STABILITY ANALYSIS OF PIT B SLOPE USING RMR (ROCK MASS RATING) AND GSI (GEOLOGICAL STRENGTH INDEX) METHODS AT PT. HALO TAMBANG BERJAYA, KALIANDA DISTRICT, SOUTH LAMPUNG REGENCY

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Abstract: *The research area is located at PT Halo Tambang Berjaya, Kalianda District, South Lampung Regency, with the main objective of analyzing slope stability in the open pit mining area using the rock mass rating (RMR) and geological strength index (GSI) methods. The RMR method is used to assess the strength of the rock mass through geotechnical parameters such as intact rock strength, rock quality designation (RQD), spacing of discontinuities, condition of discontinuities, and groundwater conditions. GSI is used to obtain a more detailed picture of the rock mass quality through the structure rating (SR) and surface condition rating (SCR) parameters. The analysis was carried out on one slope in the Pit B area with a 7 meter scanline. The RMR value obtained was 75 (good rock class), and the GSI value was 48 (good rock class). Based on these results, it can be concluded that the slope in the research area is classified as good and stable, so it is relatively safe to support mining activities. However, it is necessary to carry out regular monitoring of geotechnical conditions, especially in slope sectors with close discontinuities, to prevent potential landslides in the future.*

Keywords: *Geological strength index; slope stability; slope; rock mass rating.*

1. INTRODUCTION

PT Halo Tambang Berjaya (HTB) is a company engaged in open-pit mining using the quarry mining method. The mining process begins with stripping the overburden, drilling, blasting, dredging, transporting, and stockpiling (Oemiati dkk., 2020). In the mining process, there are several factors that must be considered, one of which is slope stability to determine the stability condition of a slope (Hariyadi & Wahyudhi, 2016). A slope is a land surface that has a certain incline and forms an angle to the horizontal plane (Das, 1985). Slopes are divided into two types: natural slopes and artificial slopes. Natural slopes are usually formed by natural geological processes. These slopes are commonly found in mountainous areas with diverse topography, such as hills and mountains (Arirupa, 2021). Meanwhile, artificial slopes are slopes formed as a result of excavation or filling activities (Rumbiak, 2016). Slope instability can be caused by geological structural conditions, such as joints, cracks, faults, groundwater pressure, and slope geometry (Munir, 2018). Geotechnical analysis is an activity that can be carried out to determine the geotechnical conditions of a slope (Arif, 2016).

Based on the mining process carried out, slope stability analysis around the pit B mining area is very necessary, because landslides can cause losses and hamper the company's mining process. This study aims to analyze the factors that affect slope stability, analyze slope stability using the Rock Mass Rating (RMR) method, and analyze slope stability using the Geological Strength Index (GSI) method.

Based on the physiography of the Tanjung Sheet Regional Geological Map according to Mangga dkk., (1993), the research area is located in the Bukit Barisan physiographic unit and the undulating hills morphological unit.

The study area is part of the Lampung Formation (QTL). The Lampung Formation (QTL) is a pyroclastic rock unit widespread in the Lampung region. Previously known as the Lampung Formation, it was originally known as the Lampung tuff, and its deposits formed on land, in fluvial areas, and in estuaries. This formation is composed of rhyolitic tuff, compacted tuff, pumiceous tuff, tuffaceous mudstone, and tuffaceous sandstone. Its estimated thickness is approximately 200 meters (Mangga dkk., 1993).

Based on field facts, the research area is composed of basalt lithology, which is a commodity for industrial mining at PT Halo Tambang Berjaya. This basalt lithology is compared to Young Volcanic Deposits (Qhv), which are composed of andesite-basalt lava, tuff, and breccia originating from Mount Ratai, Mount Pesawaran, Mount Betung, and Mount Rajabasa. This formation is Holocene in age and is distributed around the mountain of origin of the deposits (Mangga dkk., 1993)

The difference in lithology on the Tanjung Karang Sheet regional geological map and the actual field data may be due to differences in scale and level of detail in field observations. The Tanjung Karang Sheet regional geological map has a scale of 1:250,000, meaning 1 cm on the map represents 2.5 km in real-world conditions. Direct observations at the research site, on the other hand, provide more detail, demonstrating the actual lithology.

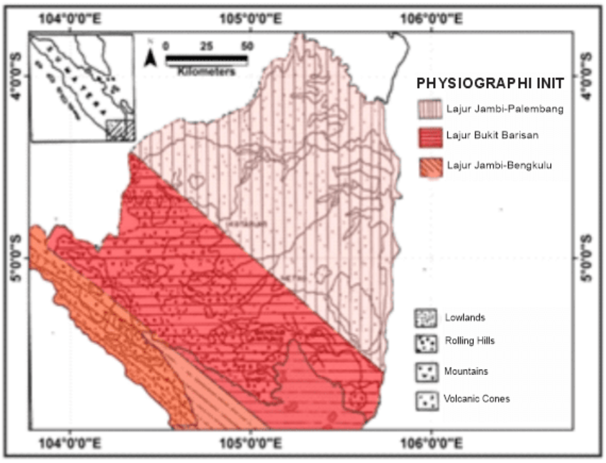

Figure 1. Regional geology of the research area and its surroundings on the Tanjung Karang geological map sheet from Mangga dkk., (1993).

2. MATERIALS AND METHODS

The research was conducted for one month, from August 4, 2025, to September 4, 2025, at PT Halo Tambang Berjaya, located in Pit B. Administratively, PT Halo Tambang Berjaya is located in Bulok Village, Kalianda District, South Lampung Regency, Lampung. Geographically, it is located at coordinates 105°29'30.7" East Longitude and 5°39'49.2" South Latitude. The research location is approximately 57 km from the Sumatra Institute of Technology.

Field data collection was conducted directly using the scanline sampling method. The research consisted of four stages: preliminary, data collection, data processing and analysis, and presentation and conclusion drawing.

2.1 Research Stages

1. Preliminary Stage

The preliminary stage is the initial stage of this research. This stage involves a literature study and company orientation.

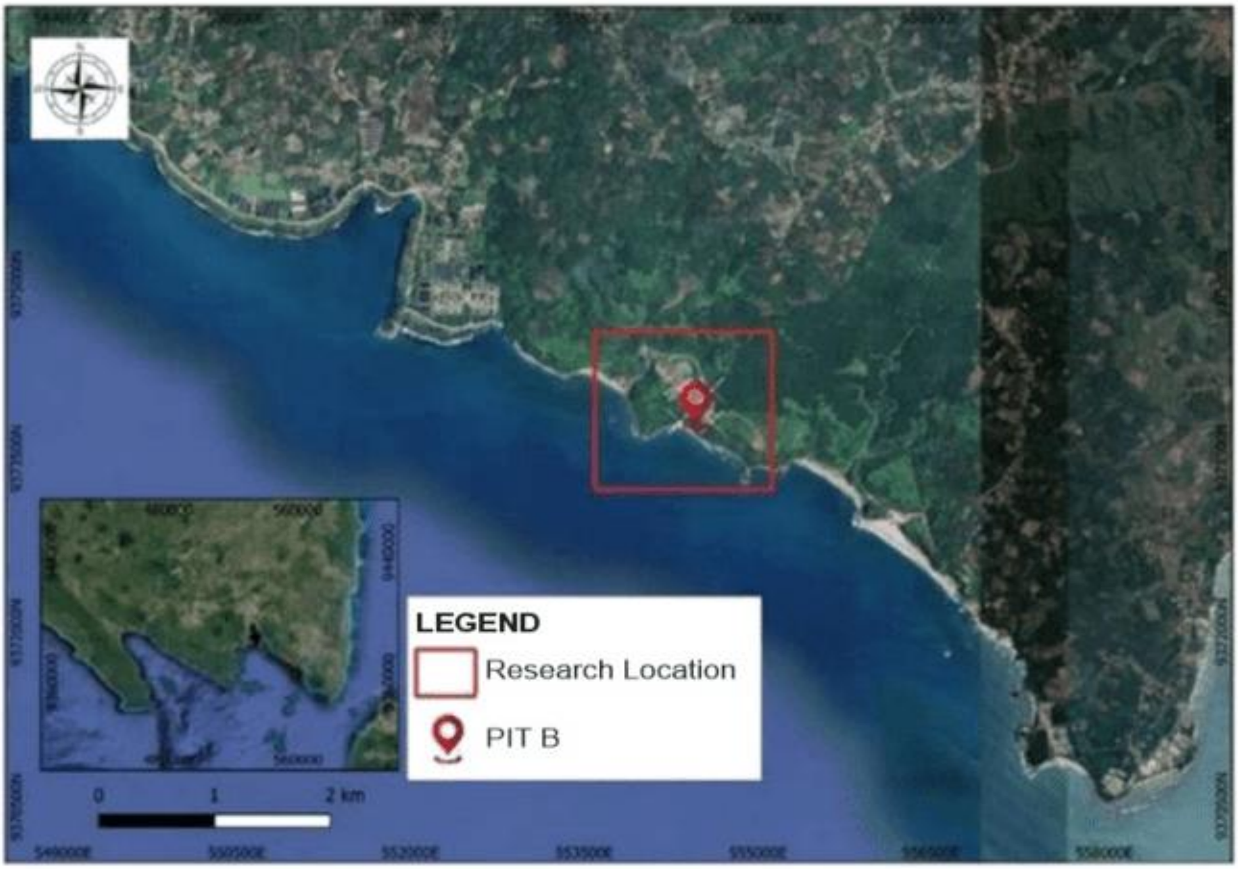

Figure 2. Research Location

Literature studies are conducted to find out about previous studies related to the research topic and location, while company orientation is conducted to find out and adapt to the company environment.

2. Data collection stage

The data required in this study are primary data collected directly in the field. The primary data collected are hammer test values, joint length, joint spacing, joint conditions, and groundwater conditions on slopes with a scanline length of 7 meters using field tools in the form of field notebooks, rulers, pencils, hammers, compasses, and meters. Furthermore, data processing and analysis were carried out using the RMR and GSI methods to obtain slope stability values found in the PT Halo Tambang Berjaya mining area.

3. Data Processing and Analysis Stage

Data processing was carried out on primary data that had been obtained during practical work activities in the field, which was then analyzed using the RMR and GSI methods to obtain slope stability values in the PT mining area. Hello Tambang Berjaya.

Figure 3. Tools used

4. Presentation and conclusion drawing stage

At this stage, the presentation of the results of data processing and analysis is carried out until a conclusion is reached.

2.2. Rock Mass Rating (RMR)

Rock Mass Rating is a classification system used to empirically evaluate the stability of rock masses by assessing weights and parameters based on their geological conditions. The RMR method can be applied and adapted to various situations, including slope stability, foundations, tunnels, and mining (Bieniawski, 1989). The RMR system aims to classify the quality of rock masses based on surface data, so that it can guide mining techniques and provide recommendations that support mine processing, as well as determine unstable areas and their estimated survival time (Najib et al., 2018).

Rock mass classification using the RMR method according to Bieniawski, (1989) Rock mass classification using the RMR method according to Bieniawski, (1989) has five parameters, namely, intact rock strength, rock quality designation (RQD), spacing of discontinuities, condition of discontinuities, and groundwater conditions.

Table 1. Classification Rock Mass Rating (Bieniawski, 1989).

Class	RMR Rating	Rating
I	Very good	81-100
II	Good	61-80
III	Moderate	41-60
IV	Poorly	21-40
V	Very Poorly	<21

2.3 Geological Strength Index (GSI)

(Hoek & E, 1980) proposed a method to obtain an estimate of the strength of a joint rock mass, based on the assessment of the bonds between structures in the rock mass and the surface conditions of geological structures, known as the Original Hoek-Brown Criterion. Rock mass classification based on the Geological Strength Index (GSI) method *(Hoek E., 1994),* combines two main parameters, namely the structure of the block properties or Structure Rating (SR) block size and shape indicating the geometry of the overall rock mass and the proportion of rock volume occupied by discontinuities and surface conditions or Surface Condition Rating (SCR) based on the structure (block size and shape) and surface (weathering, degree of hardness, and alteration).

Before obtaining the Structure Rating (SR) value, the joint volumetric value must be calculated first. Meanwhile, the Surface Condition Rating (SCR) value is obtained from the weighting of the rock mass obtained from geotechnical data collection in the form of hardness (Roughness Rating), weathering (Weathering Rating), and infilling width (Infilling Rating). The standard graph of fractured rocks created by Sonmez & Ulusay, (1999), is used to estimate the quality of the rock mass qualitatively, to obtain the GSI value from each field observation scanline.

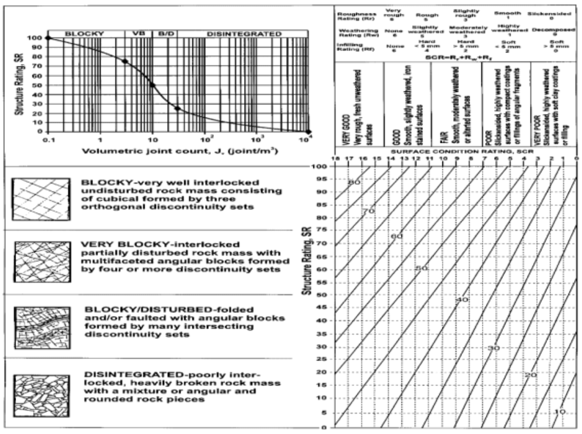

Figure 4. Geological Strength Index parameters (Sonmez & Ulusay, 1999).

3. RESULTS AND DISCUSSIONS

Field data collection was conducted in the pit B area of PT Halo Tambang Berjaya. The slope used as the object of study is a slope with a columnar joint structure located between the blasted slopes, so a slope stability analysis is required for the study location (Figure 3). The length of the slope scanline described is 7 meters, and within the observed scanline length, 16 joint data were obtained. The results of the field data obtained can be seen in Table 2.

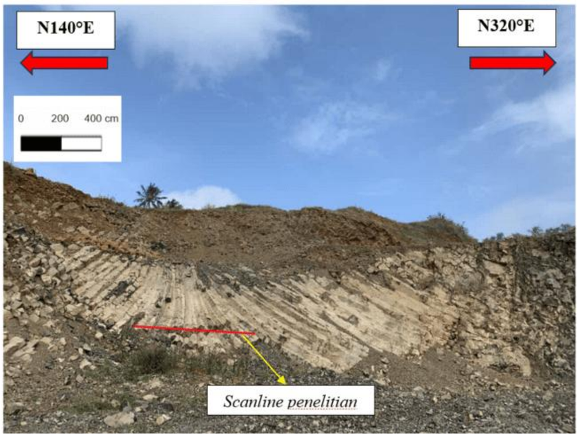

Figure 3. Pit B slope with a 7 meter scanline

Table 2. Pit B Field Data (7 meter scanline)

Discontinuity Data	*Hammer Test*	Discontinuity Length (m)	Weathering	Aperture	Infilling	Roughness	Space (m)	Groundwater Conditions
N223°E/82°E	17	5	Unweathered	1	None	Smooth	0,3	Completely dry
N265°E/66°E	17	5	Unweathered	1,2	None	Smooth	0,38	Completely dry
N178°E/86°E	17	5	Unweathered	1,5	None	Smooth	0,61	Completely dry
N242°E/62°E	17	5	Unweathered	0,2	None	Smooth	0,24	Completely dry
N233°E/75°E	17	5	Unweathered	2,3	None	Smooth	0,37	Completely dry
N226°E/74°E	17	5	Unweathered	1	None	Smooth	0,26	Completely dry
N230°E/74°E	17	5	Unweathered	1,2	None	Smooth	0,36	Completely dry
N212°E/79°E	17	5	Unweathered	0,1	None	Smooth	0,51	Completely dry
N224°E/67°E	17	5	Unweathered	0,2	None	Smooth	0,25	Completely dry
N215°E/77°E	17	5	Unweathered	0,4	None	Smooth	0,42	Completely dry
N258°E/53°E	17	5	Unweathered	1	None	Smooth	0,28	Completely dry
N258°E/40°E	17	5	Unweathered	1,1	None	Smooth	0,42	Completely dry
N267°E/28°E	17	5	Unweathered	1,3	None	Smooth	0,6	Completely dry
N260°E/44°E	17	5	Unweathered	1,2	None	Smooth	0,75	Completely dry
N238°E/39°E	17	5	Unweathered	2	None	Smooth	0,40	Completely dry
N196°E/65°E	17	5	Unweathered	2,5	None	Smooth	0,45	Completely dry
Average	17	5	Unweathered	1,13	None	Smooth	0,41	Completely dry

Table 3. Strength of Intact Rock

Hammer Test	UCS (MPa)	Rating
Peeled off by a geological hammer	>250	15
Many geological hammer blows	100-250	12
More than one blow of the geological hammer	50-100	7
Unscratched by a knife – geological hammer	25-100	4
Knife cuts – geological hammer blows	5-25	2
Crushed and scratched by a knife	1-5	1
Nail scratches	30	0

3.1 Rock Mass Rating (RMR) Weighting

Rock mass weighting based on the Rock Mass Rating (RMR) carried out at the research location uses five parameters, namely:

1. Intact Rock Strength

The strength of intact rock was tested using a geological hammer (hammer test) using consistent impact distance and force. Based on the hammer test, the rock on the slope of pit B broke when struck 17 times with the geological hammer. The value included in the weight 15 is indicated by the red box in Table 3.

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2. Rock Quality Designation (RQD)

The RQD calculation carried out at the research location uses Equation 1, namely:

$$RQD = 100e^{-0.1\lambda}(0.1\lambda + 1) \quad (1)$$

RQD = 100 $(2{,}7182)^{-0{,}1(2{,}28)}$ (0,1(2,28) + 1)
= 97,01%

Information:
RQD : Rock Quality Designation.
e : Negative distribution value with determinacy2,718.
λ : Fracture index (discontinuity/meter).

The RQD calculation results obtained were 97.01%. Based on Table 4, the RMR weight value for the RQD parameter is 20.

Table 4. Rock Quality Designation (RQD)

RQD (%)	Description	Rating
90-100	*Excelent*	15
75-90	*Good*	17
50-75	*Fair*	13
25-50	*Poor*	8
<25	*Very Poor*	3

3. Spacing of Discontinuity

Spacing of Discontinuity were conducted directly at the research location using a ruler on two adjacent joint planes along the scanline. The results of joint spacing measurements at the research location varied with a range of 0.24 – 0.76 meters with an average of 0.41 meters. Based on Table 5, the RMR weight value for the joint spacing parameter is 10 (red box).

Table 5. Spacing of discontinuity

Description	Spacing (m)	Rating
very wide	>2	20
wide	0,6 - 2	15
moderate	0,2 - 0,6	10
close	0,006-0,2	8
very close	<0,006	5

4. Conditions of Discontinuity

The condition of discontinuity is obtained from a direct description at the research location consisting of fracture length, distance between fracture surfaces, fracture hardness, fracture filling material, and fracture weathering. The length of the fracture on the studied slope is relatively the same, namely 5 m, so it is included in weight 2. The distance between fracture surfaces varies between 0.1 cm - 2.5 cm, with an average value of 1.13 cm so it is included in weight 0. The roughness of the rocks in the research area is smooth, so it is included in weight 1. The fractures on the research slope are not filled by minerals or filler materials, so it is included in weight 6. The rocks on the research slope are fresh or unweathered rocks, so it is weighted 6. Based on Table 6 the total RMR weight value for the fracture condition parameter is 15 where the red stripes indicate the weight of each parameter determining the fracture condition.

Table 6. Conditions of Discontinuity

Parameters	Description	Rating
Persistence	5 m	2
Separation/aperture	0,1 cm	0
Roughness	Smooth	1
Infilling	None	6
Weathering	Unweathered	6
	Total	**15**

5. Groundwater conditions

Groundwater conditions at the research location were directly assessed, and it was found that the groundwater conditions at the research location were dry. Based on Table 6, the RMR weighted value for the groundwater condition parameter was 15.

Table 7. Groundwater conditions

General description	Rating
Completely dry	15
Damp	10
Wet	7
Dripping	4
Flowing	0

The recapitulation of the Rock Mass Rating (RMR) values from the five parameters obtained at the research location can be seen in Table 8 as follows:

Table 8. Rock Mass Rating (RMR) Weighting Recapitulation

Parameters RMR	Rating
Intact Rock Strength	15
Rock Quality Designation (RQD)	20
Spacing of discontinuities	10
Condition of Discontinuities	15
Groundwater Condition	15

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Total Rating	**75**
Rock Mass Class	**II (Good)**

3.2 Geological Strength Index (GSI) weighting

The research scanline identified 16 joints, which were then calculated using Equation 2 to obtain the joint volumetric value. The results are as follows:

$$Jv = \frac{(N)^3}{(L)^3} \quad (2)$$

$$Jv = \frac{(16)^3}{(7)^3}$$

Jv = 11,94 joint/m^3

Information:
N : The number of joints
L : Scanline Length

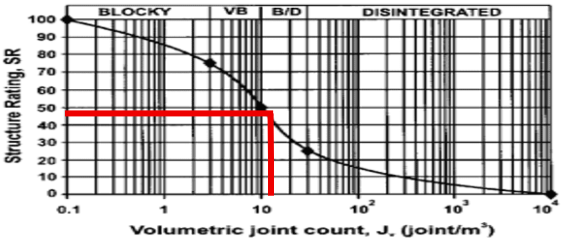

Figure 4. Joint Volumetric Curve for Structure Rating

The results of field observations on the scanline of Pit B obtained a Jv value of 11.94 joints/m3 and were entered into the curve so that the Structure Rating (SR) value was obtained at 45 and resulted in a very blocky slope shape, where the mass was spatially disturbed with multi-faceted corner blocks formed by 4 or more joint sets.

Meanwhile, the Surface Condition Rating (SCR) value is obtained from the weighting of the rock mass obtained from geotechnical data collection in the form of hardness (Roughness Rating), weathering (Weathering Rating), and infilling width (Infilling Rating). Based on Equation II.5, the Surface Condition Rating (SCR) value is:

$$SCR = Rr + Rw + Rf \quad (2)$$

Information:
SCR = *Surface Condition Rating*
Rr = *Roughness Rating*
Rw = *Weathering Rating*
Rf = *Infililng Rating*

Table 9. Surface Condition Rating Parameter Results

Parameters	Results	Rating
Roughness Rating	*Smooth*	1
Weathering Rating	*None*	6
Infiling Rating	*None*	6
Total SCR		13

Based on the Geological Strength Index (GSI) value obtained through the calculation of 2 parameters including the structure value (SR) and discontinuity surface conditions (SCR) for Pit B, the GSI value was 48 which is included in the good category (Figure 5).

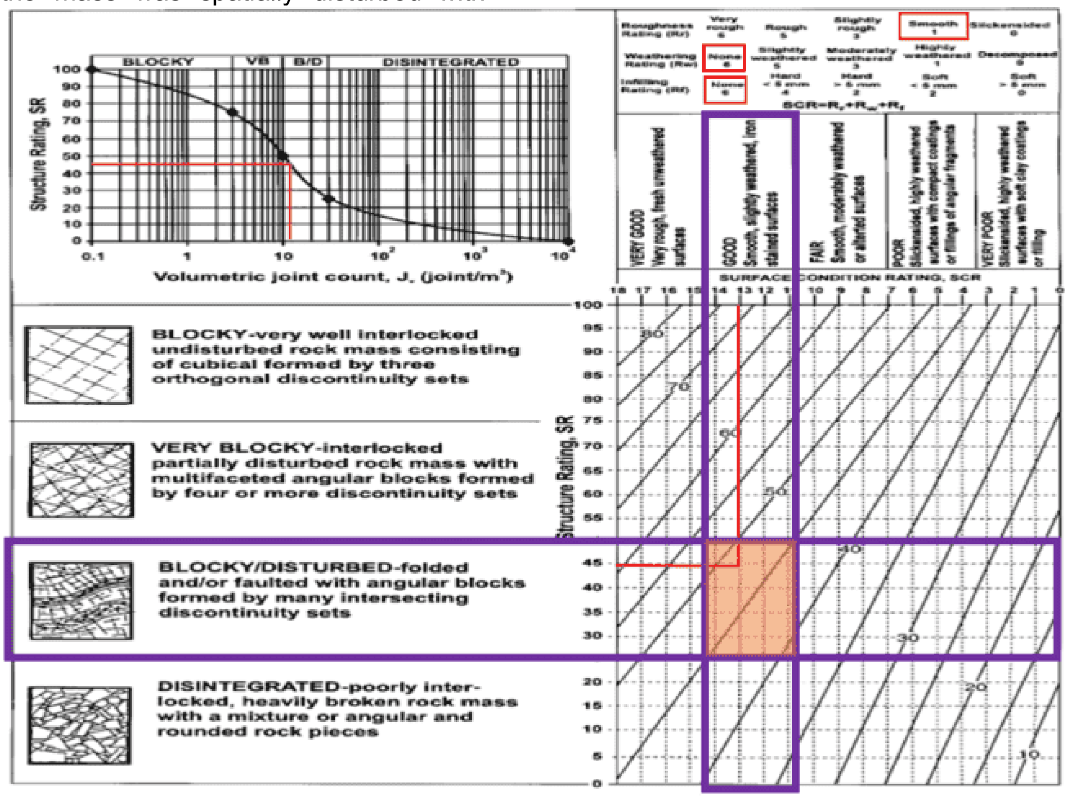

Figure 5. Geological Strength Index (GSI) results

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4. CONCLUSIONS

1. The main factors affecting slope stability are rock strength, RQD value, joint spacing, joint conditions, and groundwater conditions. In Pit B, the rock strength reached 17 blows with an RQD of 97.01%; joint spacing of 0.41 m; joint conditions weighing 15; and dry groundwater conditions.
2. Slope stability analysis using the Rock Mass Rating (RMR) method shows that Pit B is 75 which is included in the good rock mass class (class II), so it can be said that the slope condition is relatively safe.
3. Slope stability analysis using the Geological Strength Index (GSI) method strengthens these findings, with a GSI value of 48 at Pit B (SR 45, SCR 13) so that the slope is included in the good and stable category.

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