APPLICATION OF ROCLAB SOFTWARE IN DEFINING THE MECHANICAL CHARACTERISTICS OF CONTACT ROCK IN DAM FOUNDATION FOR SMALL-SCALE HYDROELECTRIC PROJECTS: A CASE STUDY IN THE LONG TAO HYDROELECTRIC PROJECT, DIEN BIEN PROVINCE

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Abstract: Roclab software (Hoek-Brown standard) is considered as an advanced approach to determining the mechanical parameters of rock mass. The results of calculating the mechanical values of rock by Roclab software are quite consistent with the values obtained by field tests. Therefore, it is possible to use this software to save costs for works that do not have an opportunity of implementing field tests but still have equivalent calculations.

The results of determination of the mechanical characteristics of the dam site of the Long Tao hydroelectric project in Dien Bien Province show that the Vietnam's standard values for the results are too low and too safety-prone, so they are used for references. The results of Roclab software are similar to those of field tests. It should be possible to use the rock mass index calculations using Roclab software to recommend design metrics.

Keywords: Roclab; Hoek-Brown standard; dam base; Long Tao

1. Introduction

Rocscience's Roclab software of Canada built basing on the Hoek-Brown standard and the Mohr-Coulomb standard has been free since 2006. The software has been quite well-structured and well-reflected in rock mechanics.

Currently, in Vietnam, to determine the mechanical characteristics of underground rock masses, hydraulic works ... there are many different methods as defined by TCVN 4253-2012 standard, determined by the in-situ tests, using Slope software to solve the inverse problem, determined by the continuity coefficient of cracks, determined by the Hoek-Brown standard, etc. Among these methods, based on the Hoek - Brown standard, Roclab software has been applied in some hydroelectric power plants, such as irrigation works, CuaDat - Thanh Hoa hydroelectric power plant, Vu Quan hydroelectric power plant - Ha Tinh province, Dac Cong 1 hydropower plant - Kon Tum province.

Based on the results of the above studies, the friction angle values in rock masses ($\varphi_{m\ of}$ the rock) determined by field experiment were varied by 2 to 5^0 compared to those calculated using Roclab software. Cohesive force value determined by field test method is 1.2-1.5 times higher than that determined by Roclab software.

RocLab software for calculating rock mass norms is built according to Hoek-Brown standard. It is a rigorous and logical experimental theoretical standard. Calculation parameters: Deformation modulus, shearing resistance, compression resistance are quantified by mathematical functions on the basis of factors such as GSI geological durability index (based on Bieneawski rocks classification - RMR of Barton - Q) The m_i - specific coefficient characterized for each rock; D - coefficient due to influence of construction. All

indicators are defined on a united system, which makes it convenient for users to collect and process data.

Therefore, the research, study and application of this Roclab software in determining the mechanical characteristics of rock bed for small-scale projects is urgent, practical and scientific significance.

2. Geological features of the rock foundation of the Long Tao hydroelectric power plant

2.1. Overview of the Long Tao Hydropower Project

The Long Tao hydropower project is located in Muong Mang commune, Muong Cha district and part of Tham mu village, Hua Muc 3 in Muong Mun commune, Tuan Giao district, Dien Bien province. The Long Tao hydroelectric power project is constructed with the mission as follows:

Power supply with installed capacity of 42MW and integrated into the regional electric network. The project is responsible for generating electricity to the national grid to meet part of the load in the area, Tuan Giao district, Muong Cha district, Dien Bien province.

Strengthening the infrastructure of the project area, socio-economic development in the project area in particular and mountainous districts in general.

Creating the landscape of the project area and gradually improving the environment.

Tab. 1. Scale parameters of the main items of the works

Order	Parameters	Notation	Symbol	Value
I	*Hydrological*			
1	Basin area	F_{lv}	Km^2	1932.30
2	Average annual rainfall	X_o	mm	1800.00
3	Total flow of the year	W_o	10^6m^3	1922.56
4	Flow module	M_o	$l/s.km^2$	31.55
5	Year flow	Q_o	m^3/s	60.96
6	Flood flow at the frequency dam site P = 0.5%	$Q_{P0,5\%}$	m^3/s	4961
7	Flood flow at the frequency dam site P = 0.1%	$Q_{P0,1\%}$	m^3/s	6421
8	Guaranteed flow rate at 90%	$Q_{90\%}$	m^3/s	15.64
II	*Hydropower*			
1	Installation capacity	N_{lm}	MW	42.00
2	Guaranteed capacity	$N_{đb}$	MW	5.74
3	The highest water column	H_{max}	m	54.15
4	The lowest water column	H_{min}	m	50.58
5	Calculated water column	H_{tt}	m	50.58
6	Power generation max	$Q_{pđ}$	m^3/s	98.31
7	Annual average power	E_o	10^6Kwh	169.794
8	Hours of installed capacity	h	h	4042.7
III	*Reservoir*			
1	Normal rising water level	MNDBT	m	350.00
2	Flood water level design	MNLTK	m	350.37
3	Dead water level	MNC	m	349.00
4	Total volume	V_{tb}	10^6m^3	38.098
5	Dead volume	V_c	10^6m^3	35.127
6	Useful volume	V_{hi}	10^6m^3	2.971

2.2. Geological features of the dam foundation

On the original rock formations of the study area, the weathered shell section includes the following zones:

-Residue layer (edQ): Developed on the surface of sound rock with a thickness of 0.5 ÷> 1.0m. The composition includes clay, sandy clay and gravel, boulder are underweathered, the upper part of the layer as well as the roots of plants.

- Fully weathered rock (IA1): The sound rock is completely weathered, mixed with soft gravel. This zone appears on the right side of the dam shoulder. The thickness varies from 4.0 ÷> 8.0m.

-Strong weathering zone (IA2): The rock is cracked and strongly weathered, most of the minerals are changed, the rock is no longer the same as original color, the cracks are enlarged, filled with the gravel and clay, the surface of cracks are iron oxide. The physico-mechanical properties of rock are reduced sharply, rocks are soft. Particles of strong weathering rock (IA2) can be broken by hand. The thickness of the zone varies from 3.0 ÷> 9.0m.

- Medium weathered rock (IB) zone: The rocks are medium to strong cracked, the mineral composition is almost unchanged, the rocks retain the original color, the open fracture, fractures' surface covered by iron oxide. Physico-mechanical properties vary depending on location. The rocks in the medium weathered zone have to use geological hammer to break. The thickness of the zone varies from 0.5 ÷> 2.0m.

-Relatively intact rock (IIA) zone: slightly weathered rock with less color variation, weak to medium crack. The rock is hard to very hard, this slightly weathered rock is only broken when it is smashed really hard by hammers, and the sound from these hits is echoed and pure.

- Intact rock (IIB) zone: Fresh rock is not color change, less chapped, not weathered. The sound when smashing these rocks by hammers is very echoed and pure, these stones are from hard to extremely hard.

- Surface layers (edQ+IA1) on the right shoulder of the dam are quite thick, from 8 to 10 meters. The left shoulder of the dam barely has no covering layers, so from the medium weathered rock (IB) to the equivalent stone blocks are clearly.

The weathering crust is shown on the cross sections at the dam site of the Long Tao hydroelectric power plant as shown in Figure 1.

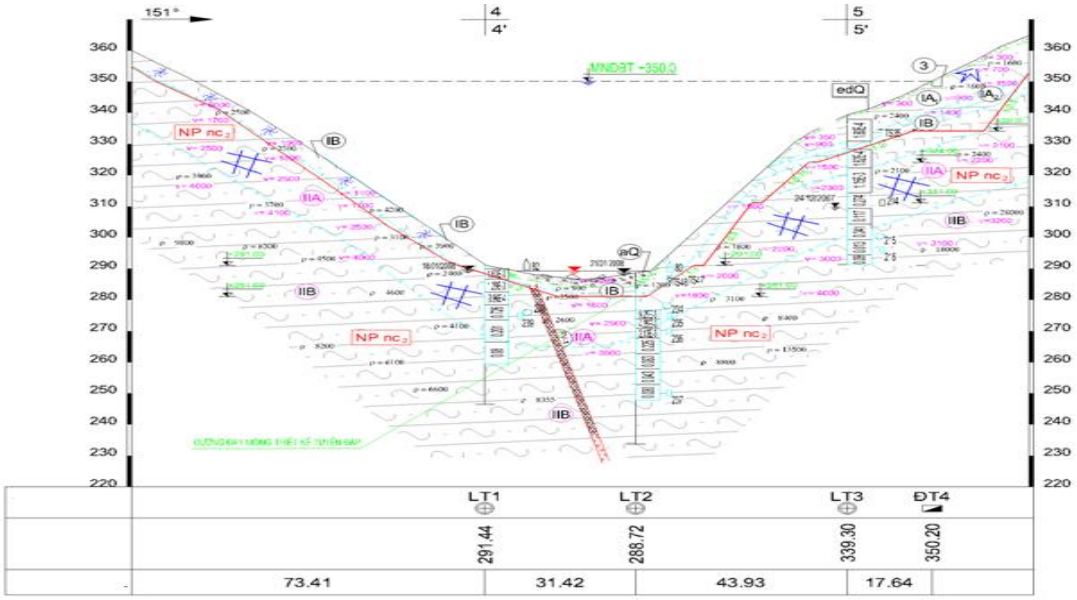

Fig. 1. Geological profile of the rock foundation of the Long Tao hydroelectric plant

Tab. 2. Laboratory testing results of rock samples of the dam

Rock type:			Sericit quartz schist		
Degree of weathering, cracking			Medium PH (IB)	Light PH (IIA)	Fresh rock (IIB)
Volume	Wet	(g/cm^3)			
	Dry	(g/cm^3)	2.38	2.61	2.64
Density			2.80	2.76	2.72
Compressive strength (kG/cm^2)		Dry	139.7	723.3	1060.1
		Saturation	87.9	636.9	1013.3
Tensile strength (kG/cm^2)		Dry	15.5	72.0	97.3
		Saturation	9.8	63.2	93
Intensity of shearing resistance					
Dry	Cohesion (kG/cm^2)		17.0	66.5	92.5
	Friction angle (^{o})		36°30	37°57	38°47
Saturation	Cohesion (kG/cm^2)		10.0	60.0	88.1
	Friction angle (^{o})		36°10	37°41	38°29

3. Application of Roclab software to calculate the mechanical characteristics of the foundation stone of the Long Tao hydroelectric dam

3.1. Input parameters of Roclab

Roclab software contains all expressions, which allow to calculate the physical values of rock blocks. Input parameters for Roclab software are as follows:

σ_{ci}: Compressive strength of saturated rock samples, (MPa);

GSI: Index of geological durability of stone blocks, determined by formula:

GSI = RMR - 5

m_i: The Hoek-Brown coefficient characterizes each rock, The harder the rock is and the harder the grain, the higher the m_i. The constant of the m_i is determined by three-axis compression test or table test. There are no triaxial experiments with rock samples, So the value of the rock material constant (m_i) is checked.

D: Impact factor of the construction method on the level of rock integrity;

Calculation for the stone background: select Application-Custom- (Enter the maximum horizontal stress value σ_{3max} (Mpa)): $\sigma_{3max}=\gamma H$, γ_c: Unit weight (Mpa).

Calculation for the tunnel: select Application - Tunnels-Enter Unit weight (Mpa) and Tunnel depth (m).

Calculation for slopes: select Application-Slopes-Enter Unit weight (Mpa) and Slope Height (m).

Roclab software will calculate and deliver the following results:

- Hoek-Brown criterion: m_b, S and a.
- Mohr-Coulomb fit includes: Cohesion C (Mpa), Friction angle (deg),
- Rock mass parameters includes: Tensile strength $\sigma_{t\ (Mpa),}$ Uniaxial compressive Strength of rock column $\sigma_{c\ (Mpa),}$ Modulus of deformation (Mpa)
- Compression and cut resistance graphs: This allows the display (and not display) of the Mohr - Colomb standard curve, values of σ_1, σ_3, σ_n, C', φ'.

3.2. Calculation results

Based on laboratory results (Table 1), the Roclab software input parameters provide the results shown in Figures 2,3,4 and Table 2.

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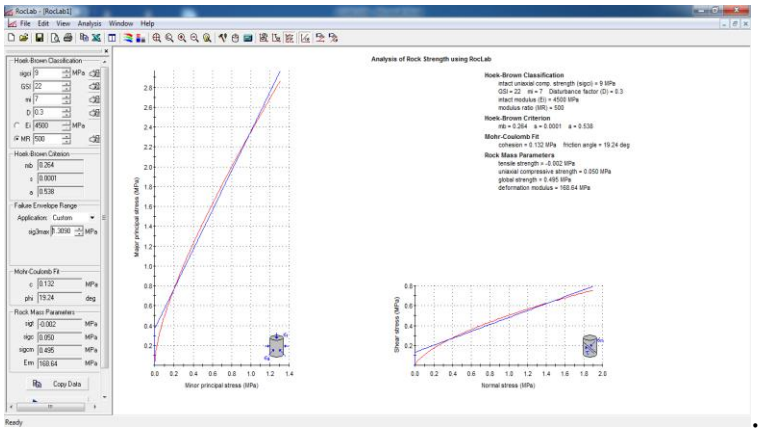

Fig. 2. Calculation for medium weathering shale sericit for the Hydroelectric Hydropower project of Long Tao - Dien Bien

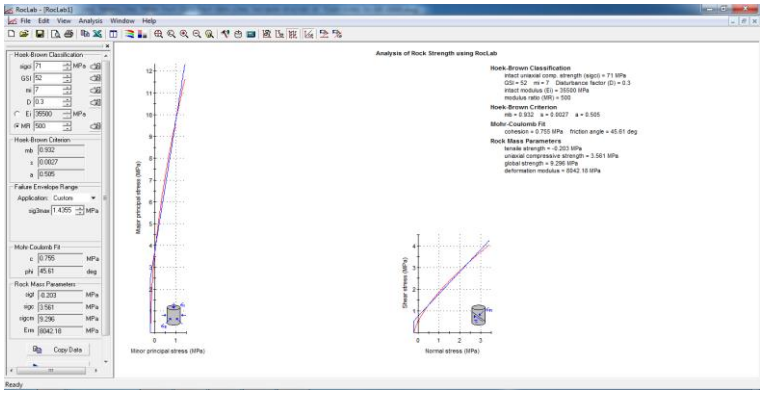

Fig. 3. Calculation for light weathering shale sericit for the foundation of Hydroelectric Hydropower project of Long Tao - Dien Bien

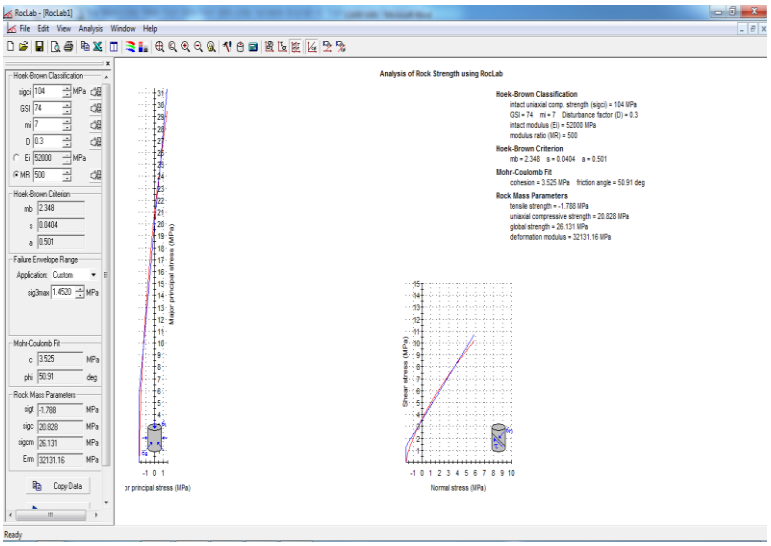

Fig. 4. Calculation for the fresh sericitic shale for the foundation of Hydroelectric Hydropower project of Lung Tao - Dien Bien

Tab. 3. Results of the physical properties of the rock foundation of the hydroelectric dam project using the Roclab software

Order	Parameters	Units	Sericit schist		
			IB	IIA	IIB
1	Unit Weight	g/cm^3	2.38	2.61	2.64
2	Density	g/cm^3	2.80	2.76	2.72
3	Calculation for the background (general case)				
	Cohesion	kG/cm^2	1.0	8.0	35.0
	Friction Angle	degree	19.0	46.0	51.0
	Compressive strength	kG/cm^2	5.00	93.00	261.30
	Deformation Modulus	kG/cm^2	1686	80421	321312
4	Calculation for slopes				
	Cohesion	kG/cm^2	0.3	4.2	30.6
	Friction Angle	degree	30.0	54.0	54.0
	Compressive Strength	kG/cm^2	3.90	80.60	238.20
	Modulus deformation	kG/cm^2	1430	59385	261394

Comments: The value of the cohesive force parameter Cm of the rock varies considerably. The affinity coefficient determined by the field test method varies from 1.2 to 1.5 times the value determined by the Roclab software.

Since the Long Tao hydropower project did not conduct field experiments with horizontal tunnels. So, we can use the results from Roclab software to propose the mechanical properties of the dam foundation.

4. Conclusion

From the results of analysis, research and evaluation, we have some conclusions as follows:

The sericitic shale of the Lung Tao Hydropower Project as well as the rocks in general have a very different and complex structure, forming a discontinuous, heterogeneous and anisotropic environment.This feature affects the mechanical features of the stone and makes a difference between the properties of the stone and the stone. Therefore, when determining the mechanical characteristics of rock masses for design and construction calculations, it is necessary to fully evaluate the factors influencing the mechanical characteristics of the rock.

Roclab software (Hoek-Brown standard) is considered as an advanced approach to determining the mechanical parameters of a rock.

The results of calculating the mechanical values of rock by Roclab software are quite consistent with the values obtained by field experiments.Therefore, it is possible to use this software to save costs for works that do not have field testing conditions but still have equivalent calculations.

The results of the determination of the mechanical characteristics of the dam of Lien Tao Hydroelectric Project in Dien Bien Province show that the values determined by TCVN standard are low, so they are just for refrences.The results of Roclab software are similar to those of in-situ tests. Therefore, it is possible to use the rock mass index calculations using Roclab software to recommend design metrics.

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