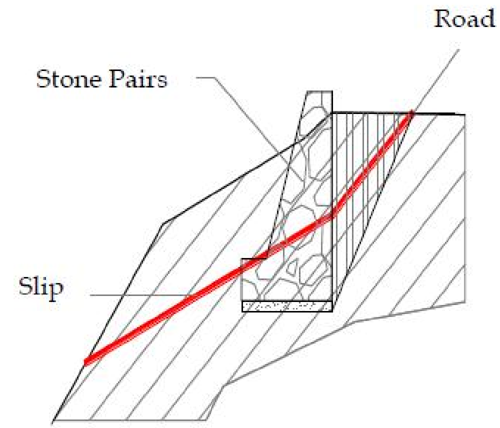


Figure 6. A typical stratification pattern that has collapsed on the slopes of Nagrak Street

Nagrak Road Avalanche Handling Technology

The technology in this section proposed a construction option, namely Reconstruction of retaining wall with pile drill foundation

Reconstruction of the retaining wall is carried out where the foundation of the retaining wall is placed under a sliding plane of at least 2 m and the width of the foundation 1.1 m, see Figure 7. below.



Fifure 7. Reconstruction of retaining wall for handling Nagrak road avalanche

Following are the results of the analysis for the planning of the Retaining Wall, see figure 8 and the details.

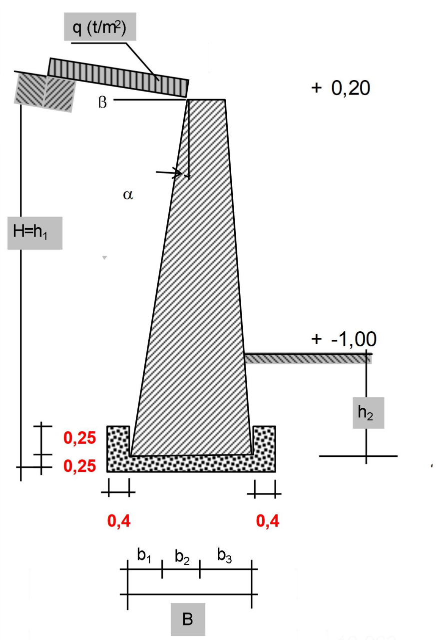


Figure 8. Analysis of Planning Retaining Wall

Upper elevation retaining wall = 0.20 m

Ground elevation = -1.00 m

Ground water level elevation = -10.00 m

Foundation elevation = -1.80 m

<u>Dimension</u>

H = 2.00 m B = 0.80 m L = 1.00 m

b_1 = 0.10 m b_2 = 0.60 m b_3 = 0.10 m

h_1 = 2.00 m h_2 = 0.80 m h_w = 0.00 m

q = 1.00 t/m^2 K_h = 0.15

γ_m = 2.20 t/m^3 γ_w = 1.00 4/m^3 γ_c = 2.40 t/m^3

Backfill Soil

γsoil = 2.00 t/m^3

γsat = 2.10 t/m^3 α = 2.86^0

∅ = 40.0 α = 2.86^0 (for stability analysis)

c = 1.50 t/m^2 β = 14.04^0 (for structural analysis)

Foundation Land

γs'= 2.00 t/m^3	Safety Number	Normal	Earthquake
γs'= 2.00 t/m^3	Bolster |e| ≤	B/6=0.33	B/3=0.27
$\emptyset_B$ = 35.0^0	Sliding Fs ≥	2.00	1.25

c_B = 1.00 t/m^3

Shear Coefficient

	Soil Bearing Capacity		
μ = 050	qmax ≥	qa=qu/3	qa e = qu/2

Lift Force Coefficient

Uμ = 1.00

A. Normal Condition

a. Stability against bolsters

|e| = 0.17 m < B/6 = 0.27 m OK !

S_f = 10.2 > 3.00 OK !

b. Shear stability

S_f = 2.04 > 2.00 OK !

c. Carrying capacity of the foundation soil

q_1 = 2.85 t/m^2 < qs = 64.16 t/m^2 OK !

S_f = 67.588 > 3.00 OK !

q_2 = 5.83 t/m^2 < qs = 64,16 t/m^2 OK !

S_f = 33.017 > 3.00 OK !

B. Earthquake Conditions

a. Stability against bolsters

|e| = 0.02 m < B/2 = 0.53 m OK !

S_f = 4.93 > 2.5 OK !

b. Shear stability

S_f = 2.99 > 1.25 OK !

c. Carrying capacity of the foundation soil

q_1 = 3.88 t/m^2 < q_s = 96.25 t/m^2 OK !

S_f = 49.83 > 2.00 OK !

q_2 = 3.27 t/m^2 < q_s = 96,25 t/m^2 OK !

S_f = 58.79 > 2.00 OK !

V. Conclusion

Based on the results of the study it can be concluded that:

a. The condition of the Nagrak road is in the form of cracks and sinks in the pavement layer which leads to slope collapse,

b. Avalanche Handling Technology in the form of reconstruction of retaining walls using masonry retaining walls with bore pile foundation.

c. The dimensions of the planned wall plan are

H = 2.00 m B = 0.80 m L = 1.00 m

b_1 = 0.10 m b_2 = 0.60 m b_3 = 0.10 m

h_1 = 2.00 m h_2 = 0.80 m h_w = 0.00 m

q = 1.00 t/m^2 K_h = 0.15

γ_m = 2.20 t/m^3 γ_w = 1.00 4/m^3 γ_c = 2.40 t/m^3

d. The foundation of the retaining wall is placed under the skid plane at least 2 m and the width of the foundation 1.1 m.

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