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Development of an Android application for rock mass evaluation (RMR, GSI, Q-Barton, SMR) with field validation in Los Guáimaros, Campo Elías, Mérida, Venezuela

Desarrollo de una aplicación Android para la evaluación de macizos rocosos (RMR, GSI, Q-Barton, SMR) con validación práctica en Los Guáimaros, Campo Elías, Mérida, Venezuela.

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Abstract

We present an Android application for evaluating rock mass quality using geomechanical methodologies (RMR, GSI, Q-Barton, and SMR). This tool optimizes the collection and analysis of geological data, facilitating its implementation in geotechnical projects. First, a flowchart defining the application's functionalities was developed. This flowchart was implemented using React Native. To validate the app, two types of tests were conducted: interface and functionality. For this purpose, two datasets were used: historical data from prior evaluations and field data collected during visits to the Los Guáimaros region, Mérida State, where three rock masses were assessed. These in-situ tests enabled evaluation and refinement of the app's performance. The results from both datasets were compared with manual calculations performed in Excel spreadsheets, based on the three cases mentioned.

Keywords: APP, React Native, Rock mechanics, Rock massif, Geomechanical classifications, Geotechnical engineering

Resumen

Presentamos una aplicación Android para la evaluación de la calidad de macizos rocosos mediante metodologías geomecánicas (RMR, GSI, Q-Barton y SMR). Esta herramienta optimiza la recolección y análisis de datos geológicos, facilitando su implementación en proyectos geotécnicos. Primero, se elaboró un diagrama de flujo que define las funcionalidades de la aplicación. Este diagrama de flujo se implementó utilizando el lenguaje React Native. Para validar la aplicación se llevaron a cabo dos tipos de prueba, la de interfase y de funcionamiento. Para ello se usaron dos tipos de datos, el primero, histórico de evaluaciones previas y el segundo, una visita de campo en la región de Los Guáimaros, estado Mérida, donde se evaluaron tres macizos rocosos, estas pruebas in-situ permitieron evaluar y mejorar el funcionamiento de la aplicación. Los resultados obtenidos con ambos conjuntos de datos se compararon con los obtenidos por cálculos realizados manualmente en hojas de Excel, utilizando tres casos mencionados.

Palabras claves: APP, React Native, Mecánica de rocas, Macizos rocosos, Clasificaciones geomecánicas

1 Introduction

Digital technologies are revolutionizing the field of geology by providing tools and techniques that improve efficiency and accuracy in the study of the Earth, responding to a technological world that demands ubiquity, speed and adaptability. Geological methodologies such as the Mass Rating Index (MRR); the Geological Strength Index (GSI); the Q-Barton system and the Slope Mass Rating (SMR) have been used for decades.

The importance of these methods lies in their ability to relate quality indices with geotechnical parameters crucial for project planning and execution. In order to optimize these processes, we propose the development of an Android application that implements the RMR, GSI, Q-Barton and S.M.R methodologies for the evaluation of the quality of rock massifs. Although the application was validated in the locality of Los Guáimaros, Mérida state, its design allows its implementation in any rock massif, regardless of its geographical location, adapting to the specific characteristics of each formation.

2 Theoretical framework

2.1 Rock mechanics

It is the theoretical and applied science that studies the mercanic behavior of rocks, rock masses and the field of forces acting in their environment (Ramírez and Alejano, 2004).

2.2 The evaluation of rock masses

It is a crucial aspect in geotechnical and mining engineering, RMR, GSI, Q-Barton and SMR methodologies are fundamental for this purpose.

2.2.1 Bieniawski's RMR Classification

The specific parameters considered by this classification are: resistance to simple compression of the rock matrix (RQD), degree of seepage of the rock mass, spacing of discontinuities, hydrogeological conditions and orientation of discontinuities (González de Vallejo, et al., 2002).

To obtain the RMR Index, the values of the first five (5) parameters evaluated are added, resulting in a value called basic RMR. The sixth (6th) parameter, corresponding to the orientation of the discontinuities with respect to the excavation, is not added directly, but is applied as a correction to the basic RMR value. This value varies between 0 and 100.

2.2.2 Geologic Strength Index (GSI), Hoek and Brown

The GSI differs from other classification systems in its qualitative rather than quantitative approach (Sönmez and Ulusay, 2002).

The GSI (Geological Strength Index) values range from 1 to 100, where lower values represent rock masses of lower quality, characterized by a high degree of weathering and fracturing. It is determined by means of a classification table that allows estimating the value based on two visual criteria: on the vertical axis, the type of rock mass structure (SR, Structure Rating) is represented, and on the horizontal axis, the surface quality of the discontinuities (SCR, Surface Condition Rating). This arrangement facilitates a quick and consistent evaluation of the rock mass in the field.

Translated with DeepL.com (free version)

2.2.3 The Q-Barton Index

The Q-Barton Index classifies rock on a scale ranging from exceptionally poor to exceptionally good, based on values ranging from 0.001 to 1000 (Barton, 2002).

The Q-Index is obtained by the following equation

$$Q = \frac{RQD}{\mathrm{Jn}} x \frac{\mathrm{Jr}}{\mathrm{Jr}} x \frac{\mathrm{Jw:}}{SRF}$$

Where the following parameters are entered:

RQD: rock quality index.
Jn: cleavage index indicating the degree of turnover.
Jr: index that contemplates the roughness, filling and continuity of discontinuities.
Ja: Description of joint alteration.
Jw: Reductive coefficient due to the presence of water.
Stress Reduction Factor (SRF): Coefficient that takes into account the influence of the stress state on the rock mass.

The variation index of the parameters is: RQD: between 0 and 100; Jn: between 0.5 and 20; Jr: between 0.5 and 4; Ja: between 0.75 and 20; Jw: between 0.05 and 1; SRF: between 05 and 20.

2.2.4 The Romana SMR Index

The Slope Mass Rating (SMR) for the classification of slopes was proposed by Romana (1985). It is obtained from the RMR index by subtracting an adjustment factor that depends on the orientation of the joints (product of three subfactors) and adding an excavation factor that depends on the method used (cited in Tomás, Delgado and Cuenca, 2005).

According to the following equation:

SMR = Basic SMR + (F1* F2* F3) + F4

The RMR is calculated according to Bieniawski's coefficients.

1. Simple compressive strength of the rock matrix.
2. RQD (measured in boreholes or estimated).
3. Discontinuity spacing.
4. Discontinuity conditions.
5. Discontinuity water flow.

On the other hand:

F1: depends on the parallelism between the direction of the joints and the slope face.
F2: depends on the dip of the plane break.
F3: reflects the relationship between the dip of the joints and the slope.
F4: adjustment factor according to the excavation method.

2.3 Rock slope stability

It is essential to know the modes of rupture that occur in rock whose movement is controlled by geological discontinuities. They are divided into: Flat breakage, wedge breakage and strata overturning breakage (Ramirez and Alejano, 2004).

2.4 Stereographic projection

This type of projection defines an inversion in space that transforms the points of the sphere into points of the plane (Tomás, Delgado and Cuenca, 2005).

2.5 Mobile application development

Mobile applications are relatively simple. Sometimes they interact with the device hardware including camera, storage device, GPS sensor, etc. (Cabrera and Cueva, 2015).
Android is an operating system developed by Goo-gle that offers advantages such as greater market reach, in addition to being used in a wide range of devices from different manufacturers (Cabrera and Cueva, 2015).

2.6 React Native

It is an open-source development framework for building native mobile applications using JavaScript and React (React Native, 2024).

3 Methodology

In order to meet the proposed objectives, the methodological scheme shown in Figure *1*was designed and is described below.

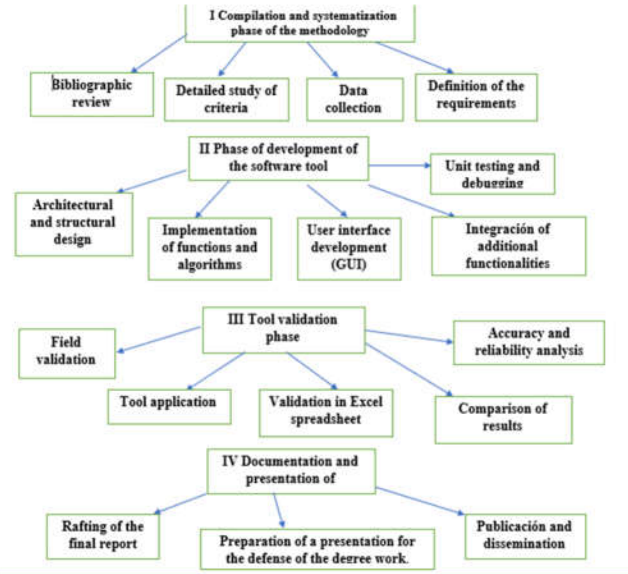


Figure 1. Methodology

3.1 Phase 1: Compilation and systematization of the Methodology.

The information available on the methodologies to be implemented is reviewed and compiled in order to thoroughly understand the criteria involved in them, which allows defining the requirements and specifications of the Application to be developed.

3.2 Phase 2: Application Development

The integral development of the application covers from the design of the software architecture and structure, to the implementation of functions and algorithms for the calculation of rock mass quality indexes, according to RMR, GSI, Q-Barton and SMR methodologies. It also includes the creation of an intuitive user interface, the integration of modules for data management and export, the automated generation of reports, as well as the execution of unit tests and debugging processes, in order to ensure an optimal and reliable operation of the system.

3.3 Phase 3: Application validation

It is carried out in two stages. First, a field validation in the Los Guáimaros region, Mérida state, in-situ data are collected from three rock massifs and the application is used to calculate the indices. The results obtained are compared with traditional rock mass evaluation methods to analyze the accuracy and reliability of the application in real conditions. Second, a validation is performed using Ex-cel spreadsheets, where the same data are entered in the application and in the spreadsheets, and the results obtained are compared to evaluate the consistency and accuracy of the system.

4 Application development

This section shows the technical and methodological aspects of the development of the application.

4.1 Technical aspects to be considered

The development of an Application with the Android operating system was chosen, oriented to the improvement of the necessary records for the evaluation of the quality of rock massifs by means of the technologies mentioned above.

4.2 Data Flow Chart

A Data Flowchart, Figure 2, is a visual representation that details the process of user interaction with the application, starting from the initial point and culminating with the final results.

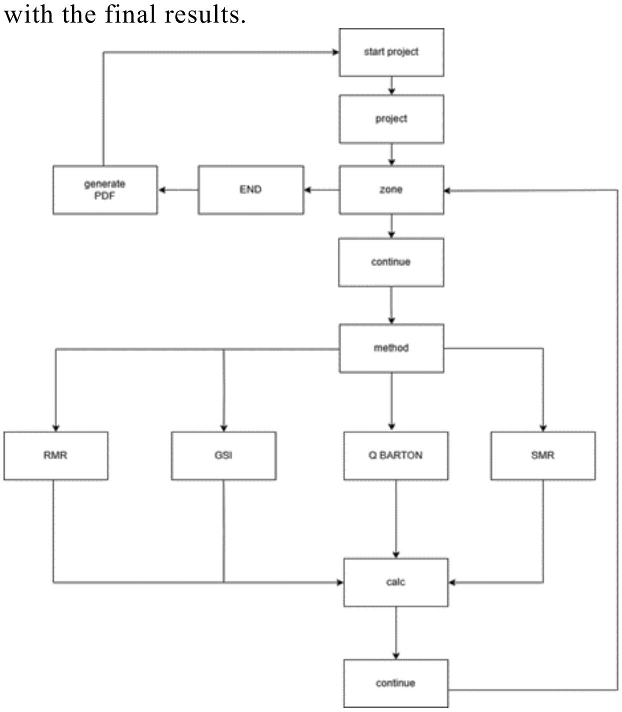


Figure 2. Data flowchart

4.3 Structure in programming language

Based on an object-oriented model where each entity of the system is represented as properties. This approach allows encapsulating both data and related behavior, facilitating the management and manipulation of information.

4.4 URI information

Uniform Resource Identifier (URI), in Spanish, identicador uniforme de recursos. This term is used for all types of names and addresses that refer to objects on the Internet, such as pages, images, videos, etc. A URI is therefore a string of characters that allows interaction between different resources on the Internet and other types of networks.

4.5. User's manual

Based on an object-oriented model where each entity of the system is represented as properties. This approach allows encapsulating both data and related behavior, facilitating the management and manipulation of information.

5 Evaluation and testing of the application.

5.1 Application evaluation and testing

The developed application has been tested so far with 3 different devices with at least 2gb of RAM, which makes it accessible to most geologists and field technicians. The devices tested so far are listed:

- Pixel 7 Android 11, 4 GB de RAM
- Redmi 9a Android 10, 2 GB de RAM
- Redmi 13C Android 14, 8 GB de RAM

5.2 Field Tests

The rock massifs studied in situ are located between the towns of Los Guáimaros and Mesa de Los Indios, in the municipality of Campo Elías, in the state of Mérida.

Figure 3 shows the expanded study area, this addition covers more territory and allows capturing a greater diversity of data from the formations: Aguardien-te, Apon, Rio Negro and Tostos. By evaluating three rock massifs, the following reports were obtained directly from the application. Figures 4, 5 and 6

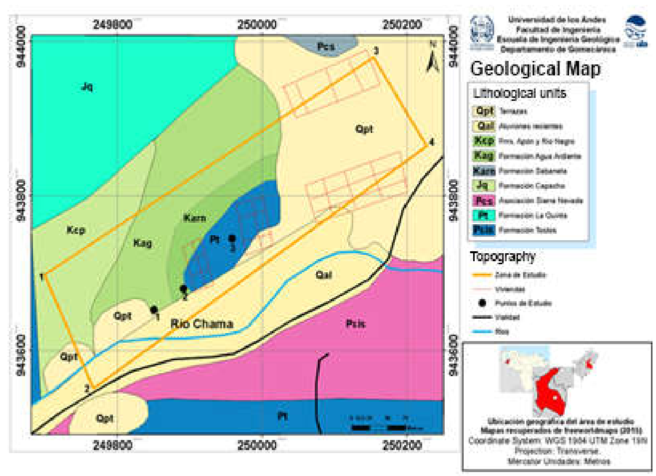


Figure 3. Enlarged study area

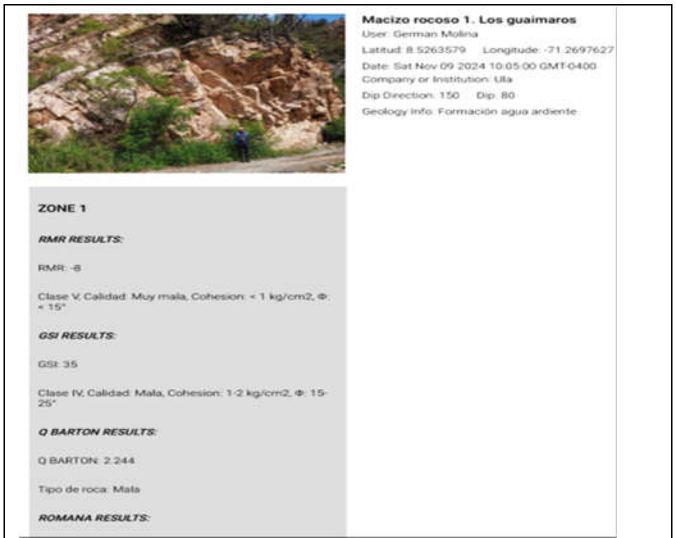


Figure 4. Rock mass 1

Figure 5. Rock mass 2

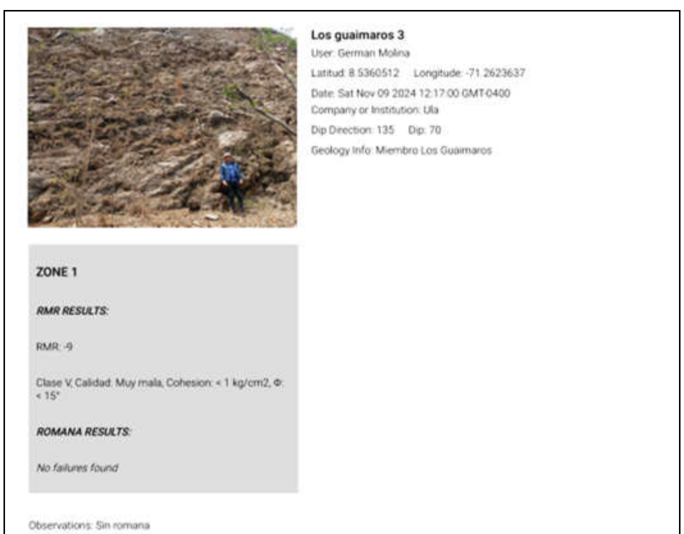


Figure 6. Rock mass 3

6 *Analysis and comparison of results*

6.1. Case 1

In case 1, a comparison was made with the graduate work: "Geomechanical study of rock massifs under the influence of external loads, located in the Los Araques sector, Sucre municipality, Merida state", carried out in November 2019 by Hernandez Yaneidy and Lopez Jesus, under the supervision of Dr. Norly Belandria. In this degree work, three families of discontinuities were evaluated. Table 1

Table 1. Orientation and dip

ORIENTATION AVERAGE	DIP DIP DIRECTION
Family 1	53/246
Family 2	59/143
Family 3	68/360

Table *2* shows the conditions of the aforementioned families

Table 2. Discontinuity family conditions

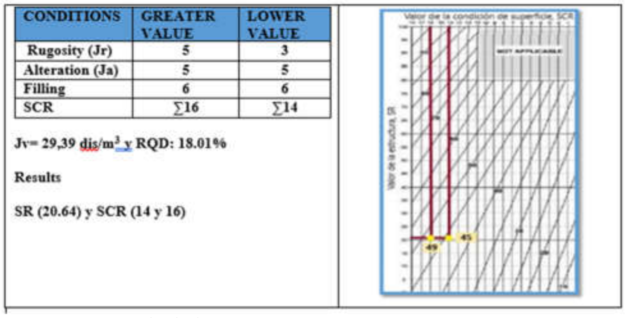
CONDITIONS	FAMILY 1	FAMILY 2	FAMILY 3
Persistence	>20m	2m	<1m
Opening	0.1-1mm	2-7mm	1cm
Rugosity	Slightly rough	Slightly rough	Rugged
Filling	Unfilled	Unfilled	Unfilled
Alteration	Slightly altered	Slightly altered	Slightly altered

The evaluation of the parameters obtained can be seen in Table *3*, which in turn indicates the basic RMR value.

Table 3. Parameter evaluation

PARAMETER	CHARACTERISTIC	GREATER VALUE	LOWER VALUE
1.α	126 Mpa	12	12
2.RQD	18.01%	3	3
3. Separation	(0.058 -1) m	15	5
4. Conditions: Opening	0.1mm – 1.cm	4	0
Persistence	<1 m - > 20m	6	0
Rugosity	Slightly rough	5	3
Filling	Unfilled	6	6
Alteration	Slightly altered	5	5
5. Water presentation	Dry	15	15
Basic RMR		∑71	∑49

In this research they also calculated the GSI, the results can be seen in Figure 7.



CONDITIONS	GREATER VALUE	LOWER VALUE
Rugosity (Jr)	5	3
Alteration (Ja)	5	5
Filling	6	6
SCR	∑16	∑14

Jv= 29,39 dis/m³ y RQD: 18.01%

Results

SR (20.64) y SCR (14 y 16)

Figure 7. GSI calculations

Using the application, the following results were found, see Figure 8

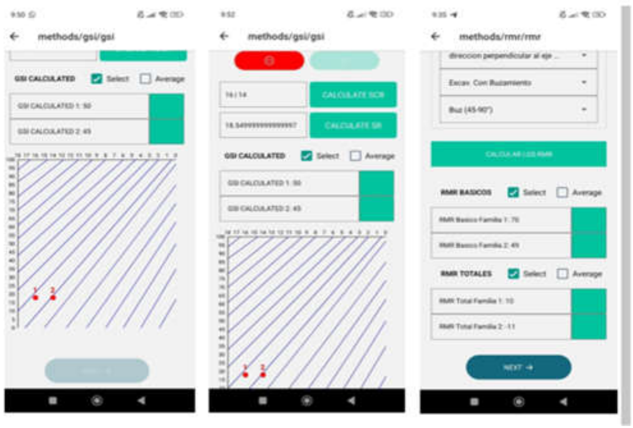


Figure 8. Application results, from left to right: GSI part 1, GSI part 2 and RMR.

Table 4 shows the results of both the research and the application.

Table 4. Results

RESULTS	APP RESULTS
RMR Basics: 71 y 49	RMR Basics: 70 y 49
GSI Results: 49 y 45	GSI Results: 50 y 45

Finally, to evaluate the performance and accuracy of the application, the same data from the case study were used and the calculations were performed manually in Excel spreadsheets, obtaining the following results. See Table 5.

The results of the case study, the application and the Excel spreadsheet vary by minimum values and suggest a remarkable similarity between them.

Table 5. Calculations using Microsoft Excel

E12 =SUMA(E2:E11)

	A	B	C	D	E
1	RMR	Parameter	Characteristic	Highest Value	Lowest Value
2	1	Strength of intact rock	126 Mpa	12	12
3	2	RQD	18,01%	3	3
4	3	separation	(0.058 - 1) m	15	5
5	4	Condition of discontinuities			
6		persistence	< 1 m - > 20m	6	0
7		opening	0.1 mm - 1 cm	4	0
8		roughness	slightly rough	5	3
9		filling	no filling	6	6
10		alteration	slightly altered	5	5
11	5	presence of water	dry	15	15
12		Basic RMR Result		71	49

6.2 Case 2

In case 2, a comparison was made with the project: Design of Hechicera-La Pedregosa Tunnel, located in Merida state, dated September 2019. Carried out by Bastidas Naila, et al, under the supervision of Dr. Norly Belandria. Table 6 shows the orientation of the discontinuities.

Table 6. Discontinuities orientation

Section	1	2	3
Orientation	Heading/Dipping	Heading/Dipping	Heading/Dipping
Tunnel	N63E / 89SE	N63E / 89SE	N63E / 89SE
Foliation	N45E / 70SE	N45E /83NW	N45E/ 70NW
Discontinuity 1	N61W /45SW	N61W /45SW	N61W /45SW
Discontinuity 2	N80E / 60NW	N80E / 60NW	N80E / 60NW
Entry slope	N30W / 42NE		
Exit slope			N30W / 30SW

Calculation of dip direction: a)70/135; b) 45/209; c) 60/350

On the other hand, the comparison between the results of the stereographic projection of the project and the application is presented. Figure .

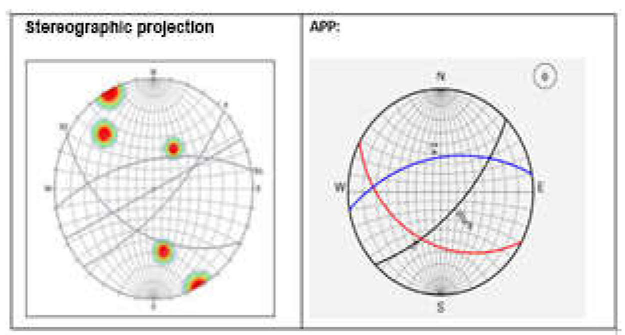


Figure 9. Comparison between project and application results

Although there are similarities, in the application there is a certain difference, the curves are more pronounced. For this reason, a comparison made with Photoshop is added by superimposing the images. Figure .

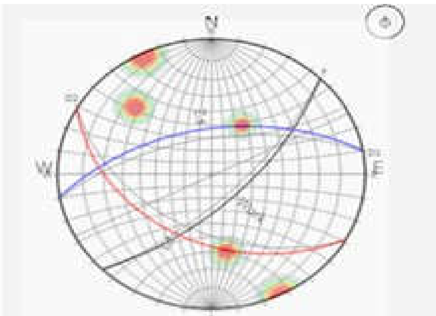


Figure 10. Comparison made with Photoshop overlaying the images

Therefore, adjustments were made to achieve better accuracy, see Figure 11.

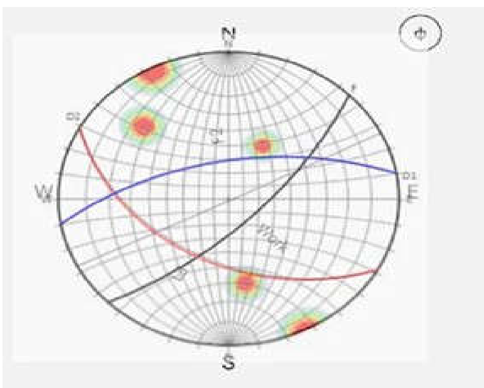


Figure 11. Image made by photoshop superimposing the images after adjustments in the application

It should be noted that the Stereonet program and the Dips program use different grids for the eastographic projection, also Stereonet has more pronounced curves than Dips. The curves of the application were tried to be similar to Dips, even using the same grid; however, both programs were used during these analyses to check results.

<u>Other tests performed with the same case study</u>

Table 7 presents data on tunnel failures, analyzed according to dip and dip direction. Information that is part of this case.

For the realization of the projection, they did not take fault 1, therefore, it was performed in this way. Figure .

Table 7. Failure data

ID	DIP	Dip Direction	Set
1	74	10	
2	89	28	
3	88	35	1
4	82	30	1
5	70	101	2
6	69	110	
7	57	97	
8	68	105	2
9	81	95	
10	71	87	
11	12	135	3
12	21	130	3
13	9	122	3
14	14	137	3
15	21	20	

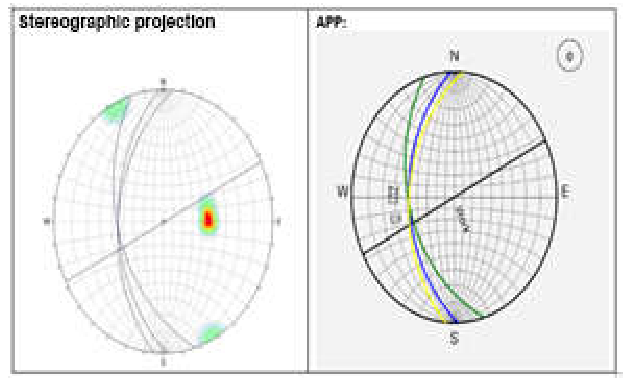


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Figure 12. Comparison between the project and the application

An overlay image is included to assess accuracy. Figure .

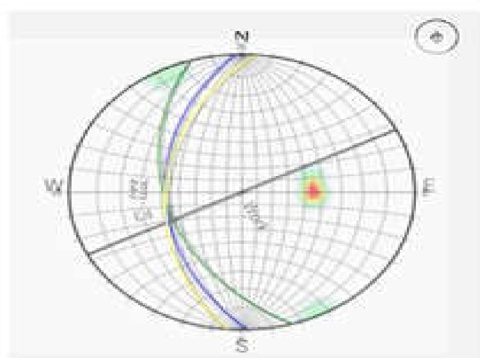

Figure 13. Comparison by superimposing both images, using photoshop

In this research they also performed the Q-Barton Calculation, the data are shown in Table *8*.

Table 8. Data for Q-Barton sections

Section	1	2	3
Quality of rock (RQD)	65,5	65,5	65,5
Diaclasate (Jn)	9	9	9
Rugosity (Jr)	1,5	1	1,5
Alteration (Ja)	2	2	2
Presence of water (Jw)	0,66	0,66	0,66
SRF	1	1	1

This calculation yielded the following result

$$Q = \frac{65{,}5}{9}\ x\ \frac{1.1{,}5}{2}\ x\ \frac{0{,}66}{1} = 2{,}40 \text{ Poor quality}$$

Using the application, the results presented in Table 9 below were found.

Table 9. Application results

Section 1	Section 2	Section 3
Result APP= 0.715	It was decided not to carry out tranche 2	Same parameters, same results
Very bad rock type		
Attached is a screenshot of the application report.		
ZONE 1 Q BARTON RESULTS Q BARTON: 0.715 Rock Type: Very Bad		

It is clarified that this study has an error in the RQD parameter since they directly used the "65.5" instead of its valuation from the RQD table. It can be affirmed then, that if he correct valuation is used, the result of the application is obtained. Finally, to evaluate the performance and accuracy of the application, the same data from the case study were used and the calculations were made manually in Excel spreadsheets, obtaining the results shown in Table 10.

Table 10. Calculations using Microsoft Excel

C23 =C17*C19*C21/(C18*C20*C22)

	A	B	C	D
16	Barton's Q	Parameter	Section 1	Note
17		RQD	13	Corrected
18		Jn	9	
19		Jr	1,5	
20		Ja	2	
21		Jw	0,66	
22		SRF	1	
23	Result		0,715	
24				
25	$Q = \frac{RQD.Jr.Jw}{Jn.Ja.SRF}$			
26				

It can be seen that the results of the study, the application and the Excel calculation coincide perfectly.

6.3 Case 3

In case 3, a comparison was made with the graduate work: Evaluation of the geotechnical properties of the outcrops between El Caucho and San José de las Flores Alto, Mérida, Mérida state, carried out in November 2022, by Bravo Jorge and Gatrif Jesús, under the supervision of Professor Germán Molina.

Table 11 shows data from the outcrops evaluated in the research.

Table 11. Outcrop data

ID	DIP	Dip Direction	Set
1	74	10	
2	89	28	
3	88	35	1
4	82	30	1
5	70	101	2
6	69	110	
7	57	97	
8	68	105	2
9	81	95	
10	71	87	
11	12	135	3
12	21	130	3
13	9	122	3
14	14	137	3
15	21	20	

Figure 14 shows the comparison between the results of the stereographic projection of the degree work and the application. They are the same results; however, it should be noted that the image of Bravo & Gatrif's thesis is distorted, it is not a perfect circle.

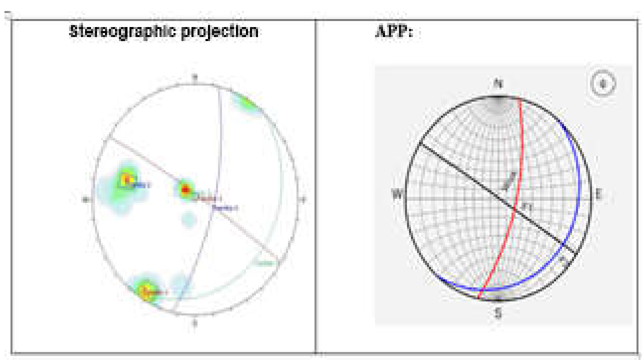

Figure 14. Comparison between thesis and application data.

In this research they also performed the calculation of Q Barton, the data can be found in Table 12.

Table 12. Calculation of Q-Barton

Family 1

Parameters	RQD	Jn	Jr	Ja	Jw	SRF
Description	Regular	3 families	Light Rough	Closed	Slightly Wet	D
Rating	13	9	3	4	1	7,5

Family 2

Parameters	RQD	Jn	Jr	Ja	Jw	SRF
Description	Regular	3 families	Rough	Closed	Slightly Wet	D
Rating	13	9	5	4	1	7,5

Family 3

Parameters	RQD	Jn	Jr	Ja	Jw	SRF
Description	Regular	3 families	Light Rough	Closed	Slightly Wet	D
Rating	13	9	3	4	1	7,5

With these data, the Q value is determined, which has an average of 0.84, indicating that the rock is very bad. The following results were obtained from the application. Table 13.

Table 13. Application results

Family 1	Family 2	Family 3
Result APP: 0.144	In parameter Jr there is no value associated with 5	They have the same parameters as family 1, therefore, the same results are obtained.
Rock type: very bad		
Attached is a screenshot of the application report.		
ZONE 1 Q BARTON RESULTS Q BARTON: 0.144 Rock Type: Very Bad		

In this case it is clear that the thesis students used a nonmenclature different from the tables used in the application, even in the second family they used a value that is not found in the theory; in the same way, a value is obtained that falls within a range close to their results.

To evaluate the performance and accuracy of the application, the same data of the case study were used and the calculations were made manually in Excel spreadsheets, obtaining the results shown in Table 14

Table 14. Calculations using Microsoft Excel

C23 =C17*C19*C21/(C18*C20*C22)

	A	B	C	D
16	Barton's Q	Parameter	Section 1	Note
17		RQD	13	Corrected
18		Jn	9	
19		Jr	1,5	
20		Ja	2	
21		Jw	0,66	
22		SRF	1	
23	Result		0,715	
24				
25	$Q = \frac{RQD.Jr.Jw}{Jn.Ja.SRF}$			
26				

All the results of the case study, the application and the Excel sheet match perfectly.

7. Conclusions

The final validation of the application in terms of its functionality and accuracy were field tests, which allowed for modifications and improvements.

Significant savings in man-hours dedicated to data collection and analysis are evident. On average, a total of 40 minutes was estimated for the RMR method and an average of 10 to 15 minutes for the other methods.

Another no less important validation is the numerical calculation machine used, with respect to those traditionally used. Comparing the results obtained with calculations performed manually on Excel spreadsheets using data from three cases available in the literature, the following results were obtained: in case 1, in case 1, they coincided 99% with the application. Case 2: there was a 100% match. Case 3: There was a 100% match.

Based on the design of the application and the rock mass data collection methodology, it is recommended to create independent projects when there are significant variations in the geometric and geo-logical properties of the study area.

The use of the application favors portability in these processes, since it would not be necessary to carry materials such as notebooks, guides or files; and reports could be sent by messages or mail, i.e., in real time.

The application is a beta version restricted to the use of the University's School.q Currently, it works with quality and accuracy, but ideally it should be further evaluated and improved to implement new functionalities.

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