Analysis Of Slope Stability Using Bamboo As An Alternative Slope Reinforcement (Case Study In Kaliwungu – Boja Street, Darupono Village, Kendal District)

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Abstract- Bamboo is a plant that can be found in Indonesia, however the utilization of bamboo as a structure material is rarely to use in our society. This study was conducted with the objective to analyze the performance of bamboo with respect to soil stability. Bamboo was used as an alternative soil reinforcement to landslide in Kaliwungu – Boja street, Darupono village, Kendal District. Two kinds of bamboos analyzed here were Betung and Tali bamboos having diameter 20 centimeters and 15 centimeters respectively. The index and engineering properties of a soil from Boja street were tested. To analyze the safety factor of the slope of Boja street, Plaxis v.8 and Slope/W were used. The result showed that 1) from soil test the cohesion (c) is 50,995 kN/m^2, phi (φ) is 36^o, γ_{sat} is 16,374 kN/m^3, and γ_{unsat} is 12,534 kN/m^3. 2) the safety factor of the slope in natural condition using Plaxis v.8 and Geostudio (slope/w) is 1,32 and the safety factor with traffic loads is 1,26 – 1,29, with these safety factor, the slope will slide because the safety factor is <1,5. Therefor, the slope strengthened with bamboo, so the safety factor of the slope increased to 1,77 - 1,87.

***Keywords*: ** Betung Bamboo, Tali Bamboo, Slope, soil reinforcement, Plaxis, Geostudio

1. Introduction

1.1. Background

Kendal Distict is a district which located at west of Semarang. Kendal Distict has two types of plain which is the plateau and lowland. The lowland was located in the north and the plateau in the south of Kendal District. At the plateau usually there is slopes that was located at settlement, street, or at the forest. The slope that was located in settlement and street could be dangerous if there are not reinforcment, because anytime could be landslide especially in the rainy season.

For the example is that happen in Kaliwungu – Boja Street, Darupono village, south Kaliwungu. At the street was landslide, so made the street disconnected. The first diagnonis is loose bonding of the soil that made by ground water when the rainy, so it was cause the landslide. The area that landslide was as long as 40 meters, with the highes was 6 meters.

All this time, to reinforcing the unstable slope was used the retaining wall or sheet pile. Of course, if the reinforcemet using such material will be spend the expencive cost. Therefor, need to another alternative to press the cost to be cheaper, that is with utilize the nature around the landslide, in this case is utilize the bamboo. however, it is need to further research to analys what is the bamboo can hold the shear force of the soil, so the bamboo can using to make an alternative landslide reinforcement.

1.2. Problem Formulas

- Whether the bamboo can hold the shear force of the soil, so the bamboo can using to make an alternative landslide reinforcement.
- How much the cost that needed to doing the reinforcement using bamboo.

1.3. Research Purpopse

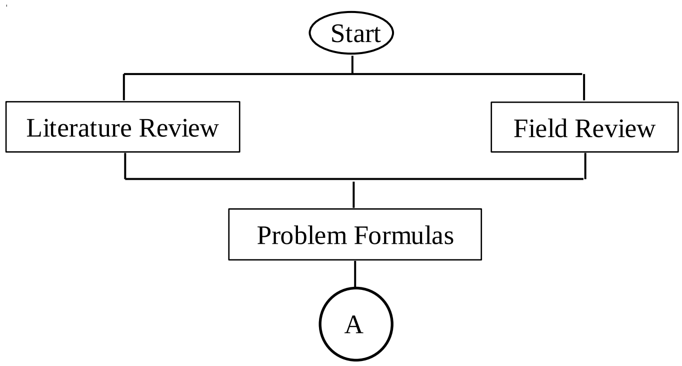
- Plan the stability and eficiency of bamboo as a slope reinforcement material in Kaliwungu – Boja street.
- Plan the bamboo, what is the bamboo feasible to use or not and can known the cost calculation.
- To comparation with the concrete pile.

1.4. Problem Scope

- Analysis the slope stability using bamboo reinforcement.
- Calculate the cost that needed with the project location is Kaliwungu – Boja street, Darupono village, Kendal district.
- The age of endurance or service of the bamboo is not the subject.

2. Methology

In this final report, needed a step processing that ragular and systematic. After got the research topic, the next step is do a literatur review and field review to determine the problem formulas that will discussed. If was determine the problem formulas, then needed supporting data that will analysis using Plaxis v.8 and Geostudio (Slope/W). The methodology flow chart can seen in Figure 1 below.



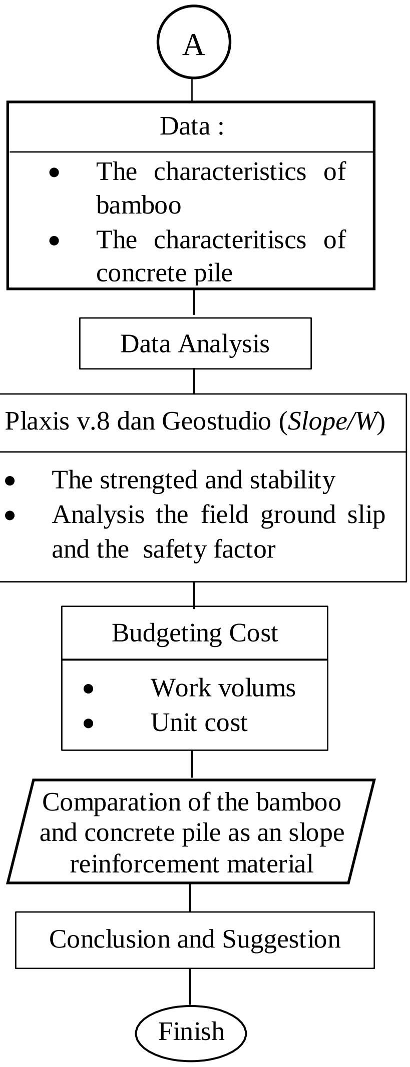


Figure. 1. Flow Chart of Research Methodolgy

2.1. Data Collect Method

- Primery Data

  Primary data is data source that obtained directly from the study area whit the interview, individual opinion, grup and the other. The primary data that used in this report is soil data test which testing in soil laboratory of Sultan Agung Islamic University Semarang and interview with Regional Disaster Management Agency (BPBD) Kendal district.
- Secondary Data

  Secondary data is data source that obtained through intermediaries or indirect which is from notes, books, and archives that was published or not published yet. The secondary data that used in this report is obtained from literature studies.

2.2. Analysis Data

Analysis data is process data activities to made an information, so the characteristic of data could be understood and used as a problem solution and then can get the conclusion.

2.3. Plaxis v.8 Flow Chart

In the Figur 2 below is a flow chart design with Plaxis v.8.

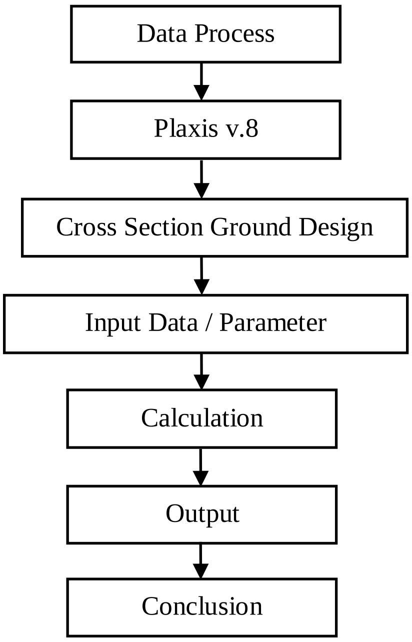
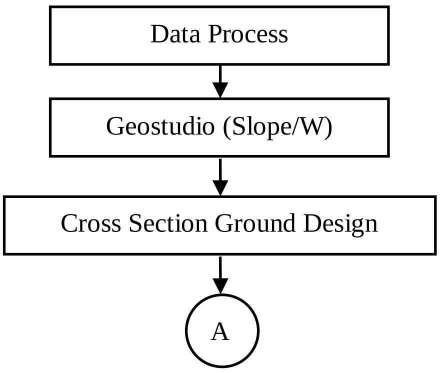


Figure. 2. Flow Chart of Plaxis v.8

2.4. Geostudio (Slope/W) Flow Chart

In the Figur 3 below is a flow chart design with Geostudio (Slope/W).



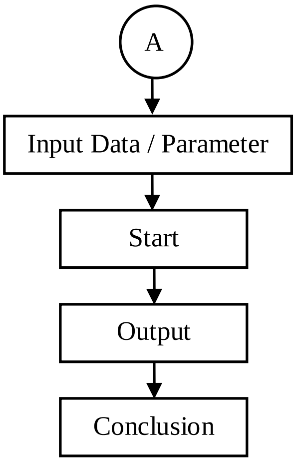


Figure. 3. Flow Chart of Geostudio (Slope/W)

2.5. Budgeting Cost Calculation

Budgeting cost calculation is a calculation to calculate how much the budget cost that used to know the total of material, worker wage, and other cost that related with the project implementation.

3. Study and Analysis

3.1. Soil Parameter

The soil parameter that used is from the laboratorium test with the sample of soil taken directly from the location. But, because the limitation of tools, so the sample of soil that was taken just 1 meter at depth. Therefore, we assumed that the soil type in all layer until a certain depth was same. The soil parameters could seen at Table 1 below.

Table. 1. Soil Parameters

γsat (kN/m^3)	γunsat (kN/m^3)	c (kN/m^2)	φ (^{o})
16.347	12.534	50.955	36

3.2. Analysis Using Plaxis v.8

- **Drawing Geometry**

The first step to analys using Plaxis v.8 is draw the geometry of a slope that will be analys. The draw geometry could seen at Figure 4 below.

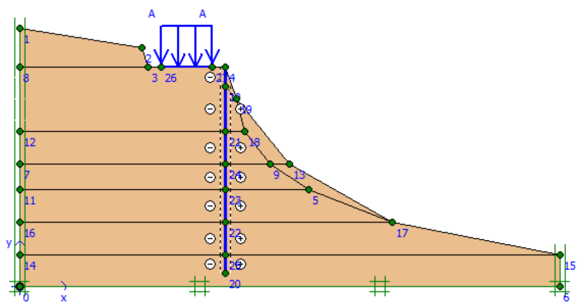


Figure. 4. The Draw Geometry Using Plaxis v.8

- **Input Material Data**

In input material data, there are any two type of material that must be input. There are soil data and pile properties. Besides of that any one parameter that must be input, there is the traffic load. For the soil properties could seen at Figure 5 and 6 below.

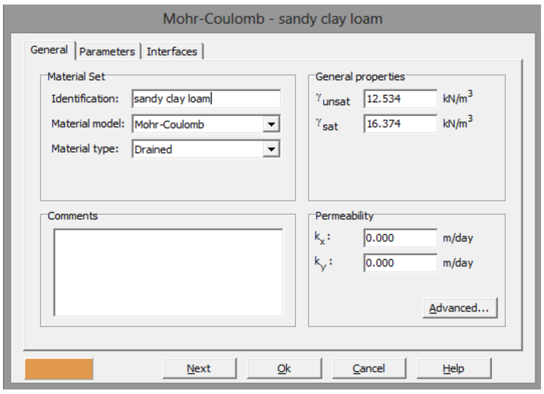


Figure. 5. General Input of Soil Material

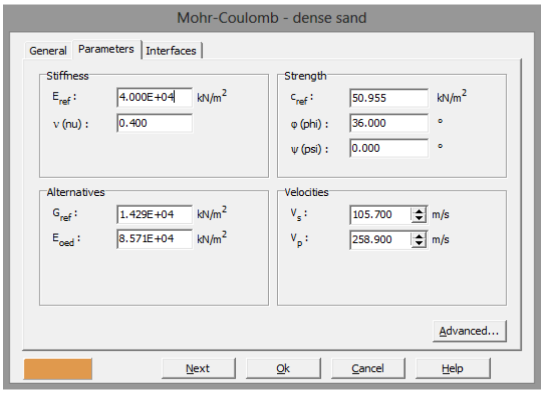


Figure. 6. Input Parameters of Soil Material

Just to know, the soil type is Sandy Clay Loam, where is the soil type can be known from the tringle of soil graph as a Figur 7 below.

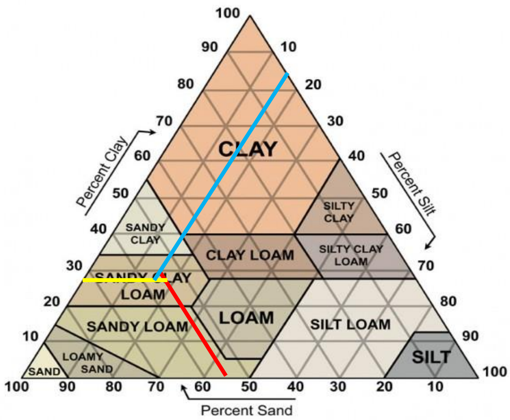


Figure. 7. Triangle of Soil Graph

After input the soil parameters, the next step is input pile properties that could be seen at Figure 8 below.

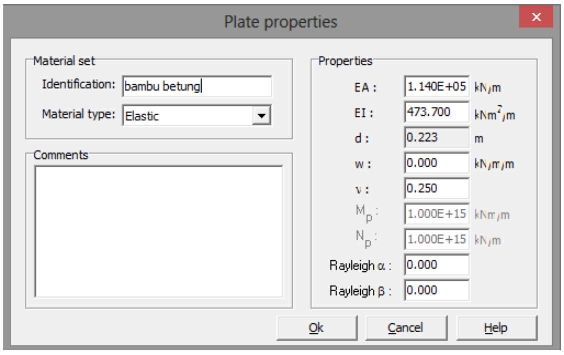


Figure. 8. Input of Pile Properties

At the Figure 8 above, there are any pile parameters that must be input. There are EA, EI, and v. To input EA and EI, so the first step is calculate such as below.

$$A = \left(\frac{\pi.d1^2}{4}\right) - \left(\frac{\pi.d2^2}{4}\right)$$

$$= \left(\frac{3{,}14.20^2}{4}\right) - \left(\frac{3{,}14.16^2}{4}\right)$$

$$= 113{,}04 \text{ cm}^2 = 1{,}13 \text{ x } 10^{-2} \text{ m}^2$$

$$I = \frac{\pi}{8}(d^3t - 3d^2t^2 + 4dt^3 - 2t^4)$$

$$= \frac{3{,}14}{8}(20^3.2 - 3.20^2.2^2 + 4.20.2^3 - 2.2^4)$$

$$= 4684{,}64 \text{ cm}^4 = 4{,}68 \text{ x } 10^{-5} \text{ m}^4$$

$$E = 1{,}0122 \text{ x } 10^7 \text{ kN/m}^2$$

$$EA = E \text{ x } A$$

$$= 1{,}0122 \text{ x } 10^7 \text{ x } 1{,}13 \text{ x } 10^{-2}$$

$$= 1{,}14 \text{ x } 10^5 \text{ kN/m}$$

$$EI = E \text{ x } I$$

$$= 1{,}0122 \text{ x } 10^7 \text{ x } 4{,}68 \text{ x } 10^{-5}$$

$$= 473{,}7 \text{ kN.m}^2$$

Notes :

A = Cross sectional area (m^2)
E = Modulus Young (kN/m^2) (R.H.H. Rambu &friends and Ginoga)
I = Moment of inertia (m^4) (J.M. Gere & S.P. Timoshenko)
d_1 = Outside diameter (cm)
d_2 = Inside diameter (cm)
t = The bamboo wall thickness

For the EA and EI in other material and configuration could seen at Table 2 below.

Table. 2. Pile Parameters

Material Type	EA (kN/m)	EI ($kN.m^2/m$)	v
A single of betung bamboo	$1,14 \times 10^5$	473,7	0.25
A pair of betung bamboo	$2,28 \times 10^5$	$2,63 \times 10^3$	0.25
Three series of betung bamboo	$3,42 \times 10^5$	$4,68 \times 10^3$	0.25
A single of tali bamboo	$6,3 \times 10^4$	145,6	0.25
A pair of tali bamboo	$1,2 \times 10^5$	832,02	0.25
Three series of tali bamboo	$1,89 \times 10^5$	$1,45 \times 10^3$	0.25
Concrete pile	$1,83 \times 10^6$	$1,37 \times 10^4$	0.2

For the configuration of material could seen at Figure 9 below.

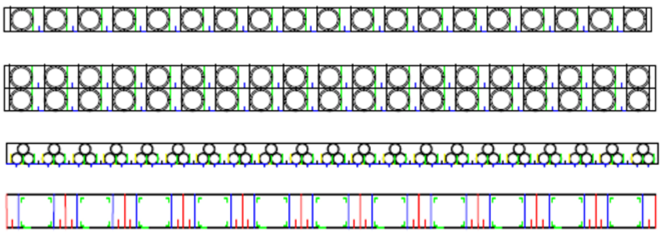


Figure. 9. Configuration of Material

And the last input is the traffic load. Where was the load obtained from the traffic load in the street on the slope. Because the street is 3 class road based UU No. 22 Years 2009 about the clasification of street, so the maximal load that allowed is 8 ton/m^2 or 79,71 kN/m^2 equivalent. As seen at Figure 10 below.

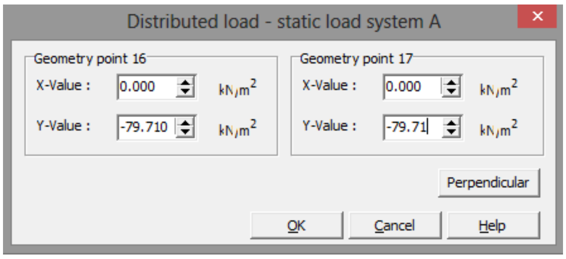


Figure. 10. Input of Traffic Load

- **Initial Condition**

  The purpose of initial condition is to define the initial conditon of geometry before and after calculation and to added the ground water level. The initial condition could be seen at Figure 11 below.

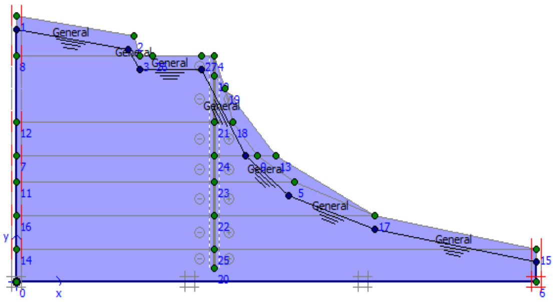


Figure. 11. Ground Water Design

- **Calculation**

After the design was done, the next step is calculation on Plaxis v.8 as seen at Table 3 below .

Table. 3. The Calculation on Plaxis v.8

Identification	Phase no.	Start From	Calculation	Loading Input
Initial condition	1	0	Plastic	Staged construction
Initial condition	2	1	Phi/c Reduction	Incremental Multipliers
Traffic load	3	0	Plastic	Staged construction
Traffic load	4	3	Phi/c Reduction	Incremental Multipliers
Traffic load and reinforcement	5	0	Plastic	Staged construction
Traffic load and reinforcement	6	5	Phi/c Reduction	Incremental Multipliers

After doing the calculation, so the result of safety factor could be seen at Table 4 below.

Table. 4. Result of Safety Factor

Material Type	Safety Factor		
	Initial Condition	Traffic Load	Reinforce-ment
A single of tali bamboo	1.32	1.29	1.86
A pair of tali bamboo	1.32	1.29	1.87
Three series of tali bamboo	1.32	1.29	1.87
A single of betung bamboo	1.32	1.29	1.87
A pair of betung bamboo	1.32	1.29	1.87
Three series of betung bamboo	1.32	1.29	1.88
Concrete pile	1.32	1.29	1.88

- **Output**

  Plaxis v.8 will produce the output there is total displacement as seen at Figure 12, 13, and 14 below.

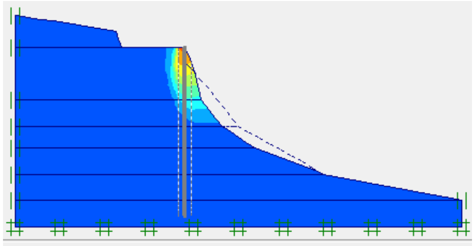


Figure. 12. Total Displacement of Initial Condition

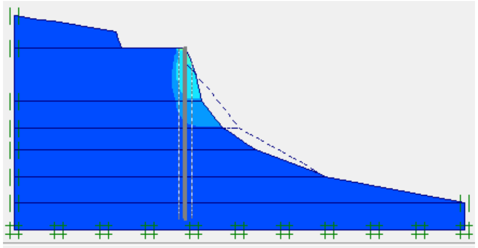


Figure. 13. Total Displacement of Traffic Load

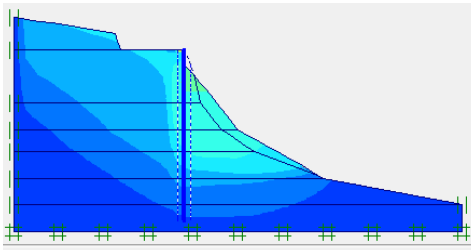


Figure. 14. Total Displacement of Reinforcement

The output of total displacement could be seen at Table 5 below.

Table. 5. Output of Total Displacement

Material Type	Total Displacement (m)		
	Initial Condition	Traffic Load	Reinforce-ment
A single of tali bamboo	1,52	1,72	0,635
A pair of tali bamboo	1,52	1,72	0,336
Three series of tali bamboo	1,52	1,72	0,318
A single of betung bamboo	1,52	1,72	0,317
A pair of betung bamboo	1,52	1,72	0,262
Three series of betung bamboo	1,52	1,72	0,453
Concrete pile	1,52	1,72	0,201

Plaxis v.8 also made the result of total displacement, bending moment, shear force, and axial force that happen on the pile as seen at Figure 15 below.

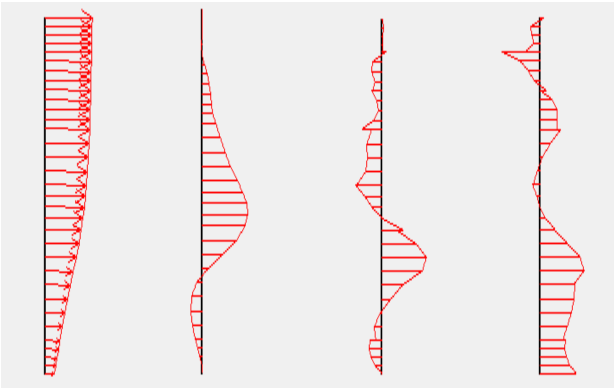


Figure. 15. Total Displacement, Bending Moment, Shear Force, and Axial Force

The result of total displacement, bending moment, shear force, and axial force as seen at Table 6 below.

Table. 6. Output of Total Displacement, Bending Moment, Shear Force, and Axial Force

Material Type	Total Displa-cement (m)	Bending Moment (kN.m/m)	Shear Force (kN/m)	Axial Force (kN/m)
A single of tali bamboo	0,634	-10,48	-11,52	-14,41
A pair of tali bamboo	0,302	-19,51	-22,15	-19,93
Three series of tali bamboo	0,321	-24,93	18,80	-24,91
A single of betung bamboo	0,318	15,66	-18,41	-22,57
A pair of betung bamboo	0,263	-28,66	17,47	-25,03
Three series of betung bamboo	0,214	-33,54	-28,03	-14,87
Concrete pile	0,189	-50,06	-26,59	-21,86

3.3. Analysis Using Geostudio (Slope/W)

- **Drawing Geometry**

The first step in analysis using Geostudio (Slope/W) is drawing geometry. But there are any different with Plaxis. The different is in Geostudio (Slope/W) every condition have a different geometry. For example could be seen at Figure 16, 17, and 18 below.

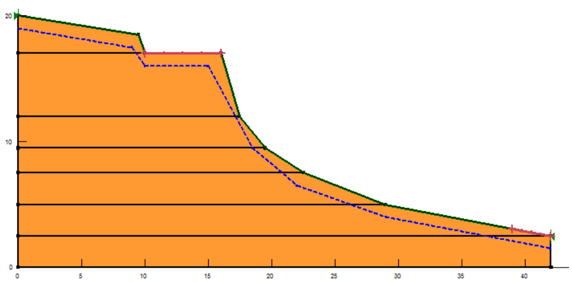


Figure. 16. Geometry of Initial Condition

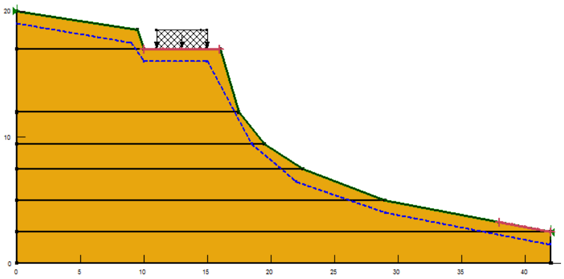


Figure. 17. Geometry of Traffic Load

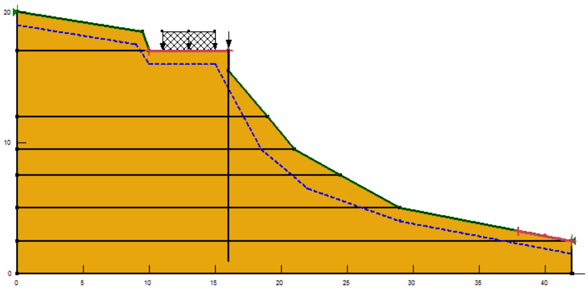


Figure. 18. Geometri of Reinforcement

- **Input Material Data**

  In the Geostudio (Slope/W), the material that inputed in the program is soil material and traffic load, while the pile properties can't be inputed because the program doesn't supported yet about the pile properties. In the Geostudio (Slope/W) only can input the reinforcement with give them spase between the pile. For input the soil material could be seen at Table 7.

Table 7 : Soil Parameter for Input Geostudio (Slope/W)

No	Soil Type	γsat (kN/m^3)	c (kN/m^2)	φ (°)
1	Sandy Clay Loam	16,374	50,955	36

- **Calculation**

  After the desaign was done, the next step is calculating the program to get the safety factor of the slope. The safety factor could be seen at Table 8 below.

Table 8 : The Safety Factor of Geostudio (Slope/W)

No.	Identification	Safety Factor
1.	Slope in Initial condition	1,32
2.	Slope with traffic load	1,26
3.	Slope after reinforcement	1,77

- **Output**

  After the calculation there are any output that could be seen at Figure 19, 20 annd 21 below.

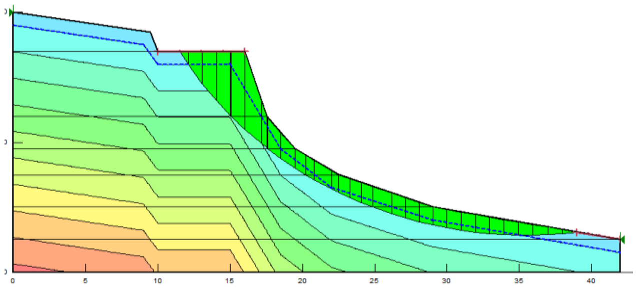


Figure. 19. Output of Slope in Initial Condition

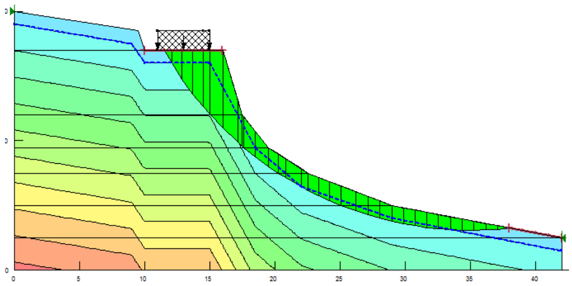


Figure. 20. Output of The Slope With Traffic Load

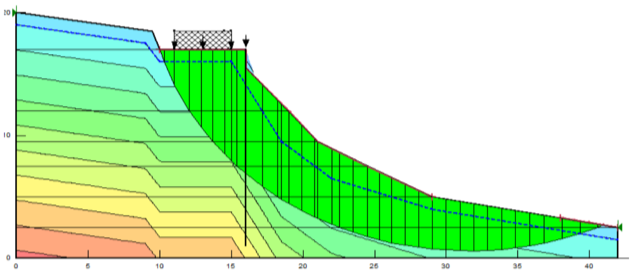


Figure. 21. Output of The Slope After Reinforcement

3.4. The Comparation Of Safety Factor

Based the analysis of safety factor using Plaxis v.8 and Geostudio (Slope/W), so the result of both software could be compare as seen at Table 9 below.

Table. 9. The Result of Safety Factor Comparation

Identification	Plaxis v.8	Geostudio (Slope/W)
Slope in initial condition	1,32	1,32
Slope with traffic load	1,29	1,26
Slope after reinforcement	1,87	1,77

3.5. Budgeting Cost Calculation

After got the safety factor, the next step is calculate the budgeting cost that needed to reinforcement the slope with bamboo and concrete pile. The example of budgeting cost calculation could seen below.

1. Excavator Rent Cost
   - Mobilitation and demobilitation cost
     = 1 ls x Rp 3.500.000,-
     = Rp 3.500.000,-
   - Excavator Rent Cost During 7 days
     = 7 days x 8 hours x Rp 160.000,-
     = Rp 8.960.000,-
   - Fuel Cost
     = 7 days x 160 liters x Rp 8.250,-
     = Rp 9.240.000,-
   - The Wage of Excavator Operator
     = 7 days x Rp 160.000,-
     = Rp 1.120.000,-
   - Total Excavator Rent Cost
     = Rp 3.500.000 + Rp 8.960.000 + Rp 9.240.000 + Rp 1.120.000
     = Rp 22.820.000,-

2. Petung Bamboo Cost (Single)
   = 133 trunk x Rp 250.000,-
   = Rp 33.250.000,-

3. Rope Cost
   = 10 meters x Rp 40.000,-
   = Rp 400.000,-

4. Worker Wage
   = 5 workers x 7 days x Rp 100.000,-
   = Rp 3.500.000,-

5. Foreman Wage
   = 1 foreman x 7 daysx Rp 125.000,-
   = Rp 875.000,-

The result of the budgeting cost calculation could be seen at Table 10 below.

Table. 10. Budgeting Cost Calculation

Code	Vol.	Unit	Work Discription	Budget	Jumlah
		A.	**Tenaga**		**Rp 4,375,000,-**
L.01	35	OH	Pekerja	Rp 100,000,-	Rp 3,500,000,-
L.02	7	OH	Mandor	Rp 125,000,-	Rp 875,000,-
		B.	**Bahan**		**Rp 33,650,000,-**
L.01	133	Buah	Bambu Betung	Rp 250,000,-	Rp 33,250,000,-
L.02	10	m	Tambang	Rp 40,000,-	Rp 400,000,-
		C.	**Peralatan**		**Rp 43,260,000,-**
L.01	1	Ls	Excavator	Rp 22,820,000,-	Rp 22,820,000,-
L.02	1	Ls	Air Hammer	Rp 20,440,000,-	Rp 20,440,000,-

Code	Vol.	Unit	Work Discription	Budget	Jumlah
Biaya					**Rp 81,285,000,-**
PPN 10 %					**Rp 8,128,500,-**
Total Biaya					**Rp 89,413,500,-**

For the budgeting cost calculation in other materials and configuration could seen at Table 11 below.

Table. 11. Recapitulation of Budgeting Cost

Material	Configuration	Budgeting Cost
Betung Bamboo	1	Rp 89,413,500,-
Betung Bamboo	2	Rp 125,988,500,-
Betung Bamboo	3	Rp 118,838,500,-
Tali Bamboo	1	Rp 58,118,500,-
Tali Bamboo	2	Rp 63,398,500,-
Tali Bamboo	3	Rp 62,738,500,-
Concrete Pile	1	Rp 88,038,500,-

For the per meter budgeting cost, could be seen at Table 12 below.

Table. 12. Recapitulation of Budgeting Cost/m’

Material	Configuration	Budgeting Cost/m’
Betung Bamboo	1	Rp 2,235,337.50,-
Betung Bamboo	2	Rp 3,149,712.50,-
Betung Bamboo	3	Rp 2,970,962.50,-
Tali Bamboo	1	Rp 1,452,962.50,-
Tali Bamboo	2	Rp 1,584,962.50,-
Tali Bamboo	3	Rp 1,568,462.50,-
Concrete Pile	1	Rp 2,200,962.50,-

4. Conclusion

Based the analysis above, so it is could be conclused, that :

1. From the calculation was shown that the safety factor between Plaxis v.8 and Geostudio (Slope/W) doesn’t much different. Although in Plaxis v.8 need the data that more detail than Geostudio (Slope/W). Especially in the soil and pile properties.
2. From the result of safety factor was give the ilustration that bamboo could use as an alternative material to slope reinforcement.
3. Although the safety factor between Plaxis v.8 and Geostudio (Slope/W) doesn’t much different, but the cost that needed tali bamboo chiper that betung bamboo and concrete pile.

Reference

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