Slope Stability Analysis Using the Rock Structure Rating (RSR) Method and Atterberg Limit at Riau - West Sumatra Cross road Km 165 Harau Subdistrict, Lima puluh Kota Regency, West Sumatra Province, In

by Ahmad Pandi

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RESEARCH ARTICLE

Slope Stability Analysis Using the Rock Structure Rating (RSR) Method and Atterberg Limit at Riau - West Sumatra Cross road Km 165 Harau Subdistrict, Lima puluh Kota Regency, West Sumatra Province, Indonesia

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Abstract

Stability on the slope was considered important for the safety of people who pass through the highway. Failure of slopes on highways can cause losses especially roads had an important role in community activities. The research was located on the Riau – West Sumatra Km 165. The purpose of this research was to find out treatment or mitigation that can be given to the research slope and know the soil classification based on the analysis Atterberg Limit. The research slope was divided into 3 parts using analytical Rock Structure Rating (RSR) method based on different slope conditions. And 1 part of the slope has become soil using the analytical method Atterberg Limit. Treatment or mitigation that can be given to the research slope, namely the use of rock shopandshotcrete based on the RSR diagram and the use of rock embankments to resist landslides.

Keywords: *Rock Structure Rating* (RSR), Atterberg Limits, Slope Stability, Landslide

1. Introduction

1.1 Sub Introduction

A slope is a surface that connects higher ground with a lower ground surface, and slope stability is closely related to landslides or ground movements which are the natural process of transferring soil mass from high places to lower places (Korach and Sarajar, 2014). This movement of the ground can occur due to changes in the carrying capacity of the soil and will stop after reaching a new balance. Failure of a slope can cause landslides, which generally occur when the soil can no longer support the weight of the soil layer above it because there is an additional load on the surface of the slope and a decrease in the binding capacity of the soil grains.

Other factors that affect slope stability include internal factors and external factors. Internal factors occur from the body of the slope itself, mainly due to the role of water in the body of the slope. While external factors occur outside the slopes, namely the influence of climate or weather, weathering and erosion, subsidence and ground movements, vibrations or earthquakes, and the result of human activities that carry out uncontrolled mining of soil, sand, or rock, causing an imbalance of the load at the top. slope with the load at the foot of the slope.

Against this background, research on slope stability is very important to provide information about areas or locations that have the potential for ground motion with existing natural features thus various preventive measures can be taken before ground motion becomes an unexpected disaster. The slopes that are the object of research are on the Riau – West Sumatra Km 165 causeway. This research uses the Rock Structure Rating (RSR) method and technical analysis Atterberg Limits.

2. Study Area

Administratively, the research location is located in Harau District, Fifty City District, West Sumatra Province. Meanwhile, geographically it is at coordinates 0° 05' 00.7" LS and 100° 41' 55.6" E. The research was conducted on one of the slopes, which is on the edge of the Riau - West Sumatra Km 165 causeway.

2.1 Regional Geology

Regional Geology in Fifty Cities District is in a series of hills known as "Bukit Barisan" and is part of the "Bukit Barisan"Volcanic Arcplate tectonic order or framework in the Sumatra area. The research location is included in the Brani formation based on the Sheet Solok geological map (P.H Silitonga & Kastowo, 1995) which is Eocene – Oligocene in age. The Brani Formation has a finger relationship with the Sangkarewang Formation (P.H Silitonga & Kastowo, 1995). The lithology of this formation is in the form of conglomerate with sandstone inserts and has a depositional environment that is alluvial fans.

The regional geological structure of the study area is strongly influenced by the geological setting of Sumatra (Fig. 1). From the geological structure, this area is included in the Payakumbuh basin area, which has fault or fault structures in the form of normal fault structures and shear faults which are reflections of basement form areaBlock Faulting System (Bunk Fault System). In general, the direction of the structure in the Fifty Cities Regency area is Northwest-Southeast. In Pre-Tertiary rocks, there are Northeast-Southwest and North-South directions in addition to these directions. The folds in Tertiary rocks generally have a slope of no more than 20°, whereas those in Pre-Tertiary rocks are sharper. The main faults in this area are part of the Northwest-Southeast trending Sumatran fault and are in the form of right-sided shear faults associated with the formation of volcanoes, besides that there are also those trending Northeast-Southwest and North-South.

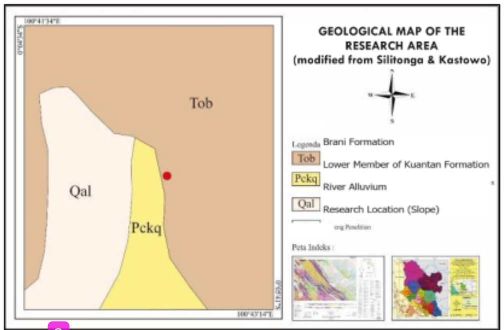

Fig 1. Regional Geological Map of Research Area.

Table 1. Table title should be placed above the table and adjust text to table width.

Occurrence	Year	Location
	2016	
Landslide	28/1/2016	Km 79 Dusun Rantau Berangin, Merangin Village
	13/11/2016	Km 77, 80, 82 Merangin Village
	2017	
Landslide	2/3/2017	Sub District Kapur IX, Regency Lima Puluh Kota
	15/3/2017	Sub District Pangkalan, Regency Lima Puluh Kota
	2018	
	19/4/2018	Km 77 Merangin Village
	23/10/2018	Causeway of Riau – West Sumatera, Hamlet Rantau Merangin, Merangin Village
Landslide	15/11/2018	Km 81 PLTA Koto Panjang
	6/12/2018	Km 110 border of Riau – West Sumatera

2.2 History of Landslides on Causeway of Riau - West Sumatra

Landslides are the displacement of slope-forming material in the form of rock, debris, soil or mixed materials, moving down or off the slope (Iswanto and Raharja, 2009). Landslides can occur due to natural factors and human factors. The Riau and West Sumatra highways have the potential for landslides due to the presence of slopes mined for stone mining by the local community. The main factor for the occurrence of landslides is the geological structure, because the slopes mined are considered rock slopes with a lot of joints and the possibility of slope failure is higher (Putra, D.E.B and Choanji T, 2016).

The following is some history of landslides that have occurred on the Riau - West Sumatra highway is in table 1.

3. Methodology

3.1 Research Object

Before conducting the research, a literature study was carried out in the form of a literature study to find an overview of the geological and geotechnical characteristics of the study area. After that, the field collected data in the field through joint data and soil samples on the research slope. The research slope has a length of 48 meters and a height of 10 meters, which is divided into four-scanline using the RSR method (Rock Structure Rating) to determine the stability of the slope and 12 meters in the form of slopes that have experienced weathering using the method Atterberg Limits to determine the classification of soil in the study area.

3.2 Method Analysis *Rock Structure Rating* (RSR)

In 1972, Wickham presented 3 tables for determining RSR values, namely parameter A (geology), parameter B (geometry) and parameter C (influence of groundwater and joint conditions). The RSR system applies the concept of valuation of each parameter, thus the equation is obtained, namely:

$$RSR = A + B + C$$

Where A is parameter A, B is parameter B and C is parameter C.

Parameters A, Geology. General assessment of geological structure, based on: Type of origin rock (igneous, metamorphic, sedimentary), Rock hardness (hard, medium, soft, weathered), and Geological structure (massive, slightly faulted/folded, moderately faulted/folded, intensely faulted/folded)

In parameter A, what must be done is to determine the type of rock on the slopes such as igneous, metamorphic or sedimentary rocks. After determining the type of rock, the hardness level of the rock is divided into hard, medium, soft or weathered. The values of these parameters are obtained from determining the type and hardness of the rock. After determining the type and hardness of the rock, then determining the geological structure found on such slopesmassive, slightly faulted/folded, moderately slightly faulted/folded andintensively faulted/folded. The rating value for the geological structure parameters is obtained if it has been determined. After the rating value for each parameter is obtained, the next step is to add up the rating values, then the rating value for parameter A will be obtained.

Table 2. Parameter A, Geology. General Geology

	Type of Rock Base				Structure Geology			
	Hard	Medium	Soft	Weathered	Massive	Few folds or breaks	Medium folds or breaks	Intensive folds or breaks
	1	2	3	4				
Igneous	1	2	3	4				
Metamorf Sediment	2	3	4	4				
Type 1					30	22	15	9
Type 2					27	20	13	8
Type 3					24	18	12	7
Type 4					19	15	10	6

Parameters B, Geometry. Effect of discontinuity pattern with respect to directiondrive, based on: distance between joints (joint spacing), stocky orientation (joint orientation, strike and dip), Tunnel direction (direction of tunnel drive).

In parameter B, the first step must be to determine the slope included instrike perpendicular toaxis orstrike in line withaxis. After determining it, calculate the joint distance on the slope. From the two data, a rating on parameter B will be obtained.

At parameter B there are two types of road direction towards the slopeor direction of drive: A is a type of road that is in the same direction or parallel to the slope, B is a type of road opposite to the slope.

Table 3. Parameter B, Geometry: Joint pattern, Direction *drive*

Average burly distance	Strike towards Axis					Strike Towards axis		
	Movement Direction					Movement Direction		
	Both	With Dip		In the contrary with Dip		One of Direction		
	Dip from stout looking a					Dip from stout looking		
	Flat	Dippin g	Vertical	Dippin g	Vertical	Flat	Dipping	Vertical
1. Very close solid < 2 in	9	11	13	10	12	9	9	7
2. Close solid, 2-6 in	13	16	19	15	17	14	14	11
3. Medium solid distance, 6-12 in	23	24	28	19	22	23	23	19
4. Medium until Blocky, 1-2 ft	30	32	36	25	28	30	28	24
5. Blocky until massive, 2-4 ft	36	38	40	33	35	36	24	28
6. Massive, > 4 ft	40	43	45	37	40	40	38	34

a *Dip*: flat: 0-20°;*dipping*: 20-50°; and vertical: 50-90°

Parameter C, Effect of groundwater and joint conditions (joint), based on: Overall rock mass quality based on combined parameters A and B, Good, poor, and very poor joint conditions, Amount of water inflow (in gallons per minute per 1000 tunnel feet)

In parameter C, the first step is determining which slope dip is included inrange value 13 – 44 or 45 – 75. The slope dip value can be seen fromslope face on that slope. There is a description of the dip value, dip is saidflat if the dip value is 0° – 20° ,dipping if the dip value is 20° – 50°, andvertical if the dip value is 50° – 90°.

After knowing range dip, then determine the flow of water on the inside slopegallons per minutes. Then determine the condition of the joints included in good, medium or bad. After everything is determined, the rating value for parameter C is obtained.

Table 4. Parameter C. Effect of Groundwater Conditions and Joint Conditions

Anticipated water inflow	Total from Parameter A + B					
	13 – 44			45 - 75		
gpm/1000 ft in tunnel	Solid condition b					
	Good	Medium	Bad	Good	Medium	Bad
None	22	18	12	25	22	18
Few, < 200 gpm	19	15	9	23	19	14
Medium, 200-1000 gpm	15	22	7	21	16	12
Heavy, > 1000 gpm	10	8	6	18	14	10

b Firm condition: good = close or cemented; medium = slightly weathered or altered; bad = very outdated, altered or open

After obtaining the values of parameters A, B and C, then these values are added up to get the RSR value. The values obtained are then plotted on the RSR diagram, thus support can be identified(treatment) to be assigned to the slope.

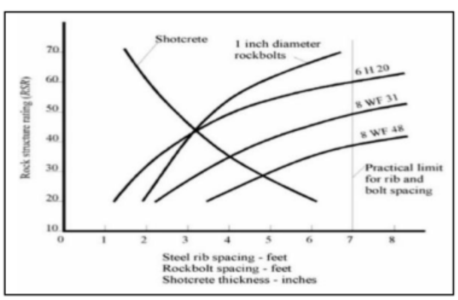

Fig 2. Diagram RSR (Wickham, 1972)

3.3 Granular Analysis / *Grain Size*

Soil properties are highly dependent on the grain size. The grain size is used as the basis for naming and classifying soil. Therefore, this grain size analysis is a test that is very frequently performed. Soil names and properties are determined or influenced by gradation (for coarse-grained soils) and consistency limits (for fine-grained soils). Which in this case is called the soil index property. Soil consists of a wide variety of grains with a ratio of the percentage of grain diversity. Can be seen in Table 5.

For distribution of coarse-grained soils, screening can be done. This filtering is technically by passing the soil through a set of filters that have different sizes.

3.3 Atterberg Limits (Boundary – Atterberg Limit)

The Atterberg Limit was created by Albert Atterberg (1911), a Swedish chemist later updated by Arthur Casagrande. Used in basic calculations of fine grained soils. If the fine-grained soil contains clay minerals, then the soil can be kneaded without causing cracks. This cohesive nature is due to the presence of water absorbed around the surface. According to Atterberg, a way to describe the consistency limits of fine-grained soils by considering the soil water content. There are several tests carried out to determine the consistency of the soil, namely:

3.3.1 Liquid Limit

Liquid limit is the water content of the soil which is at the boundary between the liquid state and the plastic state. Liquid limit determination using the Casagrande test equipment. The liquid limit analysis aims to calculate the liquid limit consistency value.

3.3.2 Plastic Limit

Plastic limit is the water content that is between semi-solid and plastic conditions which is characterized by soil that starts to crack. The plastic limit can be determined by a simple test by rolling a quantity of soil repeatedly thus it is ellipsoidal. The moisture content of the soil sample at which the soil begins to crack is defined as plastic. The plastic limit analysis aims to calculate the value of the consistency of plasticity and the plasticity index of the soil.

3.3.3 Plasticity Index

Plasticity Index (PI) is the difference between the liquid and plastic limits on the soil. The PI value is indicated by the equation:

PI = LL - PL

The plasticity index shows the plasticity of the soil, if the PI value is high then the soil contains a lot of clay, and if the PI value is low then the soil contains a lot of silt. The characteristics and properties of silt soil are that the soil will become dry with a slightly reduced water content. By Atterberg given the limit value of the Plasticity Index with its properties, soil variety and cohesiveness, as follows:

Table 5. Value of Plasticity Index and Soil Variety

PI	Trait	Soil Variation	Cohesive
0	Non Plastic	Sand	Non Cohesive
<7	Low Plasticity	Silt	Cohesive Partly
7-17	Medium Plasticity	Silty Clay	Cohesive
>17	High Plasticity	Clay	Cohesive

re conducting the research, a literature study was carried out in the form of a literature study to find out an overview of the geological and geotechnical characteristics of the study area

4. Result and Discussion

4.1 Slope Conditions

The slope to be studied has many discontinuities which are feared to cause failure. To determine the condition of the slopes, data collection is carried out based on measurements *scanline* which is divided into 4 *scanline*.

4.1.1 Scanline 1

Slope on scanline 1 has a slope length of 12 m and a slope height of 10 m. The lithology is in the form of sandstone on the bottom layer and conglomerate on the top layer. Sandstone with weathered brownish yellow color and fresh whitish yellow color, fine-medium grain size, rounded to moderate angles, good sorting, soft compactness can be crushed. Meanwhile, the conglomerate has a weathered color of yellowish brown and fresh color of whitish brown, the size of the gravel fragments (1-20cm), the shape of the fragments is rounded, open packaging, the compactness is soft-a bit hard. On scanline it has experienced high weathering, because more than half of the rock has begun to decompose and has a significant discoloration. Discontinuity data on scanline 1 was in the form of joints/fractures, found 50 joints with the average distance between joints being close, the width of the discontinuity fracture being slightly narrow, and the water conditions being moist. In taking discontinuity data, only one layer area is at the retrieval distancescanline. Can be seen in Fig. 3.

4.1.2 Scanline 2

Slope on scanline 2 has a slope length of 12 m with different slope heights, on the left the slope has a height of about 10 m, the middle is 5 m and the right is 8 m. The lithology is in the form of sandstone on the bottom layer and conglomerate on the top layer. Sandstone with brownish-yellow weathered color and blackish-gray fresh color, fine-medium grain size, rounded, well-sorted, hard compact. Meanwhile, conglomerate has a yellowish brown weathered color and whitish brown fresh color, the size of the fragments is cobble-stoned, the shape of the fragments is rounded, half-rounded, open packaging, hard compactness. On scanline 2 experienced mild weathering, because the rock experienced discoloration on the damaged aggregate or on the surface of the discontinuity plane. Discontinuity data on scanline 2 in the form of joints/fractures, found 70 joints with an average spacing between joints being moderate, the width of the discontinuity fracture being slightly narrow, and wet water conditions. In taking discontinuity data, only one layer area is at the retrieval distancescanline. Can be seen in Fig. 4.

Fig. 3. Measurement Location Scanline 1

Fig. 4. Measurement Location Scanline 2

4.1.3 Scanline 3

Slope on scanline 3 has a slope length of 12 m and a slope height of 8 m. The lithology is in the form of sandstone on the bottom layer and conglomerate on thetop layer. Sandstone with brownish-yellow weathered color and blackish-gray fresh color, fine-medium grain size, rounded, well-sorted, hard compact. Meanwhile, the conglomerate has a weathered color of yellowish brown and fresh color of whitish brown, the size of the gravel-barky fragments, the shape of the fragments is rounded, open packaging, the compactness is rather loud. On scanline 3 experienced light weathering. Discontinuity data on scanline 3 in the form of joints/fractures, found 80 joints with an average spacing between joints being moderate, the width of the discontinuity fracture being slightly narrow, and wet water conditions. In taking discontinuity data, only one layer area is at the retrieval distancescanline. Can be seen in Fig. 5.

4.1.4 Scanline 4

Slope on scanline 4 has a slope length of 12 m and a slope height of 8 m. The lithology is in the form of sandstone on the bottom layer and conglomerate on the top layer.

Sandstone with brownish-yellow weathered color and blackish-gray fresh color, fine-medium grain size, rounded, well-sorted, hard compact. Meanwhile, the conglomerate has a weathered color of yellowish brown and fresh color of whitish brown, the size of the gravel-barky fragments, the shape of the fragments is rounded, open packaging, the compactness is rather loud. Discontinuity data on scanline 4 in the form of joints/fractures, found 70 joints with the average distance between joints being close, the width of the discontinuity fracture being slightly narrow and the water conditions being moist. Scanline 3 experiences mild weathering, because the rock changes color on the damaged aggregate or discontinuity surface. In taking discontinuity data, only one layer area is at the retrieval distance scanline. Can be seen in Fig. 6.

Fig. 5. Measurement Location Scanline 3

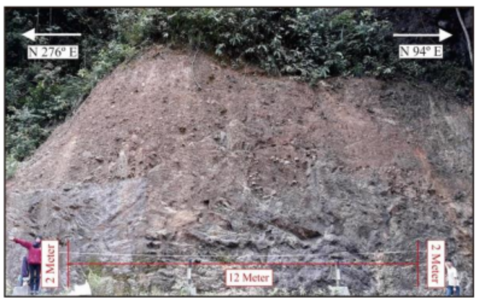

Fig. 6. Measurement Location Scanline 4

4.2 Degree of Slope Weathering

Slope weathering levels are grouped based on slope conditions in the field, then compared with weathering levels based on ISRM 1981 in Bienawski, 1989.

The research slope is divided into 4 levels of weathering, namely:

1. Weathering level II (Lightly Weathered): Sandstones on slopes that have weathering level II are characterized by changes in the color of the rock material in the field, fractures are covered with flow fill material in the form of clay which is not yet significant, there are no sand grains on the slopes, only color changes occur.
2. Weathering level III (Moderate Weathered): Conglomerates on slopes that have weathering level III are characterized by a contrasting color change in the rock material, it has begun to decompose or some of the slopes contain sand, but still less than 35% or not all of the rock material.
3. Weathering level IV (High Weathered): Sandstones and conglomerates on slopes that have weathering level IV are characterized by contrasting color changes and there is already a lot of sand or highly decomposed material, more than 35% of the conditions in the area have changed to soil and the samples have been can be picked up and squeezed by hand.
4. Weathering level V (Perfectly Weathered): Sandstones and conglomerates on slopes that have weathering level V are characterized by all material having been decomposed into soil, but the original mass structure is partially intact and some of the sides of the slope have experienced landslides.

Fig. 7. Overall Research

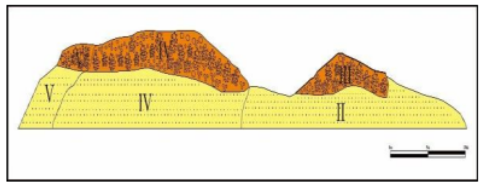

Fig. 8. Sketch of Research Slope Weathering Rate

4.3 Sieve Analysis

Research slopes that experience high weathering thus some of the rock material has become soil is used as a sample used to carry out sieve analysis (sieve analysis). The research slope is 15 meters long and 10 meters high. The soil sample used for sieve analysis was divided into two parts, namely the upper and lower parts. Can be seen in Fig. 9.

Fig. 9. Soil Sampling Research Slope

4.3.1 Sieve Analysis Test of Soil Samples at the Bottom

The results of the soil samples that have been tested for sieve analysis based on the sieve number are entered in the table. Can be seen in Table 7.

Table 6. Data from the Analysis of the Soil Sample Sieve at the Bottom

Sieve Number	Sieve Size (mm)	Restrained Weight Wn (gr)	Percentage Wn Rn = Wn / Wt	Cumulative Percentage ∑Rn (100%)	% Finer 100 − ∑Rn (%)
8	2.3	4.43	2.967	2.967	97.033
16	1.1	21.22	14.214	17.181	82.819

30	0.6	28.11	18.830	36.081	63.919
50	0.3	15.49	10.376	46.387	53.613
100	0.1	47.58	31.872	78.259	21.741
200	0.075	29.49	19.754	98.013	1.969
Pan	Pan	2.96	1.982	100	0
	Total	149.28	100		

After obtaining the values from the sieve analysis results in Table 7, then these values are plotted into the sieve analysis diagram Fig. 10 to determine the grain distribution of the soil sample. The values plotted into the sieve analysis diagram are the % Finer values and the sieve size.

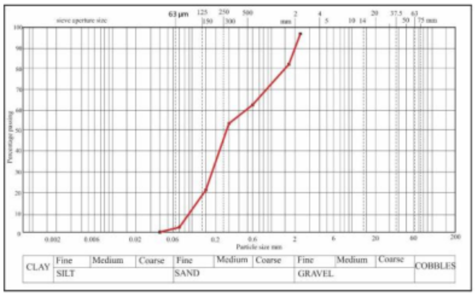

Fig. 10. Graph of Soil Sample Sieve Analysis at the Bottom

Table 7. Calculation results based on the sieve analysis graph

Cu	Cz	So	Uniformity	Gradation	Sorting
4.5	0.66	2.68	Uniform	Bad	Medium

Based on the graph in (Fig. 10) it can be concluded that in the soil samples at the bottom of the slope, the grain size distribution from the smallest silt to the largest grain size is coarse sand and the value Cu = 4.4 means the soil grains are uniform, the value Cz = 0.66 means the soil is poorly graded. Poorly graded soils are soils that have a grain size that is not evenly distributed from large to small grain sizes. And the value of So = 2.68 means moderate sorting with non-uniform grain sizes (Table 8).

4.3.2 Sieve Analysis Test of Soil Samples at the Upper

The results of the soil samples that have been tested for sieve analysis based on the sieve number are entered in the table. Can be seen in Table 9.

Table 8. Data from the Analysis of the Upper Soil Sample Sieve

Sieve Number	Sieve Size (mm)	Restrained Weight Wn (gr)	Percentage Wn Rn = Wn / Wt	Cumulative Percentage ∑Rn (100%)	% Finer 100 – ∑Rn (%)
8	2.3	7.79	5.227	5.227	94.773
16	1.1	4.05	2.717	7.944	92.056
30	0.6	9.03	6.059	14.003	85.997
50	0.3	9.8	6.575	20.578	79.422
100	0.1	90.53	60.746	81.324	18.676
200	0.075	26.93	18.070	99.394	0.606
Pan	Pan	0.9	0.603	100	0
	Total	149.03	100		

Table 9. Calculation Results Based on the Sieve Analysis Graph

Cu	Cz	So	Uniformity	Gradation	Sorting
2.3	1.3	1.28	Uniform	Bad	Good

After obtaining the values from the sieve analysis results in Table 9, then these values are plotted onto the sieve analysis diagram in Fig. 11 to determine the grain distribution of the soil sample. The values plotted in the sieve analysis diagram are the % Finer values and the sieve size.

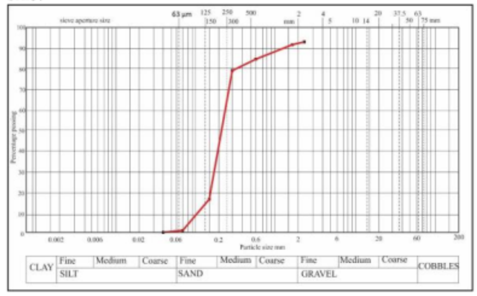

Fig. 11. Graph of Soil Sample Sieve Analysis at the Top

Based on the graph in Fig.11, it can be concluded that in the soil samples at the top of the slope, the grain size distribution from the smallest silt to the largest grain size is coarse sand and the value Cu = 2.3 means the soil grains are uniform, the value Cz = 1.3 means the soil is poorly graded. Poorly graded soils are soils that have a grain size that is not evenly distributed from large to small grain sizes. And the value of So = 1.28 means good sorting or sorting with uniform grain sizes (Table 10).

Based on the results of the sieve analysis it can be concluded, namely as follows (Table 11):

Table 10. Overall Calculation Results of the Research Soil Samples

Part	Cu	Cz	So	Uniformity	Gradation	Sorting
Above	2.3	1.3	1.28	Uniform	Bad	Good
Below	4.5	0.66	2.68	Uniform	Bad	Medium

From the calculation results it was found that the bottom soil sample had uniform grain uniformity with poor gradation and moderate sorting, medium grain size and little gravel. Whereas at the top it has uniform grain uniformity with poor gradation and good sorting, fine-medium grain size and little gravel.

4.4 Analysis Atterberg Limits (Boundary – Atterberg Limit)

Analysis *Atterberg Limits* namely analyzing soil samples on slopes that have experienced high weathering. In this analysis, the research object is a soil sample divided into 2 parts, namely the bottom and top.

4.4.1 Test Liquid Limit (Liquid Limit)

The following is an analysis of the liquid limit test in the laboratory, which is as follows:

a. Test *Liquid Limit* Lower Soil Samples

On testing *liquid limit* (liquid limit) experiment was carried out 3 times with different water levels. The result of the calculation *liquid limit* can be seen in Table 12.

On the test liquid limit Experiments were carried out 3 times with different water content. Experiment 1 was carried out with a slightly lower water content than the test results liquid limit is 59.09% and takes 80 strokes. Experiment 2 was carried out with the water content being the result of the test liquid limit its 57.68% and takes 50 hits. And experiment 3 was carried out with a lot of water content test results liquid limit its 55.62% takes 20 strokes. From the results of the three test trials liquid limit in the lower soil sample produces a liquid limit value of 57.4%.

Table 11. Calculation Result DataLiquid Limit Soil Samples at the Bottom

No	Description (gr)	I	II	III
A	Cup Number	1	2	3
B	Number of Hit	80	50	20
C	Cup Weight	31.03	31.03	31.03
D	Cup Weight + Wet Sample	100.77	91.02	84.75
E	Cup Weight + Dry Sample	81.9	74.6	68.96
F	Water Weight (D – E)	18.87	16.42	15.79
G	Dry Example Weight (E– C)	50.87	43.57	37.93
H	Water Content (F/G x 100%)	59.09	57.68	55.62
I	Liquid Limit (%)	57.4%		

After obtaining the calculated value liquid limit, then the data on the number of blows and groundwater content is plotted onto the graph. Can be seen in Fig. 12.

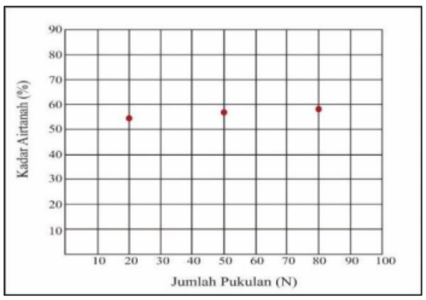

Fig. 12. Test Graph *Liquid Limit* Soil Samples at the Bottom

b. Test Liquid Limit Top Soil Samples

On testing liquid *limit* (liquid limit) experiment was carried out 3 times with different water levels. The result of the calculation *liquid limit* can be seen in Table 13.

Table 12. Calculation Result Data Liquid Limit Soil Samples at the Top

No	Description (gr)	I	II	III
A	Cup Number	1	2	3
B	Number of Hit	92	60	25
C	Cup Weight	31.03	31.03	31.03
D	Cup Weight + Wet Sample	91.90	87.35	86.34
E	Cup Weight + Dry Sample	82.35	79.80	76.85
F	Water Weight (D – E)	9.55	7.55	9.49
G	Dry Example Weight (E– C)	51.32	48.77	45.82
H	Water Content (F/G x 100%)	58.86	55.48	50.71
I	Liquid Limit (%)	55.01 %		

On the test liquid limit Experiments were carried out 3 times with different water content. Experiment 1 was carried out with a slightly lower water content than the test results liquid limit its 58.86% takes 92 strokes. Experiment 2 was carried out with the water content being the result of the test liquid limit its 55.48% and takes 60 strokes. And experiment 3 was carried out with a lot of water content test results liquid limit its 50.71% takes 25 strokes. From the results of the three test trials, the liquid limit in the bottom soil sample produces a liquid limit value of 55.01%.

After obtaining the calculated value liquid limit, then the data on the number of blows and groundwater content is plotted onto the graph. Can be seen in Fig. 13.

The conclusion from the liquid limit test of 2 soil samples obtained different values. The lower slope has a value of 38.8% and the upper slope has a value of 15.01%. From the analysis results, it is because the different water content causes each experiment to have a different number of strokes, the less water content in the sample, the greater the number of strokes. Meanwhile, the more water content in the sample, the fewer the blows.

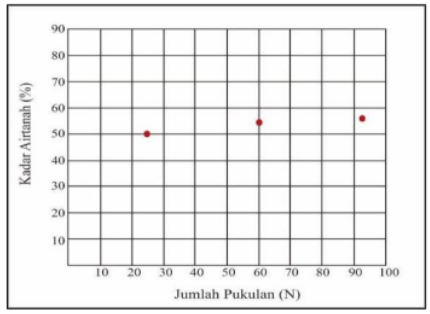

Fig. 12. Test Graph *Liquid Limit* Soil Samples at the Top

4.4.2 Test Plastic Limit (plastic limit)

The following is an analysis of the liquid limit test in the laboratory, which is as follows:

a. Test *plastic Limit* Lower Soil Samples

On testing *limited plastic* This experiment was carried out 3 times with different water content. The result of the calculation *plastic limit* can be seen in Table 14.

Table 13. Calculation Result Data limited plastic Soil Samples at the Bottom

No	Description (gr)	I	II	III
A	Cup Number	1	2	3
B	Cup Weight	31.03	31.03	31.03
C	Cup Weight + Wet Sample	40.38	47.87	40.81
D	Cup Weight + Dry Sample	38.17	45.75	38.45
E	Water Weight (C – D)	2.21	2.12	2.36
F	Dry Example Weight (D – E)	35.96	43.63	36.09
G	Water Content (E / F) x 100%	6.14	4.85	6.53
H	Plastic Limit (%)	1	2	3
I	Cup Number	5.84		

In the plastic limit test, 3 experiments were carried out. Experiment 1 was carried out with a low water content, the plastic limit test result was 6.14%. Experiment 2 was carried out with moderate water content, the result of which was the plastic limit test, which was 4.85%. And experiment 3 was carried out with a lot of water content, the plastic limit test results were 6.53%. From the results of the three plastic limit tests on the lower soil samples, the plastic limit value was 5.84%.

b. Test *plastic Limit* Top Soil Samples

On testing *limited plastic* This experiment was carried out 3 times with different water content. The result of the calculation *plastic limit* can be seen in Table 15.

Table 15. Calculation Result Data limited plastic Soil Samples at the Top

No	Description (gr)	I	II	III
A	Cup Number	1	2	3
B	Cup Weight	31.03	31.03	31.03
C	Cup Weight + Wet Sample	46.85	47.70	40.34
D	Cup Weight + Dry Sample	45.68	46.19	36.88
E	Water Weight (C – D)	1.17	1.51	3.46
F	Dry Example Weight (D – E)	44.51	44.68	33.42
G	Water Content (E / F) x 100%	2.62	3.37	10.35
H	Plastic Limit (%)	1	2	3
I	Cup Number	5.44		

In the plastic limit test, 3 experiments were carried out. Experiment 1 was carried out with a low water content, the plastic limit test result was 2.62%. Experiment 2 was carried out with moderate water content, the result of which was the plastic limit test, which was 3.37%. And experiment 3 was carried out with a lot of water content, the plastic limit test results were 10.35%. From the results of the three plastic limit tests on the lower soil samples, the plastic limit value was 5.44%.

The conclusion from the results of the plastic limit test (plastic limit) of the 2 soil samples obtained different values. The lower slope has a value of 5.84% and the upper slope is 5.44% (Table 4.9). From the analysis results, it was due to the different water content causing each experiment to have a different level of plasticity. If the less water content in the sample, the plasticity level is low, while the more water content in the sample, the plasticity level is high.

4.4.3 Test *Plasticity Index* (Plasticity Index)

After obtaining the liquid limit and plastic limit values, then calculations are carried out to find the plasticity index value and the value is plotted onto the graph (Fig. 13).

Plasticity Index Soil Samples at the Bottom

PI = LL – PL

PI = 57.4% – 5.84%

PI = 51.56%

Plasticity Index Upper Soil Samples

PI = LL – PL

PI = 55.01% – 5.44%

PI = 49.57%

Then the results of calculating the plasticity index are plotted onto a graph (Fig. 13), to determine the soil classification in the study area.

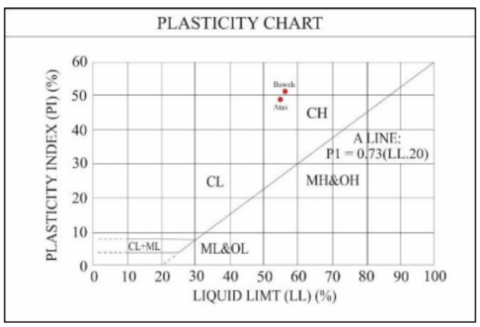

Fig. 13. Graph *Plasticity Index* of Soil Samples

Based on the Atterberg Limit analysis results, soil samples were obtained from two parts of the lower and upper slopes, namely CH (Clay High Plasticity), an inorganic clay with high plasticity. From the sample analysis, it is known that clay with high plasticity can result in slope failure or landslides because clay is capable of absorbing/storing water but cannot allow water to pass through. With the condition of high water content, the strength of the soil is getting worse, which triggers landslides. The purpose of high plasticity soil is soil that has high swelling and shrinkage of the soil, thus if the range of water content in the soil is higher, the strength of the soil will be low or poor.

4.5 Method Analysis of Rock Structure Rating (RSR)

Method analysis of Rock Structure Rating (RSR), the research slope was divided into 3 parts due to the different slope conditions and *treatment* or the resulting support is different as well.

Fig. 14. RSR Research Slope Part 1

4.5.1 Slope Section 1

The slope of part 1 in the analysis of the RSR method has a slope length of 15 meters and a slope height of 10 meters (Fig. 14). Has a high level of weathering with sandstone and conglomerate lithology. In parameter A, it is known that the type of rock is weathered sediment with type 4 and there is a geological structure in this study, namely intensive folding or fracture with a rating of 6 (Table 16).

Then in parameter B it is known that the strike is perpendicular to the axis with the direction of movement with dip known from direct field observations, then the slope face on the slope has a value of 75° which is included in the vertical table, the distance between joints is very close < 2 in, this is known from the measurement of the distance between joints using measuring tools in the field with a rating of 13. Can be seen in Table 16. Then in parameter C by looking at the water conditions on the research slope, where the research slope in section 1 is included in the no water category and the joint conditions are in the moderate category with a rating of 18. Can be seen in Table 14.

After parameters A, B and C are known, they are summed up in Table 16.

Table 16. Research Slope RSR Values Part 1

Parameter	Condition	*Rating*
A	Intensive folds or breaks	6
B	Close solid distance	19
C	No water, Condition medium solid	18
Total A + B + C		43

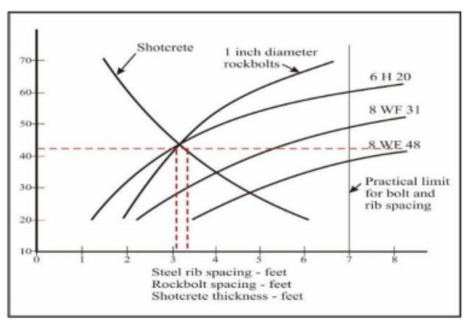

Fig. 15. Slope RSR Graph Part 1

The RSR value on slope part 1 is 43. Then this value is plotted on the RSR graph. It can be seen on the graph treatment or support on the slope part 1, namely givingrockbolts and shotcrete. Rockbolts used in the Rock

Structure Rating (RSR) method that is 1 inch in diameter, with a space between rock bolts of 3.1 feet. Then spraying shotcrete on slopes with a thickness of 3.3 inches. Can be seen in Fig. 15.

4.5.2 Slope Part 2

The slope of section 2 in the analysis of the RSR method has a slope length of 6 meters and a slope height of 4 meters. Has a mild weathering level with sandstone lithology and conglomerate Slope part 2 can be seen in Fig. 16.

In parameter A, it is known that the type of rock is hard sediment with type 2 and there is a geological structure in this study, namely intensive folding or fracture with a rating of 8 (Table 17).

Then the parameter B is known to strike perpendicular to the axis with the direction of movement with dip known from direct observation in the field, the slope face on the slope has a value of 75° which is included in the vertical table, and the distance between joints is close to 2-6 in, this is known from measuring the distance between joints using a measuring instrument in the field with rating 19. Can be seen in Table 17.

Then in parameter C by looking at the water conditions on the research slope, where the research slope in part 1 is included in the moderate water condition category and the joint condition is in the medium category with a rating of 22. Can be seen in Table 17.

After parameters A, B, and C are known, they are then summed up by entering Table 17.

Table 17. Research Slope RSR Values Part 2

Parameter	Condition	Rating
A	Intensive folds or breaks	8
B	Close solid distance	19
C	No water, Condition medium solid	22

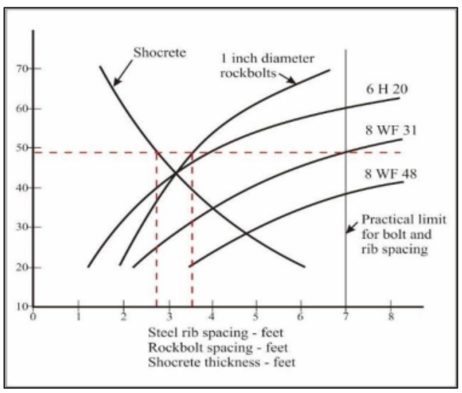

Fig. 16. Slope RSR Graph Part 2

4.5.3 Slope Part 3

The slope of section 3 in the analysis of the RSR method has a slope length of 27 meters studied and a slope height of 8 meters. Has a mild weathering level with sandstone and conglomerate lithology can be seen in Fig. 17.

In parameter A, it is known that the type of rock is hard sediment with type 2 and there is a geological structure in this study, namely intensive folding or fracture with a rating of 8 can be seen in the Table 18.

Then the parameter B is known to strike perpendicular to the axis with the direction of movement with dip known from direct observation in the field, the slope face on the slope has a value of 75° which is included in the vertical table, and the distance between joints is close to 2-6 in, this is known from measuring the distance between joints using a measuring instrument in the field with rating 19. Can be seen in Table 18.

Fig. 17. RSR Research Slope Part 3

Then in parameter C by looking at the water conditions on the research slope, where the research slope in section 3 is included in the slight water condition category and the joint condition is in the medium category with a rating of 15. Can be seen in Table 18.

After parameters A, B, and C are known, they are then summed up by entering Table 18.

After parameters A, B and C are known, they are summed up by entering Table 18.

Table 18. Research Slope RSR Values Part 2

Parameter	Condition	Rating
A	Intensive folds or breaks	8
B	Close solid distance	28
C	No water, Condition medium solid	15
Total A + B + C		51

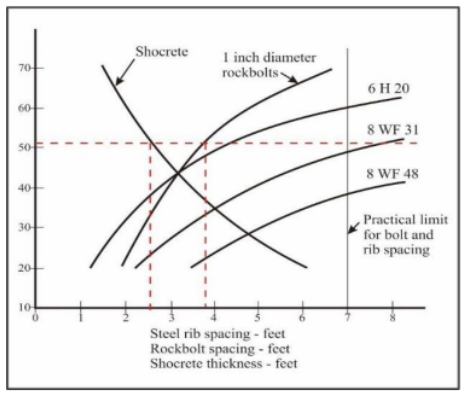

Fig. 18. Slope RSR Graph Part 3

The rating for each parameter is added up and the RSR value is obtained, the RSR value on slope part 3 is 51. Then this value is plotted on the RSR graph. It can be seen on the graph treatment or support on the slope of section 3, namely givingrockbolts and shotcrete. Rockbolts used in the Rock Structure Rating (RSR) method that is 1 inch in diameter, with a space between rock bolts which is 3.8 feet.Then spraying the shotcrete on the slope with a thickness of 2.6 inches. Can be seen in Fig. 18.

4.6 Preferences and Mitigation on Research Slopes

On the research slope of choice *treatment* or support that can be done based on the *Rock Structure Rating* (RSR) method which is divided into three parts based on slope conditions and the calculation of the RSR value discussed earlier, which are as follows:

4.6.1 Slope Section 1

Part 1 of the slope is 15 m long and 10 m high with high weathering conditions. Based on the RSR value obtained, it is known treatment that can be done is planting rockbolts with spacing rockbolts 3.1 feet than in terms of horizontal totaling 16 rockbolts in one line, whereas in vertical totaling 11 rockbolts in one line (Fig. 19). Then spraying shotcrete on a slope with a thickness of 3.3 inches or 83.8 mm (Fig. 20).

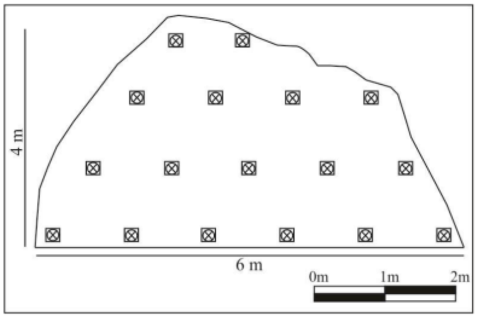

Fig. 19. Sketch illustration *Rock shop* 1 inch in diameter 3.1 feet apart on slope section 1

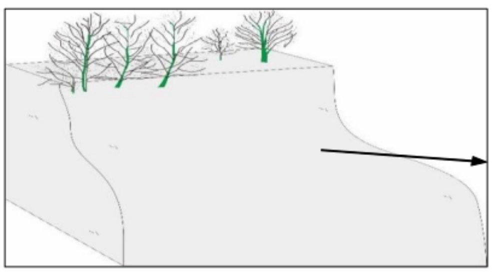

Fig. 20. Sketch illustration Shotcrete with a Thickness of 3.3 inches On Slope Section 1

4.6.2 Slope Section 2

Section 2 slope has a length of 6 m and a height of 4 m with mild weathering conditions. Based on the RSR value obtained, it is known that the treatment that can be carried out is planting rockbolts with a distance of 3.5 feet between the rockbolts, thus horizontally there are 6 rockbolts in one row, while vertically there are 4 rockbolts in one row (Fig. 21). Then spraying the shotcrete on a slope with a thickness of 2.7 inches or 68.5 mm (Fig. 22).

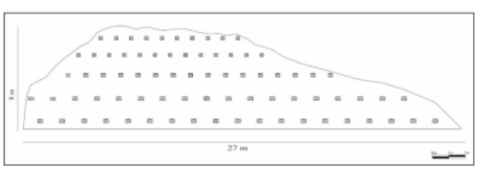

Fig. 21. Sketch illustration *Rock shop* 1 Inch Diameter 3.5 ft Spacing On Section 2 Slope

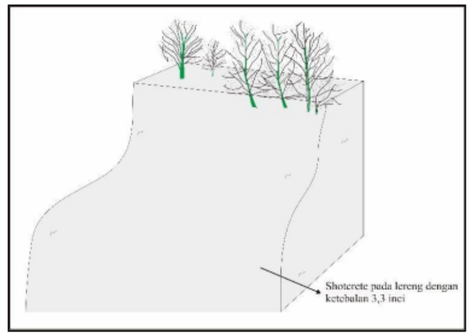

Fig. 22. Sketch illustration *Shotcrete* with a Thickness of 2.7 inches On Section 2 Slope

4.6.3 Slope Section 3

Section 3 slope has a length of 27 m and a height of 8 m with mild weathering conditions. Based on the RSR value obtained, it is known that the treatment that can be carried out is planting rock bolts on the slope of section 3 with a distance between rock bolts of 3.8 feet, thus horizontally there are 19 rock bolts in one row, while vertically there are 5 rock bolts in one row. Then spraying the shotcrete on the slope with a thickness of 2.6 inches or 66 mm.

The condition of the research slope on the left side of the slope has experienced landslides. In the landslide section, it can be seen that the rocks on the inside of the slope have experienced weathering and tend to move toward the soil. Mitigation that can be given to the slopes that have experienced landslides is different from the rock slope conditions studied. One example of mitigation given to slopes that have experienced landslides is the construction of rock embankments to resist landslides. Can be seen in Fig. 23.

Fig. 23. Landslide Mitigation with Retaining Rock Embankments

5. Conclusion

Based on the results of the data analysis that has been carried out in this study, the following conclusions can be drawn:

In the study area, the slope is divided into four-scanline which have special characteristics in each scanline. The four scanlines, it is divided into 1 part of the slope which has high weathering in the form of soil samples using analysisAtterberg Limits, and 3 sections of the slope using the Rock Structure Rating (RSR).

The final result of the analysisAtterberg Limitobtained the value of the soil sample at the bottom of the slope with a plasticity index value of 51.56% and the top of the slope is

49.57%. The two parts of the soil on the slope are CH (Clay with High Plasticity), and inorganic clay with high plasticity.

In an analysis of rock Structure Rating (RSR), the slope is divided into three parts due to different slope conditions. Section 1 slope is 15 m long and 10 m high. Treatment that can be done is plantingrockbolts on the slope of section 1 with the distance between rock bolts of 3.1 feet in terms of horizontal totaling 16rockbolts in one line, whereas vertical totaling 11 rockbolts in one line. And also spraying shotcrete with a thickness of 3.3 inches.

Section 2 slope is 6 m long and 4 m high. Treatment that can be done is plantingrockbolts on the slope section 2 with the distance between rock bolts 3.5 feet then horizontal amounting to 6 rockbolts in one line, whereas vertical amounting to 4 rockbolts in one line. And spraying shotcrete with a thickness of 2.7 inches.

Section 3 of the slope is 27 m long and 8 m high. Plantingrockbolts on the slope section 3 with the distance between rock bolts 3.8 feet than in terms of horizontal totaling 19 rockbolts in one line, whereas in vertical amounting to 5 rockbolts in one line. And spraying shotcrete with a thickness of 2.6 inches.

Another mitigation that can be carried out from the research slope is the construction of rock embankments to resist landslides on slopes that have experienced high weathering or have become soil.

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