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Slopes Stability Safety Factor On Existing Condition and After Strengthening by Counterfort Type Retaining Walls

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ABSTRACT-- *The Middle Aceh / Gayo Lues-Blangkejeren boundary section Km 438 + 775 is one of the Aceh Provincial National roads, which often experiences landslides. Avalanches that occur due to scour of runoff water, lack of optimal drainage and the absence of outlets for water disposal and the soil layer under asphalt pavement consists of loose material . Therefore, it is necessary to study the strength of slopes with Counterfort type retaining walls . This study aims to analyze slope stability by obtaining safety factor figures and identifying patterns of slope collapse by using the Plaxis program and the slice method. The input soil parameters used are dry volume weight, wet volume weight, permeability, young modulus, paisson's ratio , shear angle, cohesion. The results of the analysis of the slope stability in the existing conditions using the Plaxis program and the slice method with a radius of 65.06 meters obtained safety factor figures of 1.038 and 1.079, the slope is not safe (FK <1.25). The results of the analysis after reinforced counterfort type retaining walls and minipile with a length of 12 meters obtained a safety factor of 1.268, unsafe slopes (FK <1.5). Thus, additional reinforcement is needed using anchors. The results of slope stability analysis after being strengthened by counterfort type retaining walls, minipile and anchor with a length of 20 meters and a slope angle of 30 ° obtained a safety factor of 1.513, indicator safe slope (FK> 1.5).*

Key Words -- *Landslide, Counterfort, Plaxis, Ordinary Method, Safety Factor*

I. INTRODUCTION

Landslides on the Central Aceh / Gayo Lues-Blangkejeren (N.022) Km 438 + 775 boundary road are caused by scouring of run-off water resulting from poorly controlled and less optimal drainage and lack of outlets for water disposal. The construction of drainage channels as water control at these locations is cut off at the foot of the hill which results in the drainage of water in the channel directly to the slope's body. This can cause soil volume to increase and the condition of the slope to be saturated. The other cause is the layer of soil under asphalt pavement consists of loose material . In this case, the bending capacity (cohesion) of the soil is weak so that the soil grains can be separated from the bonds and shifted downward by dragging other grains around them to form a larger mass. The weak shear strength of the soil can be caused by water content and water permeability and potential shear fields formed from landslides .

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The purpose of this study is to analyze the safety factor on the stability of the slope in the existing conditions with the slice method and 2D Plaxis program and to analyze the safety factor after being strengthened by the construction of a Counterfort type retaining wall using only the program. To calculate the safety factor for the stability of the Counterfort type retaining wall construction is done manually.

II. LITERATURE STUDIES

2.1 Slope Stability

Surface surface that is not horizontal, the gravity component tends to move the ground down [1]. If the gravity component is so large that the counterclockwise shear that can be developed by the soil in the landslide field is exceeded, then an avalanche will occur**.**

2.2 The Slope Safety Factor Concept

In general, the value of safety factor ≥ 1.25 is a normal design to provide an estimate of the safety factor in slope stability analysis [2]. This is important to ensure that the slope design is safe and to prevent unexpected factors during analysis and construction such as incorrect data, analysis errors, work skills and lack of field supervision.

The parameters produced in the slope stability analysis are the shape of the collapse plane and safety factor [3]. The safety factor is used to identify slope stability which is defined as the ratio between the shear strength of the soil and the shear stress acting on the mass of the soil, as shown in Equation 1.

$$FK = \frac{Shear\ Strength}{Shear\ Stress} \tag{1}$$

2.3 Method of Slices

The slice method is generally used to divide a part of the slide into several vertical slices. The width of each slice does not have to be the same [4] **.**

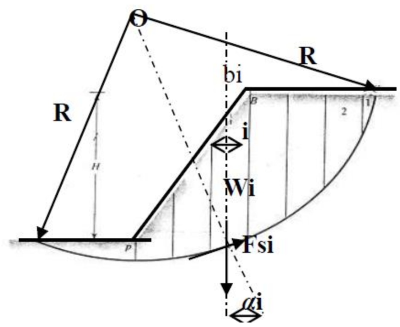

Figure 1: Division of soil mass in several slices

The calculation of the safety factor (Fs) with the slice method as shown in equation 2

$$SF = \frac{\Sigma\ (cb + (W_i)\cos \alpha_i \tan \phi)}{(Wi)\ sin\ \alpha_i} \tag{2}$$

Where :

SF = Safety Factor

c = cohesion

ϕ = Angle of Shear Soil

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b = length of the slip plane

W_1 = Weight of the 1st slice

III. RESEARCH METHODS

The research method is the steps carried out systematically with a clear frame of reference in solving problems. In this chapter it explains the stages or research methodology to determine the results to be achieved in accordance with existing objectives. Starting from the research location, sampling, parameters needed, then analyzed using the 2D *Plaxis* program .

3.1. Research sites

The location of this research is located on the border road of Central Aceh / Gayo Lues-Blangkejeren (N.022) precisely at Km 438 + 775 administratively located in the Gayo Lues district which borders north with Central Aceh, Aceh Tamiang and East Aceh, south with the districts of Southeast Aceh, South Aceh and Southwest Aceh, the west with the districts of Southwest Aceh, Nagan Raya and South Aceh and east with the districts of Aceh Tamiang and North Sumatra Province.

3.2 Sampling

Soil sampling is done using the Hand Bore method. The Hand Bore method is a soil investigation by digging the soil using a hand drill with the planned depth, then sampling is carried out using a Tube . The number of samples taken amounted to 3 points at each depth based on secondary data, namely log logs and SPT. Samples taken consisted of disturbed soil samples and undistrubed samples on the Aceh Tengah / Gayo Lues-Blangkejeren (N.022) road section Km 438 + 775

3.3 Soil Parameters

This soil parameter is the data used to obtain the results of the slope stability analysis calculation. Data used for the analysis of slope stability using the 2D Plaxis program are soil volume weight (γ), cohesion (c), and shear angle (ϕ) obtained from soil sample test results on the Middle Aceh/Gayo Lues-Blangkejeren border road (N.022) Km 438 + 775 in the laboratory. Whereas for Poisson ratio (υ), Young's modulus (E_{ref}) and soil permeability coefficient (k) are obtained from the interpretation results according to the type of soil described after testing.

Table 1: Parameter Input In Program Plaids.

Parameter Tanah	Km 438+775			Satuan
	Lapisan 1	Lapisan 2	Lapisan 3	
Material model	MC	MC	MC	-
Type of behaviour	*Drained*	*Undrained*	*Undrained*	-
Dry soil weight (γ_{dry})	10,693	12,001	14,486	kN/m^3
Wet soil weight (γ_{wet})	15,206	16,514	20,928	kN/m^3
Horizontal permeability (k_x)	0,01	0,001	0,001	m/day

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Vertical permeability (k_y)	0,01	0,001	0,001	m/day
Young's modulus (E_{ref})	78480	29430	19620	kN/m^2
Poisson's ratio (v)	0,3	0,3	0,35	-
Cohession (c)	45,093	35,774	33,648	kN/m^2
Friction angle (ϕ)	20,415	26,967	25,700	°
Dilatancy angle (Ψ)	-	-	-	°

3.4 Calculation of Slope Stability with slices Method

Calculation of the slope stability using the ordinary method, the slope stability analysis is done using the 2D Plaxis program to obtain the collapse pattern and the safety factor. The slice method is done by dividing the landslide plane into several slices to make it easier to analyze the slope safety factor. The calculation steps with the slice method are as follows:

1. Determine the plane of the curve of the slide with the help of the Autocad program to get the magnitude of the radius R and the center of the circle (P).
2. Distributing landslide fields to several slices to facilitate accurate calculation of landslide fields.
3. Determine the angle of the landslide field on each slice.
4. Perform an area calculation for each slice using an area equation based on the shape of the slices.
5. Calculate the weight of the ground slice (W).
6. Perform the calculation of the slope safety factor using equation 2.

3.5 Data Processing

Slope stability analysis using Plaxis 2D program requires modeling the slope in accordance with existing data so that accurate results are obtained. The analysis of the Plaxis 2D program has three stages, namely:

1. Data input stage.
2. Calculation stages, and
3. Stages of data output.

IV. RESULTS AND DISCUSSION

In this chapter the results of slope stability analysis in the existing conditions are obtained using the slice method and 2D Plaxis program and slope stability analysis after reinforced with Counterfort type retaining walls using only the program.

4.1 Results of slope stability analysis using the Ordinary Method and the 2D Plaxis Program

Analysis of slope stability in existing conditions by using the slice method and the 2D *Plaxis* program to obtain a number of safety factors. The calculation using the slice method is based on the landslide plane in the *Plaxis* 2D program . The results of slope stability analysis on existing conditions using program *Plaxis* 2D with the vehicle load that is equal to 15 kN/m ^{2} , as shown in Figure 2. Terms safety permitted > 1.25.

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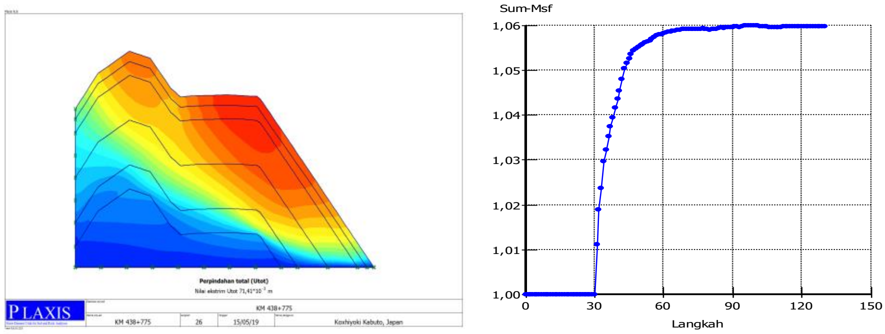

(a) (b)

Figure 2 : (a) Total displacement and (b) Safety factor

The results of the analysis of slope stability in the existing conditions using the 2D Plaxis program , showed that the safety factor at Km 438 + 775 is equal to 1,038 with unsafe slope conditions (SF <1.25)

The results of the analysis of the slope stability in the existing conditions by using the slice method , in facilitating calculations to obtain a safety factor, then it is done by distributing landslide fields into several slices.

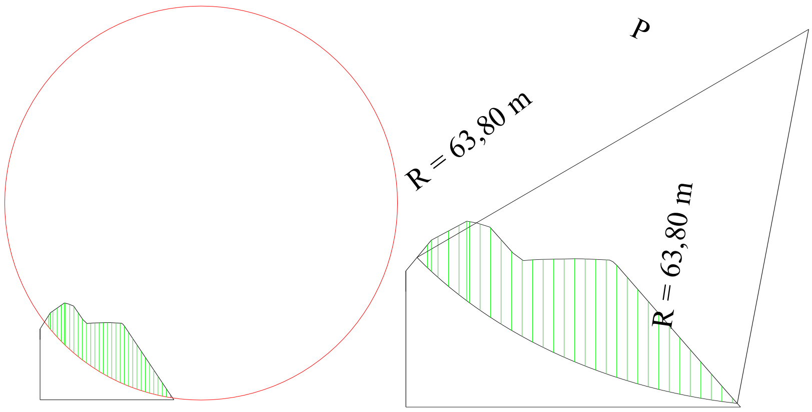

Figure 3 : (a) Field of Slope Failure and (b) Radius of Field of Slope Failure

(a) (b)

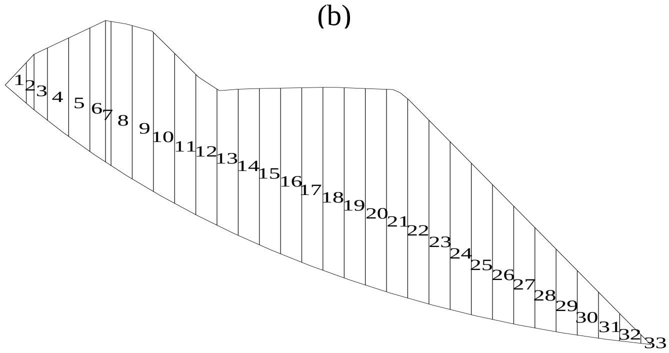

Figure 4: Division of the Slope Collapse Field into Several Slices

The results of the analysis of slope stability in the existing conditions using the slice method showed that the safety factor at Km 438 + 775 with a radius of 63.80 m obtained a safety factor of 1.079 with unsafe slope conditions (SF <1.25).

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Table 2 : Calculation of Slope Safety Factor at Km 438 + 775

No Sliced	Variable (m) h1	h2	L	Sliced Area (m^2)	γ (kN/m^3)	c (kN/m^2)	φ (°)	Weight of Slice (W) (kN/m)	α	α (rad)	sin α	cos α	W sin α	W cos α	SF
	1	2	3	4	5	6	7	9 = 4 x 5	10	11	12	13	14 = 9 x 12	14 = 9 x 13	15
1	0,00	3,88	2,19	4,249				88,915	52	0,907	0,788	0,616	70,028	54,790	
2	3,88	5,27	0,81	3,706				77,554	51	0,889	0,777	0,630	60,238	48,847	
3	5,27	6,89	1,32	8,026				167,960	50	0,872	0,766	0,643	128,593	108,048	
4	6,89	9,36	2,12	17,225				360,485	48	0,837	0,743	0,670	267,738	241,382	
5	9,36	11,74	1,98	20,889				437,165	46	0,802	0,719	0,695	314,284	303,873	
6	11,74	13,44	1,42	17,878				374,147	45	0,785	0,707	0,708	264,403	264,720	
7	13,44	13,70	0,50	6,785				141,996	45	0,785	0,707	0,708	100,347	100,467	
8	13,70	14,57	1,86	26,291				550,220	43	0,750	0,682	0,732	375,019	402,620	
9	14,57	15,11	1,81	26,860				562,134	41	0,715	0,656	0,755	368,562	424,449	
10	15,11	14,19	1,82	26,663				558,003	40	0,698	0,642	0,766	358,450	427,646	
11	14,19	13,33	1,71	23,530				492,427	38	0,663	0,615	0,788	302,973	388,191	
12	13,33	12,94	1,70	22,330				467,312	36	0,628	0,587	0,809	274,498	378,195	
13	12,94	13,88	1,68	22,529				471,483	35	0,610	0,573	0,819	270,252	386,342	
14	13,88	14,85	1,60	22,984				481,009	33	0,576	0,544	0,839	261,799	403,523	
15	14,85	15,74	1,64	25,084				524,954	32	0,558	0,530	0,848	277,994	445,304	
16	15,74	16,58	1,59	25,694				537,732	31	0,541	0,515	0,857	276,763	461,041	
17	16,58	17,38	1,56	26,489	20,928	33,648	25,7	554,358	29	0,506	0,484	0,875	268,571	484,956	1,079
18	17,38	18,07	1,55	27,474				574,971	28	0,488	0,469	0,883	269,743	507,769	
19	18,07	18,67	1,52	27,922				584,360	26	0,453	0,438	0,899	255,985	525,308	
20	18,67	19,23	1,51	28,615				598,844	25	0,436	0,422	0,906	252,902	542,821	
21	19,23	19,93	1,49	29,174				610,558	24	0,419	0,406	0,914	248,158	557,851	
22	19,93	17,46	1,48	27,669				579,048	22	0,384	0,374	0,927	216,758	536,948	
23	17,46	15,95	1,46	24,389				510,419	21	0,366	0,358	0,934	182,785	476,568	
24	15,95	14,40	1,46	22,156				463,670	20	0,349	0,342	0,940	158,469	435,750	
25	14,40	12,81	1,44	19,591				410,005	18	0,314	0,309	0,951	126,605	389,968	
26	12,81	11,19	1,43	17,160				359,124	17	0,296	0,292	0,956	104,920	343,456	
27	11,19	9,54	1,42	14,718				308,025	16	0,279	0,275	0,961	84,840	296,110	
28	9,54	7,86	1,41	12,267				256,724	15	0,262	0,259	0,966	66,396	247,989	
29	7,86	6,14	1,40	9,800				205,094	13	0,227	0,225	0,974	46,102	199,846	
30	6,14	4,39	1,40	7,371				154,260	12	0,209	0,208	0,978	32,048	150,894	
31	4,39	2,61	1,39	4,865				101,815	11	0,192	0,191	0,982	19,413	99,947	
32	2,61	0,83	1,38	2,374				49,675	10	0,174	0,174	0,985	8,619	48,921	
33	0,83	0,00	0,65	0,270				5,645	9	0,157	0,156	0,988	0,882	5,576	
Σ			49,70					`					6315,138	10690,116	

Calculation of 1st Slice

W = γ x Sliced Area 1

= 20,928 kN/m³ x 4,249 m²

= 88,915 kN/m

Safety Factor Calculation = 1.079

$$SF = \frac{\Sigma(c'l + Wt\,cos\,\alpha\ tan\,\varphi')}{\Sigma Wt\,sin\,\alpha}$$

$$SF = \frac{\Sigma(33{,}648\ x\ 49{,}70) + (10690{,}116\ \ (\tan(25{,}7) x\ 0{,}01744))}{6315{,}138}$$

SF = 1,079

So, the safety factor of the slope is SF = 1.079

4.2 Slope Stability Analysis Results After Strengthening the Counterfort Type Retaining Wall Using 2D Plaxis Program

The results of the analysis of the slope stability after being strengthened by a counterfort type retaining wall using the Plaxis program with a vehicle load of 15 kN / m^2 . Calculation of safety factors after reinforced counterfort type retaining walls as shown in Figures 5. Permitted safe requirements SF > 1.50.

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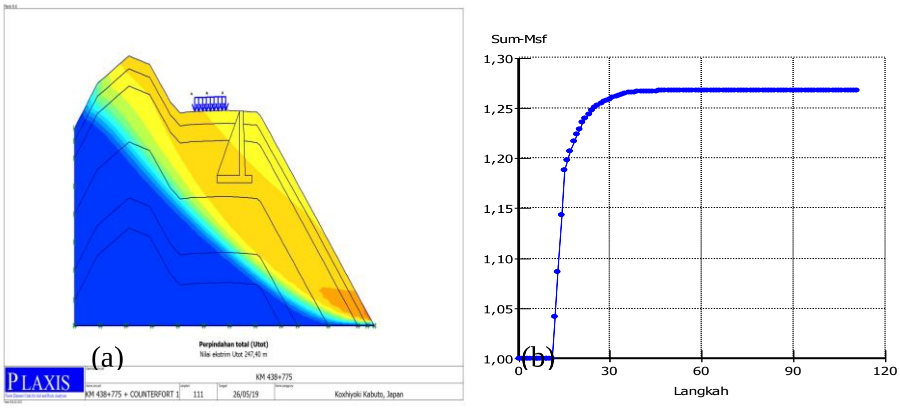

Figure 5: (a) Total Displacement and (b) Safety Factors After Reinforced Counterfort Type Retaining Walls

The results of slope stability analysis after reinforced counterfort type retaining walls using the Plaxis program showed that the safety factor at Km 438 + 775 was 1.268 with unsafe slope conditions (SF <1.50).

The results of slope stability analysis after being strengthened by counterfort type retaining walls and minipile using the Plaxis program with a vehicle load of 15 kN/m^2. Calculation of safety factors after reinforced counterfort type retaining walls and minipile, as shown in Figures 6. Permitted safe requirements SF > 1.50.

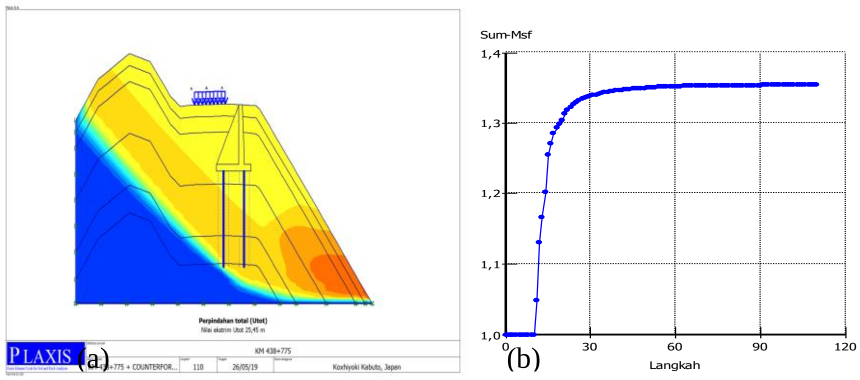

Figure 6: (a) Total Displacement and (b) Safety Factors After Reinforced Counterfort Type Retaining Walls and Minipile

The results of slope stability analysis after reinforced counterfort type retaining walls and minipile with a length of 12 meters using the Plaxis program, showed that the safety factor at Km 438 + 775 was 1,354 with unsafe slope conditions (SF <1.50).

The results of slope stability analysis after being strengthened by counterfort types retaining walls, minipile and anchor using the Plaxis program with a vehicle load of 15 kN / m^2 . Calculation of safety factors after reinforced counterfort type retaining walls, minipile and anchor, as shown in Figures 7. Permitted safe requirements SF> 1.50.

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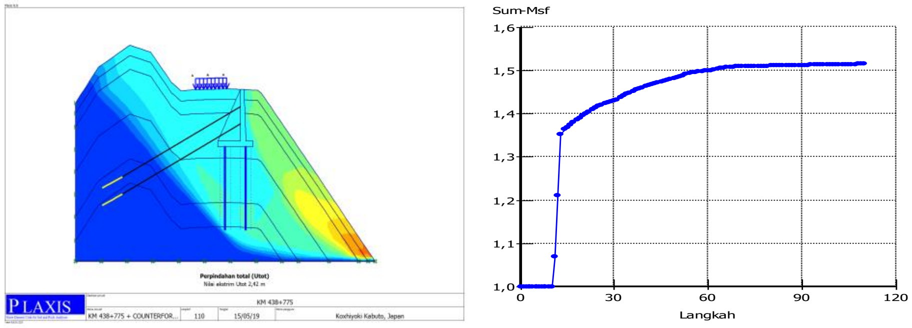

(a) (b)

Figure 7: (a) Total Displacement and (b) Safety Factors After Reinforced Counterfort Type Retaining Walls, Minipile and Anchor

The results of the analysis of slope stability after reinforced counterfort type retaining walls , minipiles with a length of 12 meters and anchor with a length of 20 meters and a slope angle of 30° using the Plaxis program, showed that the safety factor at Km 438 + 775 is equal to 1.513 with safe slope conditions (SF > 1.50).

4.3 Discussion

The results of the analysis of the slope stability in the existing conditions using the data as in Table 1 at Km 438 + 775 using the Plaxis 2D program, obtained a safety factor value smaller than 1.25 in unsafe conditions (SF <1.25). Whereas calculations using the Km 438 + 775 slice method with a radius of 63.80 m obtained a safety factor value smaller than 1.25 in unsafe conditions (SF <1.25). Thus, it is necessary to strengthen the slope using Counterfort type retaining walls .

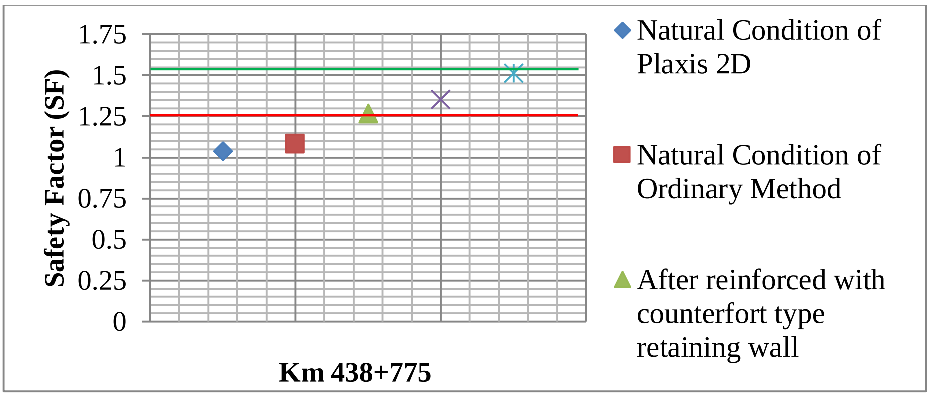

Figure 8: Safety Factor Calculation Chart for Existing Condition and After Slope Strengthening

Figure 8 shows that the results of slope stability analysis after being strengthened by a Counterfort type retaining wall at Km 438 + 775, show that the safety factor value is less than 1.50 in unsafe slope conditions (SF <1.50). This is because, the reinforcement on the slope does not pass through the sliding plane so that additional reinforcement is needed by adding a minipile. The results of slope stability analysis after the reinforced soil retaining wall of types Counterfort and minipile over 12 meters at Km 438 + 775 obtained the value of the safety factor is less than 1.50 in conditions unsafe slope (SF <1.50). Based on the analysis results obtained the value of the safety factor increases after additional reinforcement is performed. Thus, additional reinforcement is needed to increase the safety factor, by installing anchors on Counterfort type archery walls . The results of slope stability

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analysis after reinforced counterfort type of retaining walls, minipile and anchor at Km 438 + 775 with a length of 20 meters and a slope angle of 30 °, obtained a safety factor of 1.513 with safe slope conditions (SF> 1.50).

V. CONCLUSION

Based on the results and discussion of slope stability analysis by calculating the slice method and using the 2D *Plaxis* program, the following conclusions can be drawn:

1. The Safety Factor in existing conditions with the 2D Plaxis Program and the slice method at Km 438 + 775 is 1,038 with unsafe slope conditions (SF <1.25)
2. The Safety Factor after being strengthened by a Counterfort type retaining wall with the 2D Plaxis Program at Km 438 + 775 is 1.268 with unsafe slope conditions (SF <1.50). Thus, additional reinforcement to improve the safety factor (FK).
3. The Safety Factor after being strengthened by a Counterfort type retaining wall and minipile with a length of 12 meters with the 2D Plaxis Program at Km 438 + 775 is 1,354 with unsafe slope conditions (SF <1.50)
4. The Safety Factor after being strengthened by a Counterfort type retaining wall , minipile with a length of 12 meters and anchor with a length of 20 meters and a slope angle of 30 ° with the 2D Plaxis Program at Km 438 + 775 is 1.513 with safe slope conditions (SF> 1.50)

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