An Analysis of Slope Reinforcement using the Vegetation Method at Way Sekampung Dam Lampung

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Abstract:- Way Sekampung Dam is one of the national strategic projects located in Pringsewu Regency, Lampung. One of the main works in the Way Sekampung Dam Project is the excavation of slopes. Natural slopes are converted into angular slopes, to maintain soil stability at the site, but the potential for landslides due to erosion and water flow is still very likely. Referring to these problems, protection is needed to reduce erosion that occurs due to water flow on the surface of the excavated slope. Natural slopes are converted into slopes with a certain slope with the aim of maintaining soil stability at the location. However, the potential for landslides due to erosion and water flow is still very likely. Referring to this, protection is needed to reduce erosion problems that occur due to water flow on the surface of the excavated slope. This protection is expected to be used in high and steep locations. This research was conducted to analyze the effectiveness of the use of vegetation as protection against excavated slopes in the area around the dam which will be seen from the safety factor (SF) parameter as the main indicator. In this research, an analysis of three different conditions was carried out, slopes in natural conditions, slopes in disturbed conditions (due to excavation) and slopes with disturbed conditions that were strengthened in the form of vegetation. From the results of the analysis of the safety factor (SF) value in natural slope conditions was 1.9; while on slopes with disturbed conditions, the SF value was obtained by 1.3 and after the addition of vegetation on the surface of the slope was disturbed, an SF value of 1.5 was obtained. This indicated an increase in slope stability after the addition of vegetation on the soil surface of the slope is disturbed. Thus, it could be concluded that planting vegetation on the surface of the slope was quite effective to increase the strength and stability of the soil and can reduce the danger of erosion on the slope.

Keywords:- *Slope Stability, Safety Factor (SF), Reinforcement, Erosion*

I. INTRODUCTION

The national strategic project located in Pringsewu Regency of Lampung Province is the Way Sekampung Dam project which is at coordinates 104° 48' - 105° 08' (BT) east longitude and 5° 12' - 5° 33' (LS) south latitude. One of the main works that are the key to the construction of the Way Sekampung Dam project is the excavation work. Excavation work is the main point, if the excavation work is delayed, the entire work will also be hampered because the excavation is a critical part of the work. The main review is the potential for landslides that occur after changing the existing conditions with excavations.

The excavation process further changes the natural structure of the soil or rock which is then formed in such a way with various parameters. The goal is to ensure that the excavated soil can maintain its stability to avoid the danger of landslides. The excavated soil is converted into a slope to maintain the stability of the soil but does not eliminate the potential for landslides due to erosion from the water flow passing through the slope surface. In addition, the slope of the excavated results has steep dimension characteristics so that it supports the occurrence of water scouring.

When erosion occurs, the potential for a decrease in slope stability is higher, and the possibility of landslides is even higher. In the event of a landslide, it takes time to make repairs. This event can cause a delay in work. Referring to this, protection is needed that can reduce erosion that occurs due to the flow of water on the surface of the excavated slope. This protection is expected to survive at steep altitudes and locations.

The surface condition of the excavated slopes at this work reaches 115 m with geological characteristics consisting of soil slopes, rocky soil slopes, and schist rock slopes. With the high slope of the excavation, it is necessary to use vegetation as a cover for the surface of the excavated slope with the main function as a control of land erosion. To make it easier to find out the application of this vegetation method to slope stability, the study used Plaxis 2D.

ISSN No:-2456-2165

II. THEORETICAL REVIEW

A slope is a ground surface that is inclined and forms a certain angle to a horizontal and unprotected plane (Das, 2011). In general, the soil slopes are divided into two categories:

- Natural slopes, naturally formed natural slopes are usually found in an area with the contours of hilly and mountainous areas.
- Engineered slopes, engineered slopes formed by man are usually used for construction work, such as the construction of earthen dams, river embankments, and railway bodies.

Slopes can collapse due to the onset of thrust due to the load on the ground. Basically, natural slopes are resistant to soil shear, while their roots serve as soil retainers. If the ground retaining force is smaller than the driving force, it will result in cladding on the slope.

A. Slope Stability

Slope stability analysis is an analysis by determining the Safety factor (SF) value of the landslide field. Safety factor (SF) value is defined as the value of the ratio between the holding force and the resistance force. From the comparison above, we will obtain the Safety factor (SF) which is the slope stability value. The basic formula of slope (soil material) Safety factor (SF) introduced by Fellenius than developed by: (Lambe & Whitman, 1969; Parcher & Means,1974).

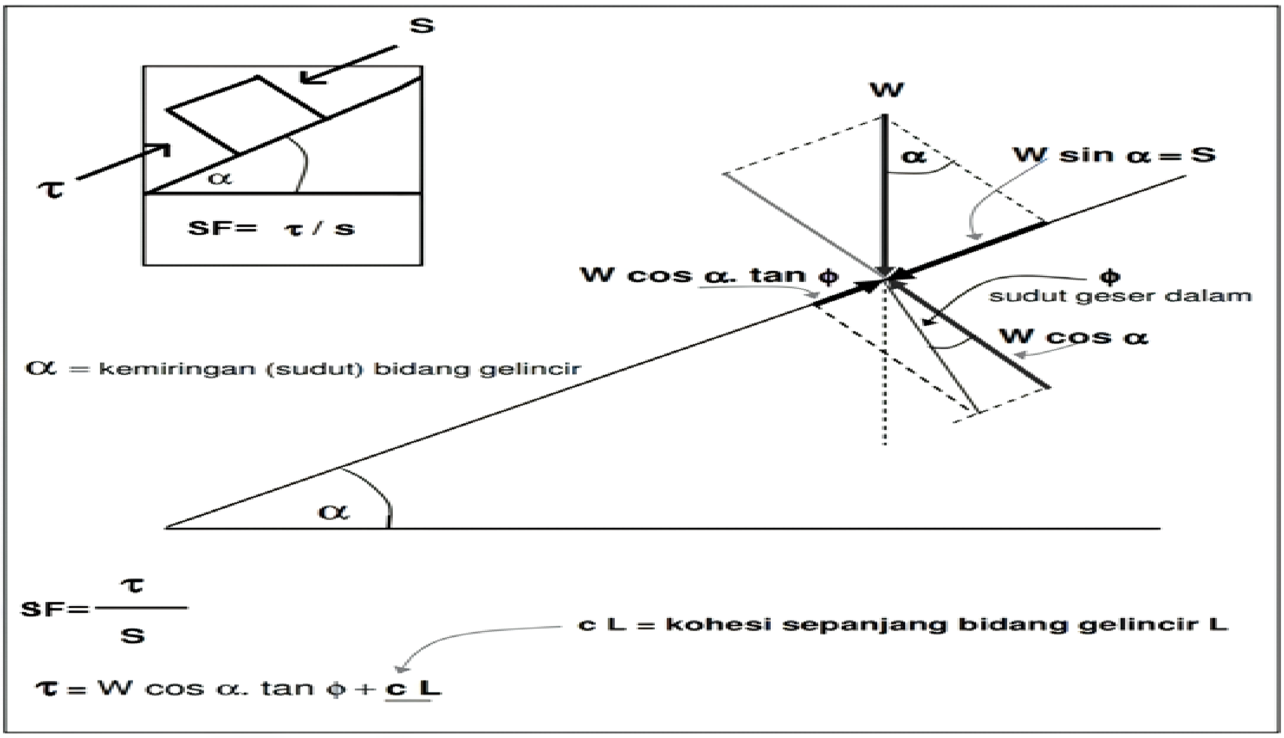

Fig 1 Slope Sliding Geometry and Safety Factor: Ratio of Force (S) and Shear Resistance (T)

$\tau = c_L + \{(W+V)cos\alpha - \mu\}\, tan\, \varphi$
$s = (W+V)\sin\alpha$
$SF = \Sigma\, \tau/s$

Description :

SF : safety factor
L : length of the slip line (m)
τ : the available shear strength on the slip line (ton/m^2)
S : shear stress (ton/m^2)
c : cohesion (ton/m^2)
φ : sliding angle-in the mass of the slope (degrees)
W : mass weights above the slip line (ton)
V : external load (ton)
μ : pore pressure ($\gamma_{water} \times h \times L$)
h : equipotential line length to center of gravity L (m)
α : angle formed by the plane of the slide with a horizontal plane (α^o)

B. Slope Stability Analysis

Broadly, slope stability analysis is divided into three parts, namely:

➢ *Visual Observation*

It is a method of direct observation in the field by comparing the condition does not move slope with moving slope or estimated to be moving. This method estimates both unstable and stable slopes by utilizing experience in the field. This method is less accurate, depending on experience. This method can be used if there is no risk of landslides occurring during the observation. This method is similar to mapping indications of soil movement into a map of slope.

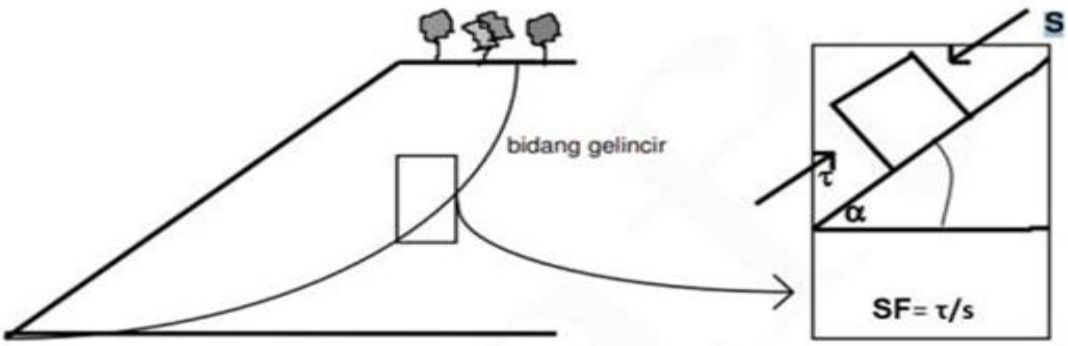

Fig 2 Analysis of Forces (τ and S)

➢ *Computing*

It is to perform calculation based on the formula of the slice method, the Bishop method and the Fellinius Method, Mohr Coulomb and others. Fellenius and Bishop's method calculates the Safety factor (SF) of the slope and analyzes its strength.

➢ *Chart*

This method uses standard charts such as (Janbu, Hoek & Bray, Taylor, Cousins and Morganstren) to calculate the slope stability. This method is done for homogeneous materials with a simple structure. Heterogeneous material (consisting of several layers) that can be approached by formulas (computational methods). Stereonets, such as schmidt net diagrams can explain the direction of cladding or rock collapse by measuring the strike/dip of the stocky (joints) and strike/dip of the rock layer. Based on previous studies and comprehensive slope failure studies, 3 safety factor (SF) range groups are divided in terms of the intensity of their cladding (Bowles, 1989), as shown in Table 1

C. Mohr Coulomb's Theory of Collapse

The maximum shear theory introduced by Coulomb explains that a failure of the pressure value at the time of the change in shape will still occur if the given shear pressure reaches a critical value of the soil ability, then this theory is refined by Mohr known as Mohr Coulomb's theory shown in Figure 3. Mohr Coulomb's theory states that the shear stress of the soil has a functional relationship with cohesion (c) soil and friction between particles expressed in the following equation:

$$\boldsymbol{\tau = c + \sigma \tan \phi}$$

Description :

$\boldsymbol{\tau}$: ground shear tress
c : cohession
σ : normal oltage
ϕ : inner sliding angle

In saturated soil conditions, the total normal stress at a point is equal to the sum of the effective stresses plus the pore water pressure, or:

$$\boldsymbol{\tau = c + (\sigma - u) tan\phi = c + \sigma' tan\phi}$$

Description :

u : pore water pressure
σ' : effective stress

Table 1 Relationship between Slope Safety Factor (SF) and Landslide Intensity

Safety Factor	Landslides Intensity
$F < 1.07$	Unstable slopes or landslide frequently happened
	Critical slopes or landslide have occurred
$1.07 \leq F \geq 1.25$	Stable slope or landslide rare occurred
$F > 1.25$	

(Source: Bowles, 1989)

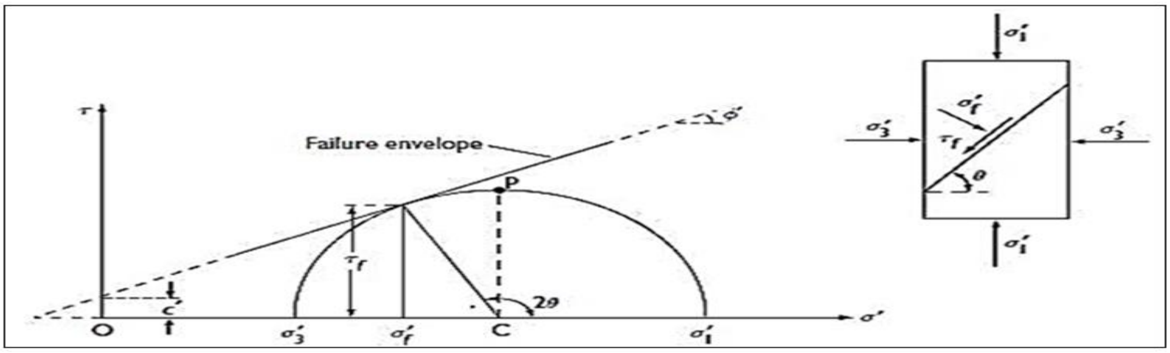

Fig 3 The Mohr Coulomb Failure Criteria (Source : Braja M Das,1995)

D. Method of Erotion Control Green MattressVegetation

Green Mattress Vegetation is a protection especially on slopes with extreme slopes, with Green Mat media as erosion protection and vegetation bending as a damper for surface water flow and extreme weather.

E. Method Of Erotion Control

The Erotion Control method is protection, especially on slopes with extreme slopes, with green mattress media as erosion protection and vegetation bending as a dampener for surface water flow and extreme weather.

The root is one of the most important parts of the root arena can be able to bind the soil properly and function as a slope retaining construction system besides that the roots can absorb water in the soil which can function to lower the voltage of pore water.

In previous studies, namely Faisal and Normaniza (2008), stated that the presence of plant roots in the soil has an effect on increasing soil cohesion (c) but the influence on the shear angle of the soil is not too great. This effect was later implemented in the mohr-coulomb collapse law (Wu, 1979).

$$\tau = (c + C_R) + (\sigma - u) \tan \phi$$

$$C_R = 1.2 \cdot T_R \cdot RAR$$

Description :

C_R : contribution of roots to soil cohesion
T_R : strong pull roots

For the ratio of regions (RAR) a linear equation shown in **Figure 4** with the ratio distribution of the root regions is used :

$$RAR = (1/400) \cdot (2 - z)$$

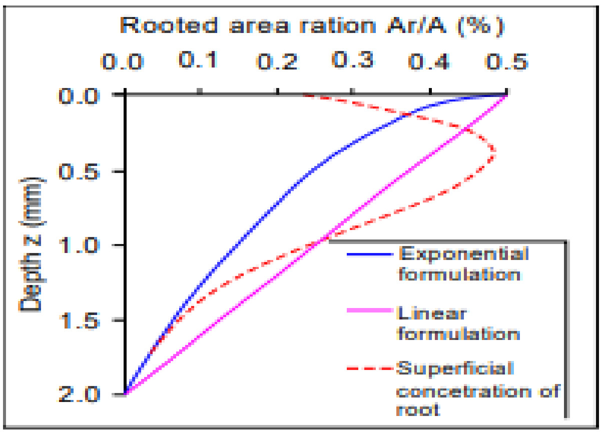

Fig 4 Hypothetical Curve of the Rooted Area Ratio (RAR)

F. Vegetation Reinforce Design

As a support for basic planting media, especially in sloping soil locations, additional strengthening of planting media is needed that can support plant growth. The material is a material that is perforated so that plant roots can continue to grow into the soil layer bound by the strengthening layer. The material consists of :

- Geomat Layer
- Gabion Wire Lining
- Planting Media
- Composite Seeds

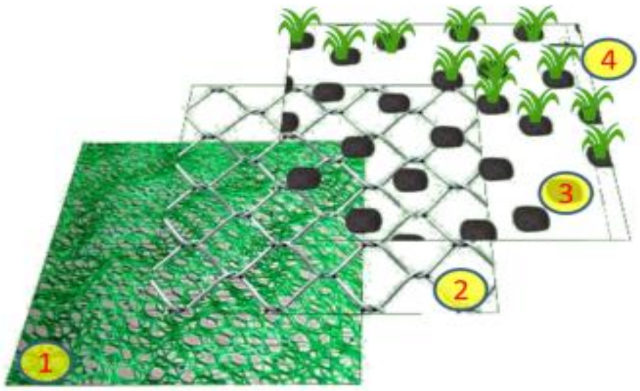

Fig **5** Green Mattress Consist of Perforated Geomats Reinforced by Wire and Composite Seed

Slope reinforcement using vegetation is designed by installing additional plant media (green mattress) which is then straengthened with anchors as a binding tool for the planting media.

G. Composition of Planting Media

The composition of the planting medium in the form of composite seedlings consisting of the following :

- Buto Beans (KB)
- Centocema Pubecens (CP)
- Colopogonium Mucoides (CM)
- Green Alder Plant

Fig 6 The Composition of Seedlings of Vegetation Plants after Mixing

Below are the results of previous research using tensile testing machines conducted by Daniele Cazzuffi and Enrico Crippa (2005), the results can be correlated being the maximum tensile strength (T_R) vs root diameter (d) which can be seen in.

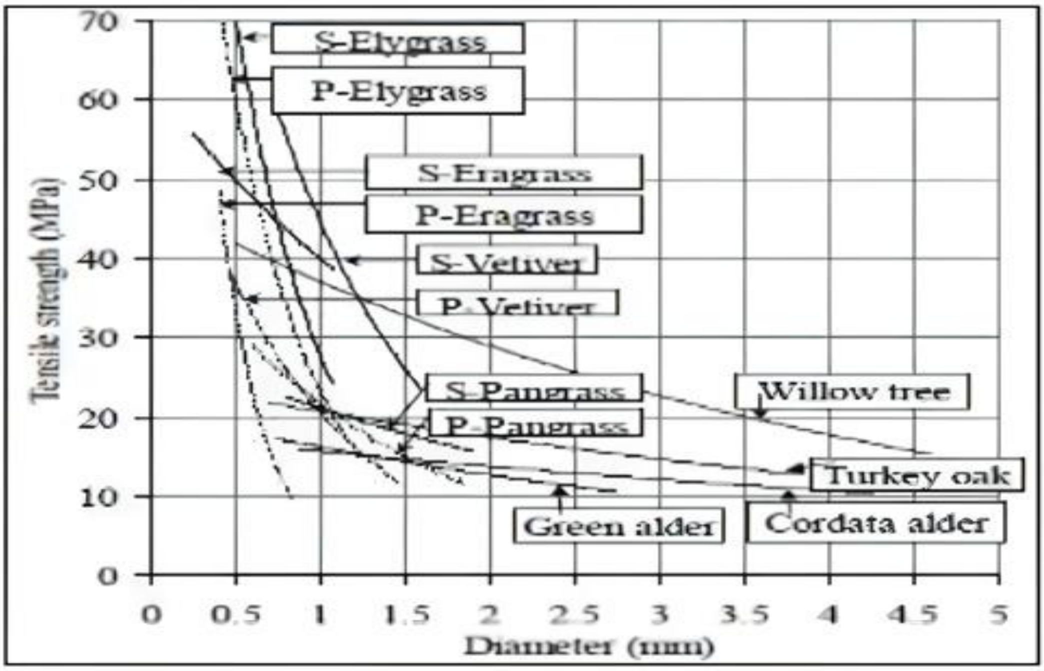

Fig **7** Research Results of Cazzuffi and Enrico Crippa (2005)

III. RESEARCH METHOD

A. Research Location

This research object was carried out at the Way Sekampung Dam Project, which is one of the national strategic projects located in Pringsewu Regency, Lampung Province, at coordinates 104° 48' - 105° 08' (BT) east longitude and 5°12' - 5°33' (LS) south latitude.

B. Research Flow

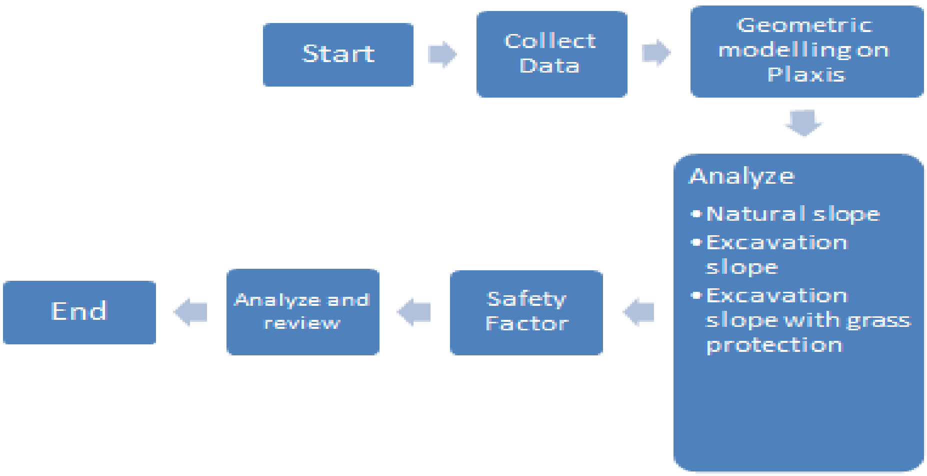

Fig 8 Research Flow Chart

C. Research Tools and Materials

The tool or device used in this study was using software Plaxis 8.2 V.2D. The materials of this study are topographic data, boring maps of the Way Sekampung Dam, laboratory investigation results on soil samples of Way Sekampung Dam, and images of strengthening vegetation slopes.

D. Research Analysis

Geometry Modeling using Plaxis v.8.2 as slope stability analysis software. Plaxis v.8.2 is a program or software based on the finite element method to analyze deformations or changes in the shape of slopes and stability in a problem or geotechnical constraint.

Plaxis can also provide technical analysis results in the form of displacement, deformation, and stresses in the ground.

ISSN No:-2456-2165

IV. RESULT AND DISCUSSION

A. *Data Processing*

In processing this data, the things that need to be done are modeling and analyzing slopes, input the parameters of the soil used. It is necessary to know the soil parameters before strengthening using vegetation / at the beginning of taking soil samples before digging, SPT testing is carried out where laboratory data is carried out so that the specific gravity (G_s) value can be known. Meanwhile, after strengthening, it does not take soil samples to find out the value of its G_s because it has taken a sample of the plant where the plant can be correlated into the added power of strengthening from the initial condition soil (native soil).

Data processing is carried out in several stages:

- Step 1 (Modeling) Geometry Modeling using Plaxis v.8.2 as slope stability analysis software. is a program or software by means of an element method to analyze deformation or changes in the shape of slopes and stability in a problem or geotechnical constraint
- Step 2 (Entering Data) Collecting materials or secondary data taken from the results of laboratory tests of soil samples.as for the parameter is the value: γ, G_s, c, φ.
- Step 3 (Data Calculation 1) Calculation of slope stability with calculations using the Plaxis 2D.v-8.2 program
- Step 4 (Data Calculation 2) Perform calculations by looking at the safe number (SF).
- Step 5 This stage is the final stage, which is in the form of data analysis and discussion of the calculation results that have been carried out on the software. In this phase the results obtained can be made a conclusion and if necessary can give advice.

B. *Initial Condition of the Slope*

At the initial conditions the soil parameters used for this modeling include the weight of the soil contents, soil type, pore number, Poisson number, modulus of elasticity, cohesion (c) and shear angle of the soil. Each layer of soil has a different value of soil parameters. The values of soil parameters included in the slope modeling can be seen in Table 2.

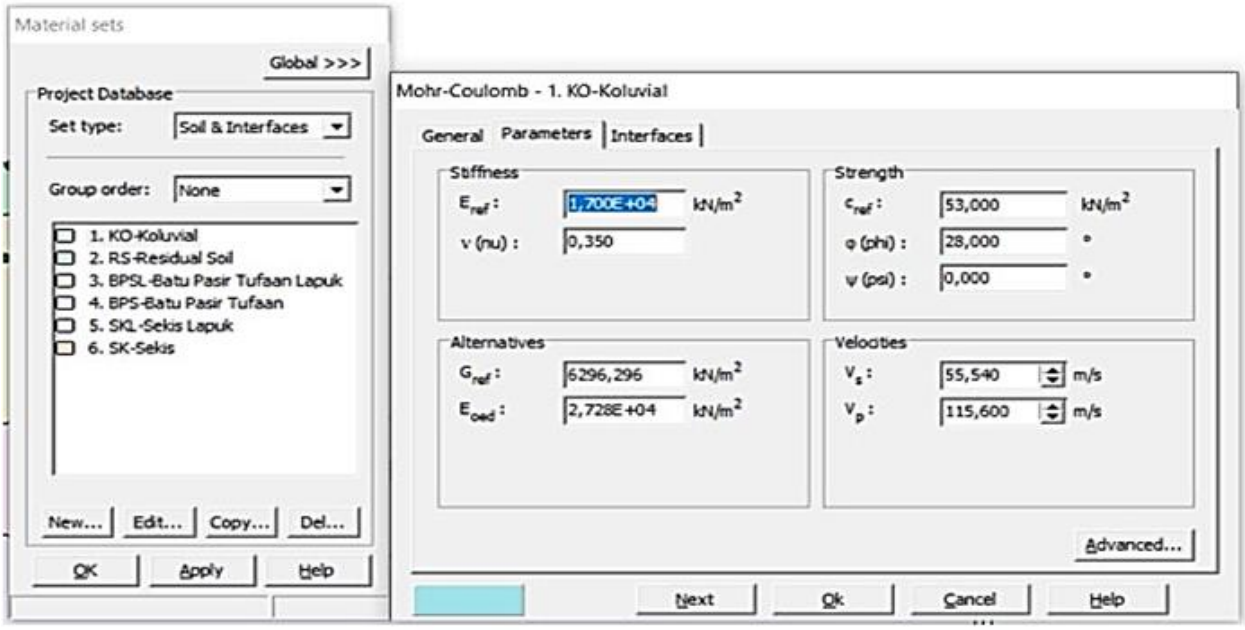

Fig 9 Input Parameter

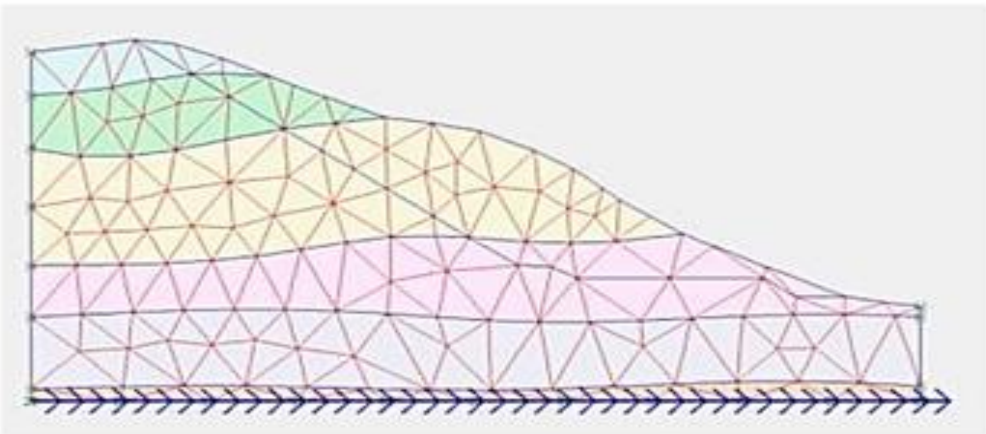

Fig 10 Model Mesh Modeling Results

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Table 2 Soil Parameters Preliminary Conditions

Nama Lapisan	**N**	**RQD**	**PI**	**Edrained (kPa)**	**Eundrained (kPa)**	**Drained Poisson's Ratio**	**Undrained Poisson's Ratio**	**ϒ (kN/m³)**	**ϒsat (kN/m³)**	**c' (kPa)**	**ϕ' (°)**	**cu (kPa)**
IKO-Koluvial	16		21	1.7×10^4	2.1×10^4	0.35	0.495	20	20	53	28	128
2RS-Residual Soil	28		20	1.7×10^4	2.1×10^4	0.35	0.495	18	19	53	29	168
3BPSL-Batu Pasir tufaan lapuk	>60		20	2.7×10^4	3.4×10^4	0.35	0.495	18	19	87.5	33	360
4BPSL-Batu Pasir tufaan		10		8.0×10^6	1.0×10^7	0.35	0.495	20	20	100	45	
5SKL-Sekis lapuk		20		2.8×10^7	3.5×10^7	0.35	0.495	24	24	658	1	
6SK-Sekis		60		4.0×10^7	3.5×10^7	0.35	0.495	24	24	1812	1	

The Data Calculation Process in the plaxis v8.2 program is used to calculate the Safety factor (SF) of the slope by means of phi-c reduction. Phi-c reduction is a method of calculating the value of slope stability by the program by continuously reducing the parameter values of tan φ and c until a failure of the soil structure occurs. At the safety factor (SF) calculation stage carried out, the Safety factor (SF) value of this slope is 1,939 shown in Figure 11.

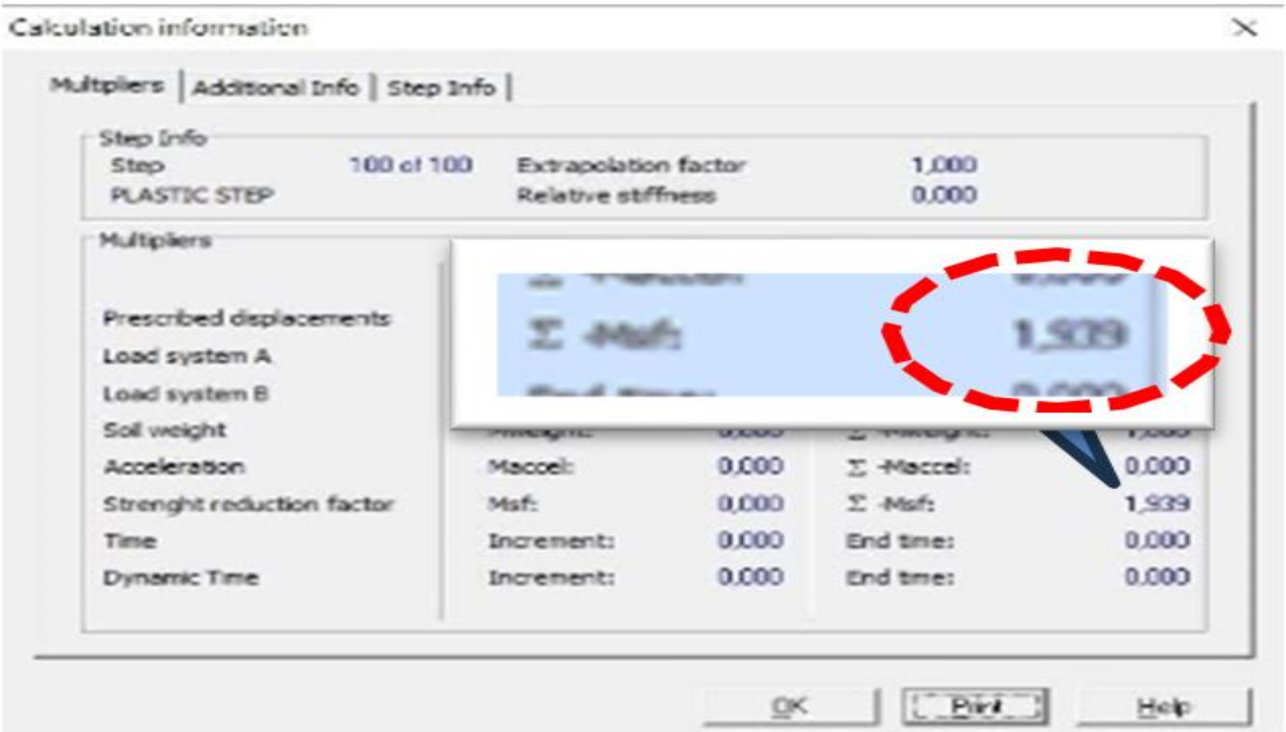

Fig 11 The Original Safety Factor (SF) Calculation Stages of the Slope

C. Excavated Slope Conditions Without Vegetation Strengthening

The following is the making of slope modeling after excavation without strengthening vegetation with a high excavation slope of 5 m with a slope slope of 1:1 The model can be seen in Figure 12 steps / stages and the calculation process is the same as the natural slope modeling.

After the calculation process is carried out by plaxis software or calculated, a safety number (Safety factor (SF) of 1,352 is obtained, shown in Figure 13.

In slope conditions after excavation, the Safety factor (SF) is 1.3. With a safety score equal to 1.3, the slope condition after excavation tends to be stable and not landslides. It should be noted that the slope image is designed to have a slope of 1: 1 where the design is most effectively slope slope so that before being strengthened the slope condition remains stable not past the critical SF limit but for the long term with the influence of natural conditions so it is necessary to be given a strengthening of the slope that will increase the strength of the SF.

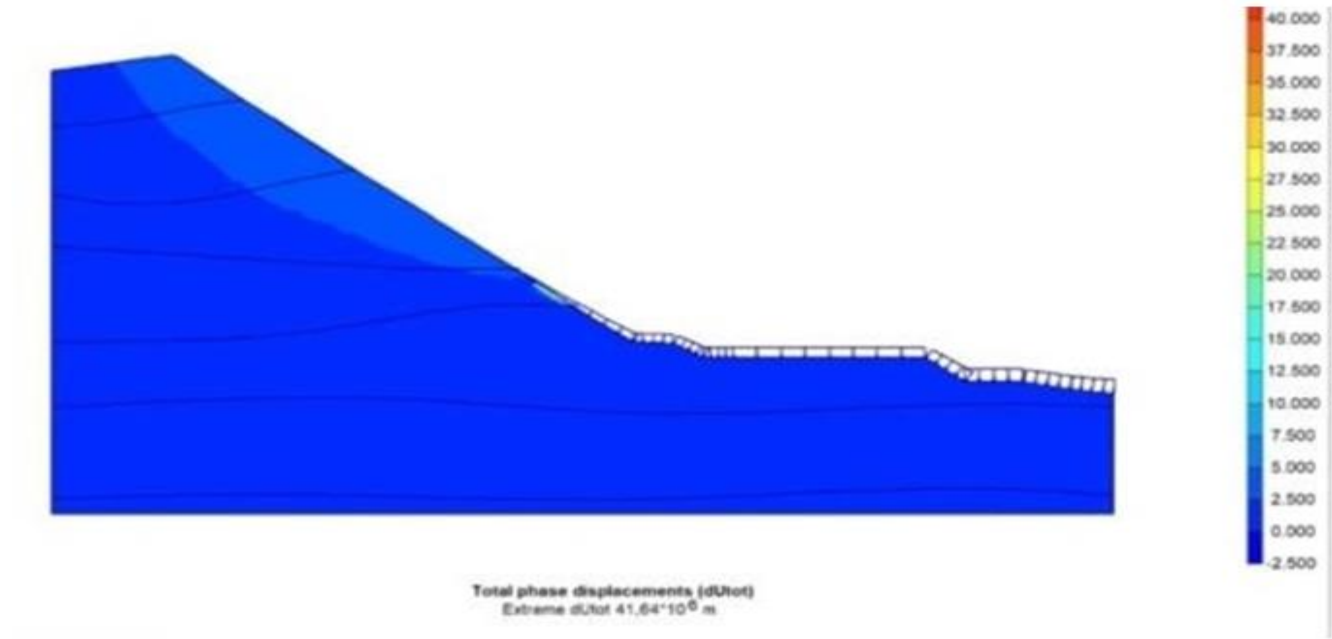

Fig 12 Excavated Slopes without Vegetation Strengthening

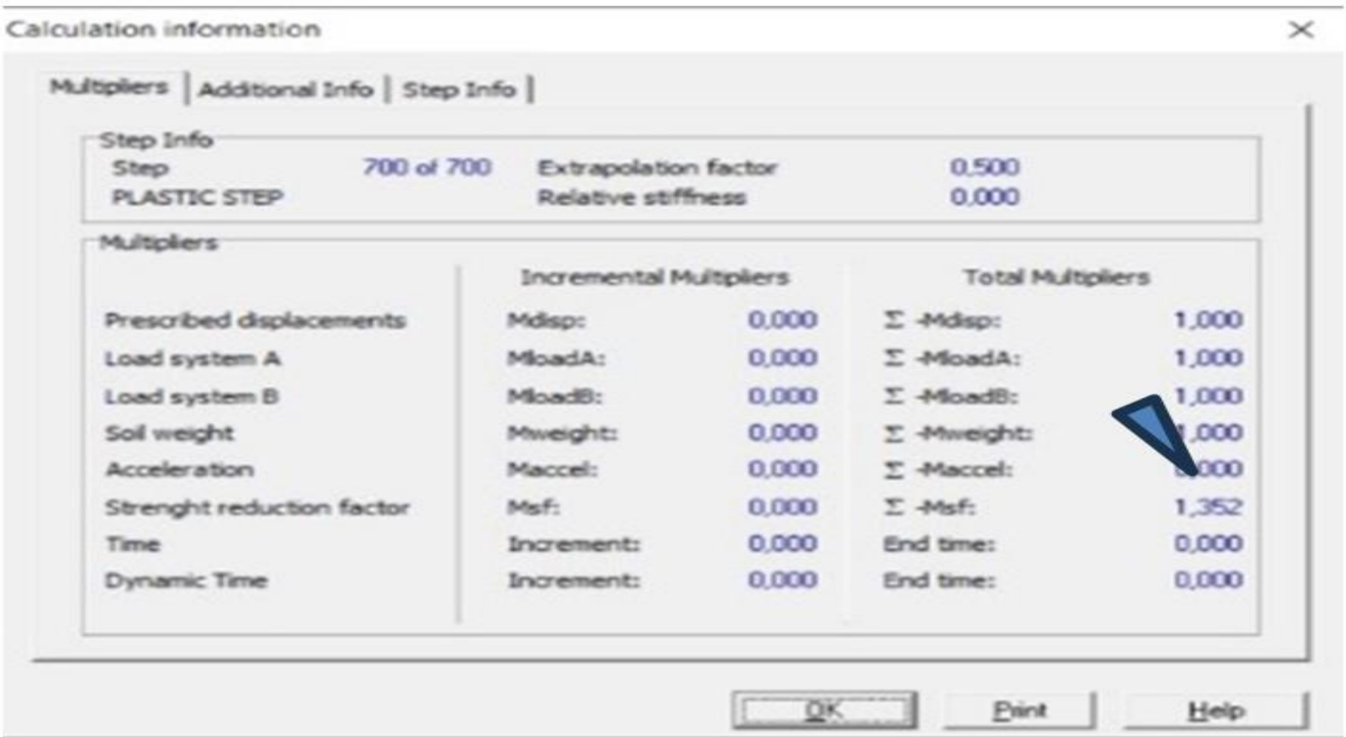

Fig 13 Stages of Calculating the Safety Factor (SF) of Excavated Slopes without Vegetation Strengthening

D. Excavated Slope Conditions with Vegetation Strengthening

The following is the modeling of the condition of the slope after being excavated using vegetation strengthening carried out with the following stages.

- The depiction or description of the slopes and the restriction of the calculated area is the first step to creating a model in Plaxis v8.2 is to draw the shape of the slope according to the figure, seen in Figure 14
- Input of soil parameters.

ISSN No:-2456-2165

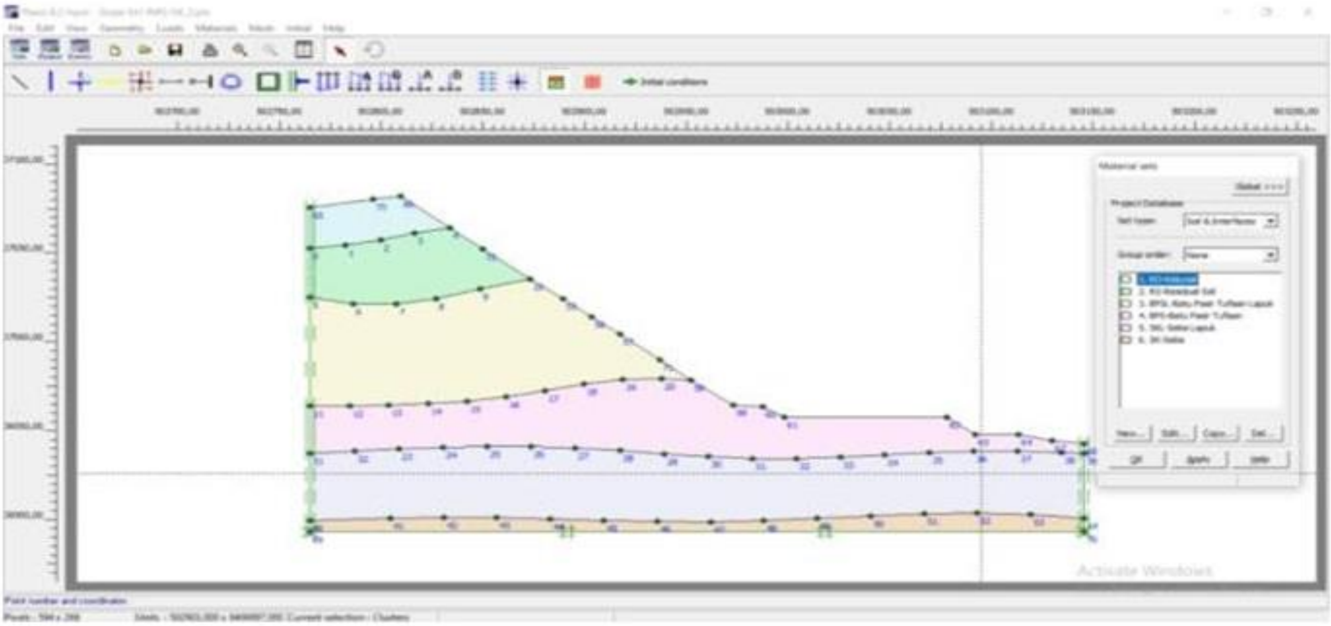

Fig 14 Stages of Calculating Safety Factor (SF) With Vegetation Strengthening

Soil parameters are obtained from the correlation of root strength from plants into cohesion values in the soil where in plaxis modeling it is limited to carry out strengthening ruralization using vegetation so that the initial modeling before there is strengthening using the parameters of the initial cohesion value of the original soil (Table 2) then after calculations are obtained additional cohesion values resulting from the root strength approach taken from the parameters of diameter length and root attraction which will be strengthened modeled into ground (parameter c plus) from c' to $c' + C_R$. Referring to the legal theory of the Mohr-Coulomb Collapse, the C_R value is then sought by calculating the T_R (MPa) value based on the results of tests conducted by Cazzuffi and Enrico Crippa (2005), shown Figure 15 below.

As for the diameter and depth of the roots obtained field data. The following are the results of the calculation of RAR values and C_R values shown in Tables 3 and 4.

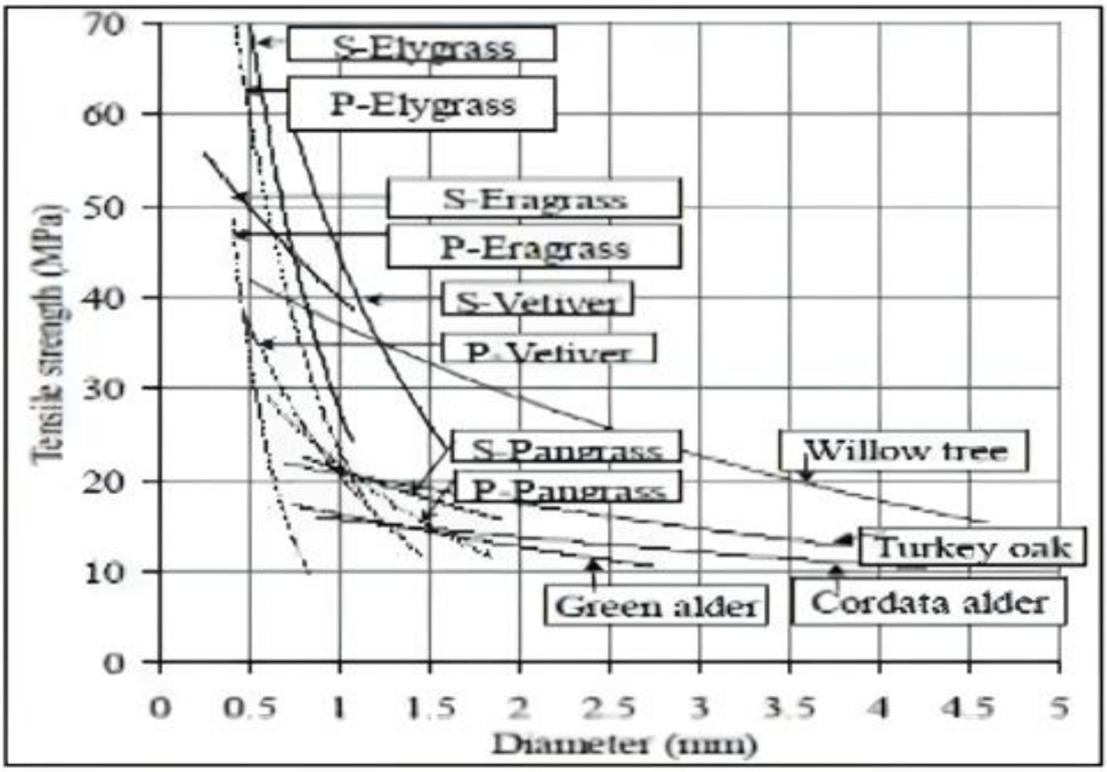

Fig 15 Test Results Conducted by Cazzuffi and Enrico Crippa (2005)

Table 3 Calculation of Average C_R Value

No	d (mm) Diameter akar	z (m) Kedalaman	RAR RAR=(1/400)*(2-z)	TR (MPa) TR=bacaan grafik	CR (kPa) CR=1.2*TR*RAR
1	2.5	1	0.0025	11	33.00
2	2.6	0.5	0.0038	11.5	51.75
3	2.6	0.75	0.0031	11.2	42.00
4	2.4	0.6	0.0035	11.7	49.14
5	2.3	0.65	0.0034	11.9	48.20
6	2.4	0.45	0.0039	11.1	51.62
7	2.2	0.85	0.0029	11.3	38.99
8	2.7	1	0.0025	11.7	35.10
9	2.3	0.9	0.0028	11.5	37.95
10	2.4	0.8	0.0030	11.2	40.32
Rata-rata					42.81

Table 4 Soil Parameter

No	Nama Lapisan	c' (kPa)	CR (kPa)	c'+CR (kPa)
1	IKO-Koluvial	53	42.81	95.81
2	2RS-Residual Soil	53	42.81	95.81
3	3BPSL-Batu Pasir tufaan lapuk	87.5	42.81	130.31
4	4BPSL-Batu Pasir tufaan	100	42.81	142.81
5	5SKL-Sekis lapuk	658	42.81	700.81
6	6SK-Sekis	1812	42.81	1854.81

After calculations were made to obtain the parameters of the excavated condition soil after being strengthened vegetation the data was input into the plaxis v.8.2 program shown in Figure 16.

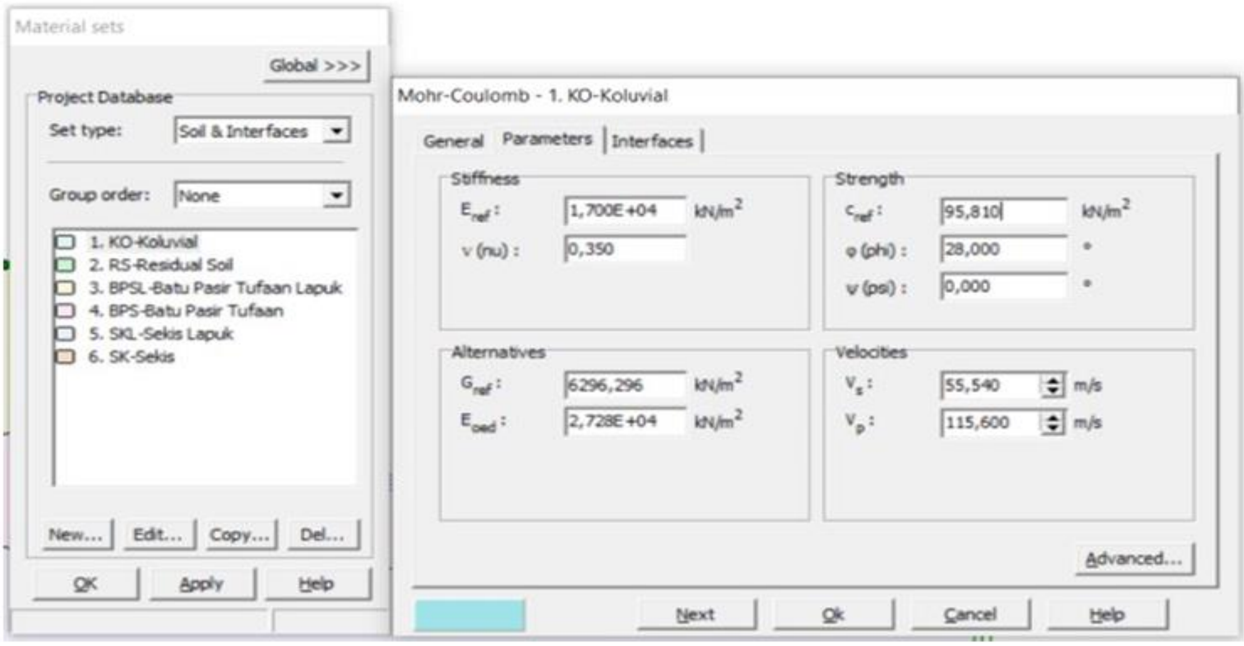

Fig 16 Input Parameters

- Creation of element nets or Finite Element Model (FEM) Element nets serve to show soil behavior due to loads and structures. The process of making a net of this element is carried out automatically by Plaxis. The output produced by the element net is in the form of calculations of ground stress and the shape of slope collapse. The element net for slope modeling is shown in Figure 17.
- The Data Calculation Process in the Plaxis v8.2 program is used to calculate the Safety factor (SF) of slopes by means of phi-c reduction. Phi-c reduction is a method of calculating the value of slope stability by the program by continuously reducing the parameter values of tan φ and c until a failure of the soil structure occurs. At the Safety factor (SF) calculation stage carried out, the Safety factor (SF) value of this slope is 1.59 shown in Figure 18 The running results of the Plaxis 2D program can be seen from the following figure

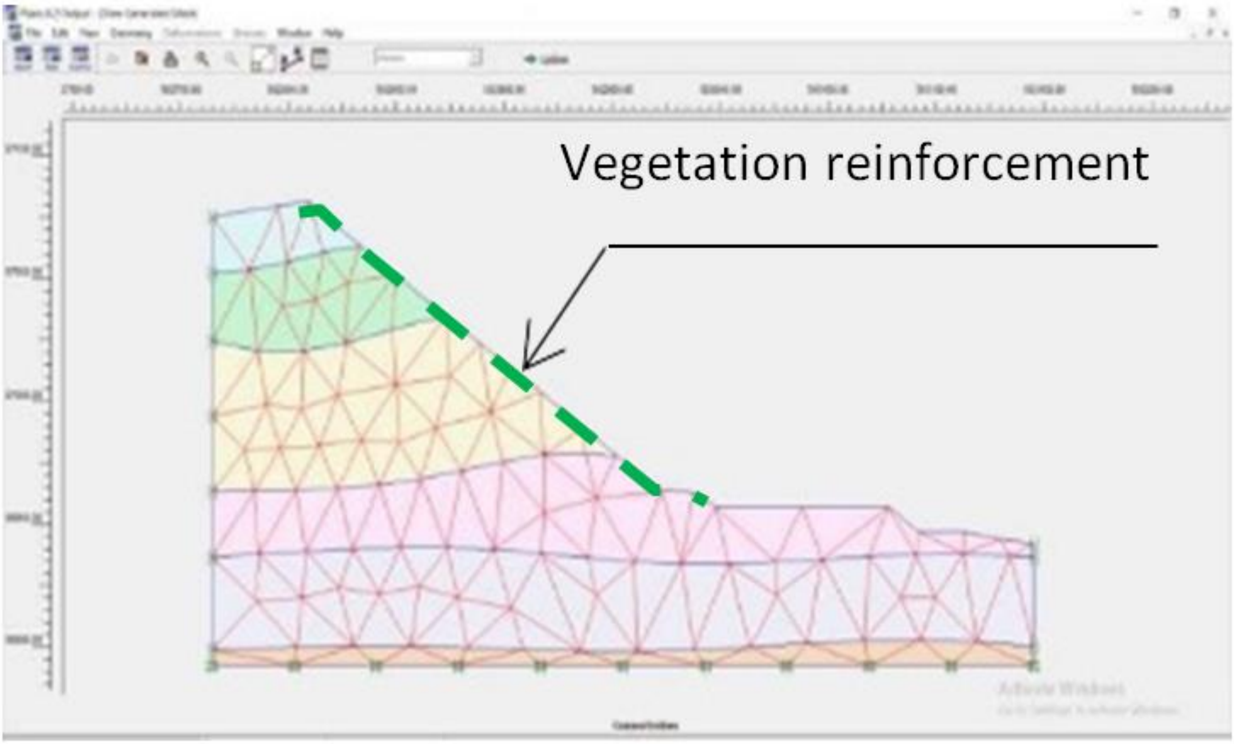

Fig 17 Model Mesh Modeling Results

In slope conditions with vegetation strengthening, safety factor (SF) is, 1.5 With a safety number value greater than 1.3 then slope conditions tend to be more stable and not landslides. The parameters that affect the strengthening are of the plant based on the length of the root diameter of the root and the attractiveness of the roots, the attractiveness of the roots is taken from a previous study conducted by Daniele Cazzuffi and Enrico Crippa (2005), which is described in Figure 15 of the results of strong testing of plant roots.

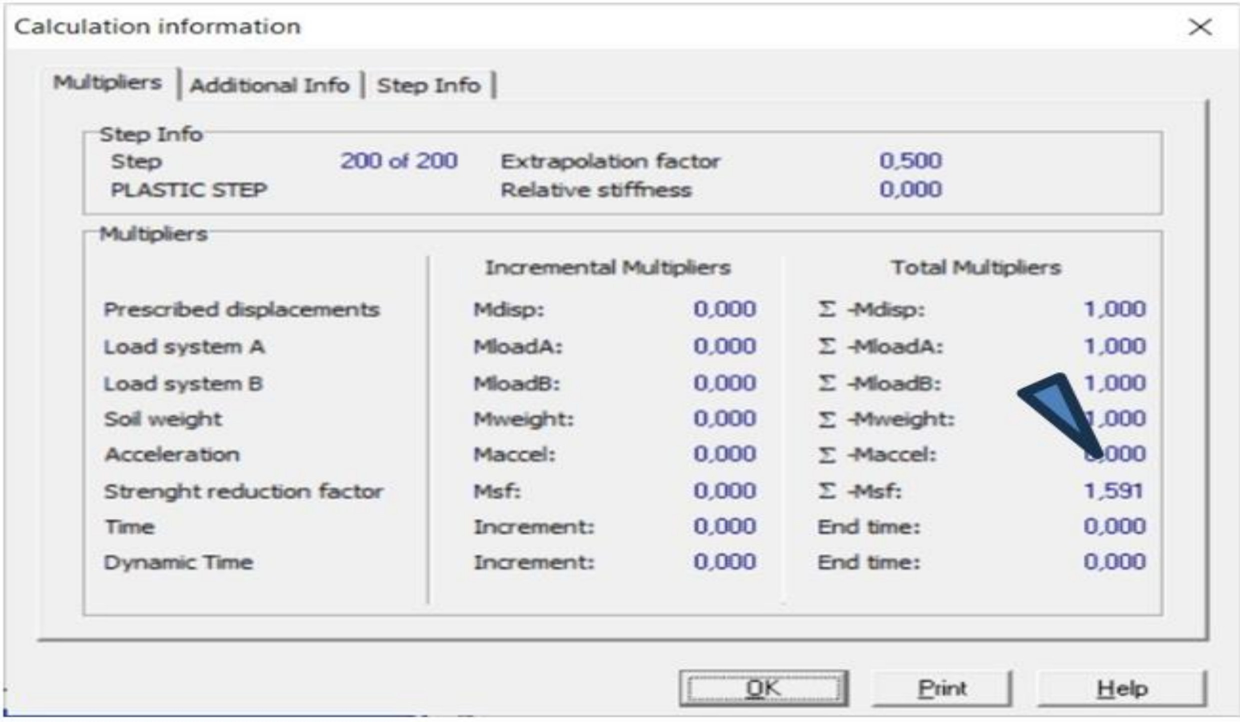

Fig 18 Stages of Calculating the Safety Factor (SF) of Excavated Slopes with Vegetation Strengthening

V. CONCLUSION

In the research analysis of strengthening slopes with vegetation methods in the Way Sekampung dam project in Pringsewu district, conclusions can be drawn, namely:

- The Safety factor (SF) value in natural slope conditions before excavation work is 1.9, so the slope condition is considered stable.
- The Safety factor (SF) value in slope conditions after excavation without using vegetation strengthening is 1.3, then the slope condition is stable or the cladding level is very low. What is considered slope safety factor 1.3 is the condition of the slope that is static against time meaning that the slope is considered always the best condition. In reality this is unattainable which is happy to happen over time. This means that the nature of the slope cannot be maintained due to erosion caused by climate change. This erosion causes the slope to be unstable due to the loss of its optimal state.
- The safety factor (SF) value in slope conditions after excavation work after using vegetation strengthening is 1.5 From the results above, it can be seen and concluded that the condition of the excavated slope work is in a more stable condition if given vegetation protection reinforcement.

REFERENCES

[1]. Bowles, JE. (1989), *Sifat - sifat Fisik & GeoteknikTanah*, Erlangga, Jakarta.
[2]. Bishop, A.W. (1955). *The use of the slip circle in the stability analysis of slope*. Geotechnique 5(1): 7-17.
[3]. Cazzuffi, D., Crippa, E. (2005). *Contribution of Vegetation to Slope Stability: An Overview of Experimental Studies Carried Out onDifferent Types of Plants. Erosion of Soils and Scour of Foundations.*
[4]. Coduto, Donald P., (1994), *Foundation Design: Principles and Practices, Prentice Hall International Editions*
[5]. Coder, Kim. D. (2010). *Root Strength & Tree Anchorage.* Warnell Scholl of Forestry & Natural Resources University of Georgia.
[6]. Das, Braja M., (2011), *Geotechnical Engineering Handbook*. U.S.A: J.ROSS Publishing
[7]. Faisal, H., Normaniza, O. (2008). *Shear strength of soil containing vegetation roots. Soils and Foundation,* 48(4), pp. 587-596.
[8]. Hoek and Bray, J., (1981), *Rock Slope Engineering 4rd Ed*., The Insitutution of Mining and Metallurgy: London. Pg. 176-189.
[9]. Lambe, T.W., Withman, R.V., (1969), *Soil Mechanics, John Willey & Sons Inc*., New York, 553 p.
[10]. Nugraha, Fikri Yuhistira. (2016). *Analisis Stabilitas Lereng Menggunakan PerkuatanTanaman Switchgrass.* Teknik Sipil Itenas.
[11]. Meyerhof, G.G. (1956). *"Penetration Test and Bearing Capacity of Cohesi on less Soil." Journal of the Soil Mechanics and Foundations Division. American Society ofCivil Engineers.* Vol. 82. No. SM-1. pp. 1- 19.
[12]. Pangular, D. (1985), *Petunjuk Penyelidikan & Penanggulangan Gerakan Tanah*, Pusat Penelitian dan Pengembangan Pengairan, Balitbang Departemen Pekerjaan Umum.
[13]. Pratiwi, D. A. (2015). *Pengaruh Infiltrasi Hujan Dalam Analisis Stabilitas Lereng Kondisi Jenuh Sebagian Menggunakan Metode Elemen Hingga*. Bandung: Institut Teknologi Nasional.
[14]. Terzaghi, K. and Peck, R.B. (1948), *Soil Mechanics in Engineering Practice, Wiley,New York.*
[15]. Wu, T., McKinnell, I., & Swanston, D. (1979). *Strength of tree roots and landslides on Prince of Wales Island, Alaska. Canadian Geotechnical* Journal 16, 19-3