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Slope Stability Review Using Soil Nailing Reinforcement in the Construction Project of Underpass Km. 101 Tatakan

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ABSTRACT

Box underpass is a tunnel panel used as a connecting route for vehicles which is usually built under a road. To strengthen the stability of the slope at the location, additional reinforcement in the form of soil nailing is used. The aim of this plan is to analyze the characteristics of the soil on the slope of the location, analyze the value of the safety factor on the slope before and after soil nailing reinforcement.

In this planning, soil investigation data is interpreted through Standard Penetration Test (SPT) testing and laboratory testing. Analyzing safety factors for slope stability before and after strengthening using the plaxis program.

From the results of this planning, it is known that the average characteristics of the soil layer are dense sandy clay. From the Standard Penetration Test (SPT), it can be seen that the consistency of the soil layer at all drill points is very stiff, even at point BH-1 a hard soil layer was identified. Analysis of the safety factor for slope stability using the plaxis program showed that the safety factor figure before strengthening was 0.6190. Meanwhile, the safety factor figure obtained after soil nailing reinforcement was 2.6081

Keywords: Box Tunnel, Soil Nailing, Safety Factor, Plaxis, Tatakan

1. INTRODUCTION

Box Tunnel, or also known as a box underpass, refers to a tunnel panel that serves as a connecting route or vehicle passage. Usually, this structure is built beneath the road surface or bridge. The construction process involves the cast-in-situ method, which means casting is done on-site. Afterward, the box tunnel will be pushed vertically into the ground following the planned route.

Soil nailing was introduced in 1961 as a method of soil improvement involving the insertion of steel rods into the ground, which are then filled with grout. This method is considered a form of passive reinforcement in soil. In certain situations, soil nailing can be a more advantageous choice in terms of implementation, cost, and construction time compared to other slope reinforcement systems.

This planning will study the soil properties on the slopes at the location of underpass 101 Tatakan, as well as evaluate the slope's safety factor (FK) before and after

reinforcement with the soil nailing method. These observations will be analyzed using the plaxis program.

2. THEORITICAL STUDY

Soil Classification

Soil classification is a system that groups various types of different soils with similar properties into categories and subcategories based on their use (Das, 1995). Many soil classifications use simple tests to determine soil characteristics, which are then used to assign their classes. Generally, soil classification relies on particle size obtained from sieve analysis and plasticity tests (Soedarmo & Purnomo, 1993).

Slope Stability

The gravitational component tends to push the soil downwards. If the gravitational force is so great that it exceeds the soil's ability to withstand shear on its slip plane, the slope will experience landslides. Research on the stability of these sloping slopes is known as slope stability analysis (Hardiyatmo, 2003).

Soil Nailing

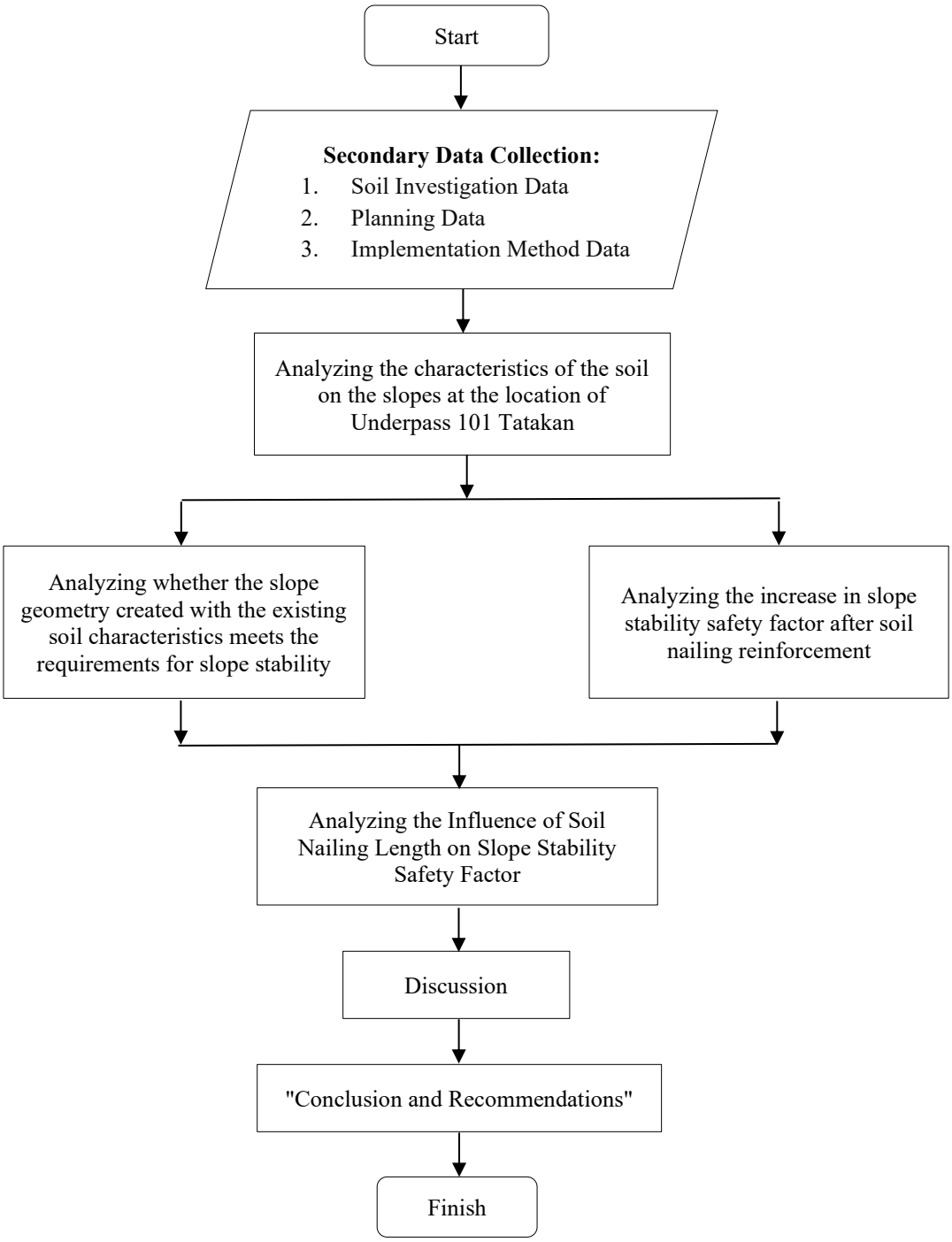
Soil nailing functions to reinforce or stabilize steep slopes and excavations with a construction process that progresses from top to bottom. This method achieves reinforcement through interaction with soil deformation, resulting in increased tensile force on the soil nails. Additionally, soil nailing can also increase normal force and soil shear resistance during potential soil slip planes, as well as reduce frictional thrust on cohesive soil slip planes.

Plaxis 8.6 Program

Plaxis is one of the computer software that uses two-dimensional finite element method to analyze deformation and stability in geotechnical fields. With Plaxis 8.6, users can model actual conditions in the form of either strain planes or axisymmetrically. The user-friendly graphical interface in this program allows users to quickly create geometric models and element networks based on the cross-sections of the conditions to be analyzed.

3. METHOD

These design steps are structured to explain more clearly the design method used, so that the problems analyzed in the design and their solutions can be well understood. The explanation of this method is presented in the form of a design flowchart, which can be seen in Picture 1.



Picture 1. Flowchart

4. RESULTS AND DISCUSSION

- **Soil Parameters**

  The soil parameter data obtained from secondary data are shown in the following Table 1.

Table 1. Soil Data Parameters

Depth	Description	E	v	c	ϕ	Ψ	γ	K
0-10	Sandy Clay	30000	0,3	9,12	19,8	0	20	0,0001
10-16	Compacted Clay	7000	0,3	16,5	20,41	0	20,5	0,0001

- **Platform Data Calculation**

  Concrete Quality (fc') = 35 MPa

  Elastic Modulus (E) = 4700 x √fc'

  = 4700 x √35

  = 27805,57498 MPa

  = 27805574,98 kN/m^2

- **Bored Pile Data Calculation**

  Diameter (B) = 0,8 m

  Length of the Pole (L) = 20 m

  Upper Pile Area (A) = π x r^2

  = 3,14 x 0.4 x 0.4

  = 0.5024 m^2

  Concrete Quality (fc') = 35 MPa

  Elastic Modulus of Piles (Ep) = 4700 x √fc'

  = 4700 x √35

  = 27805,57498 MPa

  = 27805574,98 kN/m^2

  Moment Inertia (Ip) = $\frac{1}{12}$ x B x L^3

  = $\frac{1}{12}$ x 0,8 x 20^3

  = 533,33 m^4

Normal Stiffness (EA) = Ep x A

= 27805574,98 x 0.5024

= 17795567,99 kN

Flexural Regidity (EI) = Ep x Ip

= 27805574,98 x 533,33

= 14829639989 kNm^2

- **Calculation of Steel Sheet Pile Data**

  The parameter data for steel sheet piles is obtained from the following Table 2.

Table 2. Steel Sheet Pile Parameter Data

	Sheet pile specification (Steel)
EA	1.200E + 07 KN/m
EI	1.200E + 05 KNm^2/m
d	0.346 m
w	8.300 KN/m
ν	0.15
Mp	1.000E + 15 KNm/m
Np	1.000E + 15 KNm/m

- **Struth**

  Normal Stiffness (EA) = 2000000 kN

  L spasi = 5 m

- **Calculation of Soil Nailing Data**

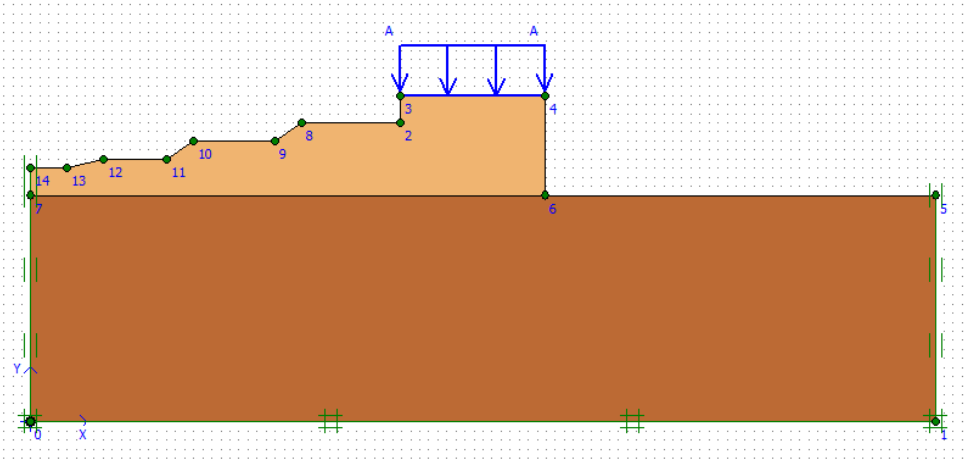
  The parameter data for soil nailing can be seen in the following Table 3.

Table 3. Spesifikasi Soil Nailing D32

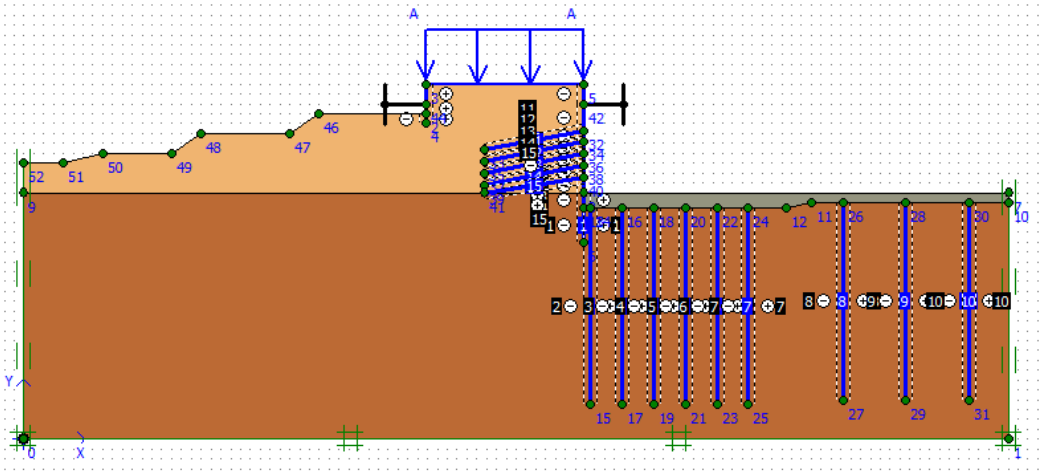
Parameter	Symbol	*Grout body*	Unit
Modulus of elasticity	E	$210*10^6$	kN/m^2
Material weight	γ	60	kN/m^3
Pile type	Pile type	Predefined	-
Predefined pile type	Predefined pile type	Massive circular pile	-
Diameter	Diameter	0.032	m
Spacing	$L_{spacing}$	1.0	m
Axial skin resistance		Linear	
Skin resistance	$T_{skin,start,max}$, $T_{skin,end,max}$	1000	kN/m
Lateral skin resitance		Unlimited	
Base resistance	F_{max}	0	kN
Interface stiffness factor		Default values	-

- **Slope Geometry Modeling**

The geometric modeling of the slope can be seen in the following picture.

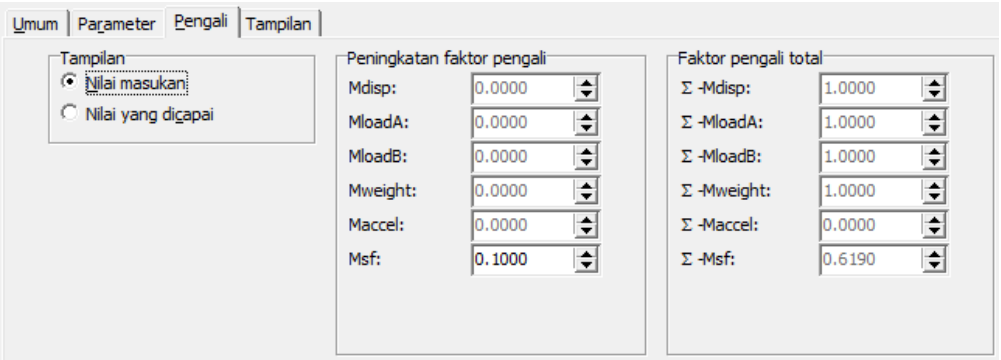


Picture 2. Unreinforced Slope Modeling

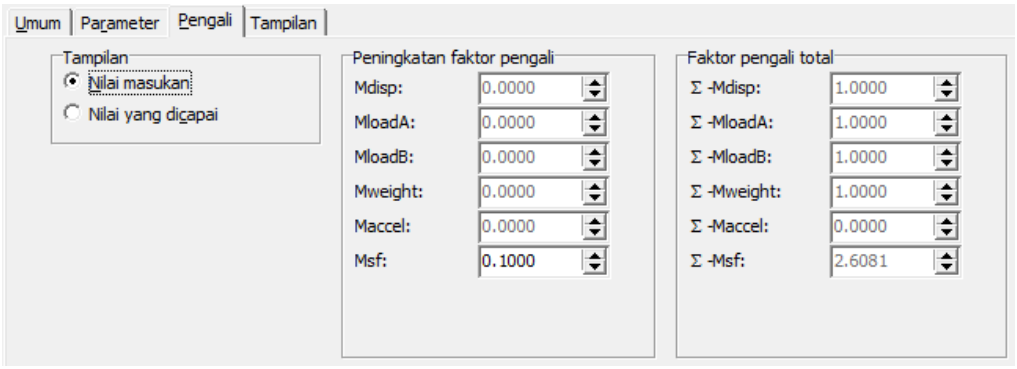


Picture 3. Slope Modeling with Reinforcement

- **Plaxis 8.6 Output Results**



Picture 4. Results of Slope Safety Factor Without Reinforcement



Picture 5. Slope Safety Factor Results with Reinforcement

According to the analysis results using the Plaxis program, the slope safety factors before and after reinforcement differ. Before reinforcement, the safety factor was 0.6190, while after reinforcement it became 2.6081. This difference indicates that the slope stability before reinforcement did not meet safety standards, so additional reinforcement is needed to achieve safe stability. With reinforcement, the slope stability safety factor increased from 0.6190 to 2.6081.

5. CONCLUSION

Based on the results of the planning conducted, the following conclusions can be drawn:

A. Through Standard Penetration Test (SPT) testing at five points (BH-1 to BH-5) at the Underpass Km.101 Tatakan location, the average characteristics of the soil layers were obtained, consisting of densely packed sandy clay. The SPT test results also indicate that the consistency of the soil layers at all bore points is very stiff, with a hard soil layer identified at BH-1.

B. The slope geometry created with the existing soil characteristics does not meet the slope stability requirements, as the obtained safety factor value is 0.6190 or < 1.5, indicating that the slope condition can be considered unsafe. Therefore, additional slope reinforcement is needed to ensure the slope safety factor is safe and meets the slope stability safety factor requirement, which is a safety factor value > 1.5.

C. After the reinforcement of soil nailing was installed on the slope, a higher safety factor value was obtained compared to before the reinforcement. The initial safety

factor value without reinforcement was 0.6190, which increased to 2.6081. Therefore, with this safety factor value, the slope stability can be considered safe and in accordance with the requirements for slope stability safety factors.

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