Proceedings of the 17th Pan-American Conference on Soil Mechanics and Geotechnical Engineering (XVII PCSMGE), and 2nd Latin-American Regional Conference of the International Association for Engineering Geology and the Environment (IAEG), La Serena Chile, 2024.

Influence of Carbonate Concentration Cores on Physical and Mechanical Properties of a Metabasalt

Influencia de los Núcleos de Concentración de Carbonatos en las Propiedades Físicas y Mecánicas de un Metabasalto (Influência de Núcleos de Concentração de Carbonatos nas Propridades Físicas e Mecânicas de um Metabasalto).

Carolina Crissafe dos Santos Lemos, Carolina de Souza Pires Costa, Natália de Faria Silva & Eduardo Antonio Gomes Marques.
Department of Civil Engineering, Federal University of Viçosa, Brazil, carolina.crissafe@ufv.br.

ABSTRACT: Carajás Sierra, in Northern Brazil, is the biggest mineral province on Earth and hosts the Carajás mine, currently known as the largest open-pit iron ore mine of the world. Due to the great geological and economic importance of this region, understanding the rock properties within the mines is crucial. In this context, the present work aimed at performing laboratory tests, such as determination of the P-wave propagation velocity, physical indices and point load strength ($Is_{(50)}$), of a basic embedding rock outcropping at Carajás mine. Three blocks of a metabasalt were used to prepare samples to perform the tests - one of which had carbonate concentration cores, in order to evaluate the influence of the presence of these cores on the properties of the rock under study. The results of the wave propagation velocity test and the index properties showed that the difference in the values obtained for the samples with and without carbonate cores was very small. However, the results of the point load test showed that the carbonate concentration cores resulting in a 69% increase in the $Is_{(50)}$ value of the metabasalt. Thus, it is concluded that the presence of these mineralogical features can provide an increase in strength to the rock material, even without causing significant changes on its index properties.

KEYWORDS: Metabasalt, Geomechanical Characterization, Carbonate Concentration Cores, Mineralogy, Rock Properties.

1 INTRODUCTION

The Carajás Sierra, situated in Pará, stands out as the largest mineralogical province globally. Within this sierra lies the Carajás Complex, home to some of the world's largest open-pit iron ore mines, and the leading global producer of high-grade iron ore, as reported by Vale (2023). This region holds significant geological and economic importance, underscoring the necessity for studies in rock mechanics, due to its importance in the stability of slopes in numerous existing open pits.

Determining the physical and mechanical properties of rocks is extremely important for understanding their behavior when subjected to various applications in engineering works, including open-pit mines, underground mines, tunnel works, dams, among others. In this context, factors such as mineralogical composition can significantly influence the mechanical behavior of rocks, as highlighted by Cowie and Walton (2018).

Ündül (2016) emphasizes that petrophysical, mechanical, and elastic properties, including crack initiation stress levels and crack propagation, are responsible for variations in the geomechanical properties of rocks and their behavior in different engineering facilities. For this reason, understanding the interaction between microtextural variations, petrophysical properties, mineralogical features, mechanical properties, and crack processes to assess the immediate and long-term behavior of rocks is important and relevant to various geotechnical engineering projects.

Therefore, the main objective of this work was to determine the physical and mechanical properties of a metabasalt, using samples of two different types, with and without carbonate concentration cores, in order to evaluate the influence of these cores on the properties of the rock under study. To accomplish this, tests including P-wave propagation velocity (Vp), physical indices, and point load strength ($Is_{(50)}$) were conducted, with statistical comparison of results between the two sample groups. This research contributed to the advancement of studies in this area by illustrating the impact of mineralogical composition on the geomechanical properties of the investigated rock.

2 MATERIALS AND METHODS

2.1 *Metabasalt*

For the development of this study, three blocks of metabasalt were collected at the N4 open pit mine in Serra de Carajás, located in Northern Brazil. Among these blocks, one of them presented visually perceptible carbonate concentration cores, while the other two blocks did not present these mineralogical features. The carbonate concentration cores varied in size, generally between 5 to 7 mm in diameter, and exhibited a whitish coloration, distinct from the gray-colored surrounding rock matrix.

2.2 *Sample preparation*

Twenty specimens were extracted from rock blocks and then were sawed and machined, as recommended by International Society for Rock Mechanics – ISRM (2007). Of these specimens, ten had carbonate concentration cores and the others ten did not have such cores. The rock samples were prepared with height/diameter (H/D) ratio between 0.3 to 1.0 for point load tests, as determined by ISRM

(2007), and the diameter was equal to 54 mm. These samples were also used to P-wave propagation and for physical indices determination.

2.3 *Index properties*

The determination of index properties, including apparent dry specific weight (γ_d), apparent porosity (η) and apparent absorption capacity (α), was carried out using the buoyancy technique, in accordance with the suggestions of ISRM (2007).

For the execution of this procedure, fragments of samples resulting from the Point Load test were utilized after their rupture.

2.4 *P-wave propagation velocity*

The P-wave propagation velocity test is a non-destructive test, in which ten samples with carbonate cores and ten without cores were tested. The ISRM (2007) recommends samples in "slab" format, with an H/D ratio close to 0.1, or "block" format with this ratio close to 1.0, for conducting this test. However, the same samples were tested which were subsequently subjected to the point load test, meaning they exhibited an H/D ratio ranging from 0.3 to 1.0.

The P-wave velocity was determined using the Proceq Pundit Lab+ equipment, with the utilization of 250 kHz transducers, following a prior calibration procedure for such transducers. A layer of vaseline was used to provide better adhesion between the sample and the transducers, thus ensuring better signal transmission, as recommended by ISRM (2007).

2.5 *Point Load test*

After preparing the samples, the Point Load test was conducted following the ISRM (2007) recommendations for diametral testing. In total, ten samples with carbonate concentration cores and another ten samples without these cores were tested, with a H/D ratio ranging from 0.3 to 1.0.

During the procedure, the fracture pattern of the specimens was also evaluated, which should occur in a manner crossing the two contact points of the testing equipment's tips with the sample to be considered valid.

2.6 *Statistical treatment of data*

After conducting the laboratory tests, a statistical analysis of the obtained data was performed. The average values, sample standard deviation, and coefficient of variation of the *Vp* values were calculated for both groups of samples. Regarding the $Is_{(50)}$ value, the overall mean was calculated considering all tested specimens, along with the corrected mean, which excluded the two highest and two lowest values from each group, as recommended by ISRM (2007). Additionally, an analysis of variance (One-Way ANOVA) was conducted, with a significance level of 5% (P-Value = 0.05), to assess whether the carbonate cores significantly influenced the *Vp* and $Is_{(50)}$ values of the studied metabasalt.

3 RESULTS AND DISCUSSION

3.1 *Index properties*

The results of the physical index test are presented in Table 1, with the values obtained for the samples containing carbonate concentration cores, classified as Group 1, and the samples without these cores, classified as Group 2.

Based on these results, it is possible to observe that the apparent dry specific weight (γ_d) of the samples with carbonate cores is approximately 1.4% higher than that of the samples without these cores. Moreover, the porosity (η) and absorption capacity (α) of the samples with these mineralogical differences were 2.9% and 7.7% lower than the samples that did not have carbonate cores, respectively. Thus, it was found that the differences in mineralogical composition, represented by the carbonate cores, had little influence on the physical properties of the studied metabasalt.

Table 1. Results of metabasalt index properties.

Group	Condition	γ_d (kN/m³)	η (%)	α (%)
1	With carbonate cores	27.23	0.34	0.12
2	Without carbonate cores	26.85	0.35	0.13

Furthermore, the value of γ_d obtained for samples without carbonate cores, corresponding to Group 2, was similar to values found for basaltic rocks in other studies, such as that of Gomes and Rodrigues (2007), who investigated twelve occurrences of columnar basalt in the northern portion of the Paraná Basin, Brazil, and obtained an average dry specific weight of 27.97 kN/m³. However, the values of η and α obtained for Group 2 were lower than those found by other researchers, such as Yaşar and Erdoğan (2004) and Karakuş and Akatay (2013), indicating that the rock under study exhibits very low porosity.

3.2 *P-wave propagation velocity*

The P-wave propagation velocity (*Vp*) results obtained in this study are shown in Table 2.

Table 2. P-wave propagation velocity test results.

Group 1: Samples with cores		Group 2: Without carbonate cores	
Sample	*Vp* (m/s)	Sample	*Vp* (m/s)
1.1	6154	2.1	6269
1.2	6154	2.2	6111
1.3	6176	2.3	6094
1.4	6471	2.4	6111
1.5	6154	2.5	6102
1.6	5897	2.6	6122
1.7	6154	2.7	6441
1.8	6154	2.8	6786
1.9	6154	2.9	6724
1.10	6111	2.10	6154
Average	6157.9	Average	6291.4
Standard deviation	136.9	Standard deviation	267.1
Coefficient of variation	2.2%	Coefficient of variation	4.3%

It can be noted that the difference between the average *Vp* values obtained for the samples with and without carbonate cores was very small, equal to 0.95%. Additionally, the One-Way ANOVA resulted in a P-Value higher than the significance level of 0.05, indicating no significant influence of carbonate cores on the *Vp* value of the analyzed metabasalt.

However, it is noteworthy that the average *Vp* values obtained, of 6,231.7 m/s and 6,291.4 m/s, for the samples of the studied metabasalt with and without carbonate concentration cores, respectively, were similar to those obtained by other researchers in the literature for similar rocks, such as Goodman (1989), Gupta and Rao (1998), Karakuş and Akatay (2013), Aldeeky and Hattamleh (2018), and Goulart (2019).

3.3 *Point Load test*

The point load strength results obtained in this test are shown in Table 3.

Table 3. Point Load test results.

Group 1: Samples with cores		Group 2: Without carbonate cores	
Sample	$Is_{(50)}$ (MPa)	Sample	$Is_{(50)}$ (MPa)
1.1	6,45	2.1	2,50
1.2	4,57	2.2	3,10
1.3	6,17	2.3	2,39
1.4	6,88	2.4	5,04
1.5	6,10	2.5	3,51
1.6	6,09	2.6	2,71
1.7	5,32	2.7	3,76
1.8	6,40	2.8	4,65
1.9	7,46	2.9	4,82
1.10	7,36	2.10	9,12
Average	6,28	Average	4,16
Corrected average	6,35	Corrected average	3,76

Analyzing these results, it can be observed that the $Is_{(50)}$ corrected average value obtained for samples with carbonate cores is approximately 51% higher than the value obtained for samples without carbonate cores. This represents a 69% increase ([6.28-4.16]/4.16 = 69%) in the point load resistance value of the metabasalt.

The One-Way ANOVA resulted in a P-Value lower than the significance level of 0.05, indicating that the presence of carbonate cores significantly influenced the point load resistance value of the analyzed metabasalt. Thus, it can be observed that, although the physical properties of the rock were not influenced by these mineralogical features, an increase in mechanical strength was conferred to the metabasalt due to the presence of these carbonate cores.

A visual confirmation of this increased strength was observed in some cases where the rupture surface developed around these cores, resulting in a rougher texture, as showed in Figure 1, which illustrates two samples exhibiting this behavior. In other cases, the rupture surface traversed through these cores.

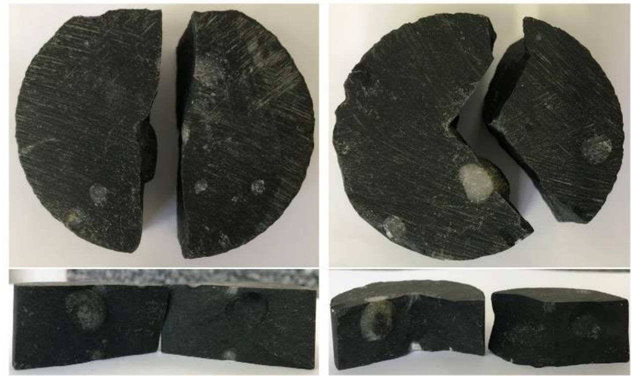

Figure 1. Rupture surfaces developed around the carbonate cores.

Finally, it is noteworthy that the $Is_{(50)}$ results determined in the present study are similar to those obtained by other researchers in the literature, such as Aggistalis *et al.* (1996), Gupta and Rao (1998) and Bhowmick, Ram and Mondal (2022) for basalts.

4 CONCLUSIONS

Based on the results presented in this study, it was observed that the index properties, including apparent dry specific weight, apparent porosity and apparent absorption capacity, as well as the P-wave propagation velocity, were minimally or not influenced by the carbonate concentration cores.

However, the One-Way ANOVA demonstrated that the carbonate concentration cores significantly influenced the point load resistance of the studied metabasalt, resulting in a 69% increase in the $Is_{(50)}$ value of the samples, compared to those without these cores.

Therefore, it can be concluded that the presence of these mineralogical features increased the resistance of the metabasalt, although it did not cause significant changes in its physical properties.

Thus, this study contributed to the development of research that demonstrates the influence of mineralogical composition on the geomechanical properties of rocks.

5 REFERENCES

Aggistalis G., Alivizatos A., Stamoulis D., Stournaras G. 1996. Correlating uniaxial compressive strength with schmidt hardness, point load index, young's modulus, and mineralogy of gabbros and basalts. *Bulletin of The International Association of Engineering Geology*, 22 (1), 3-11.

Aldeeky H., Al Hattamleh O. 2018. Prediction of Engineering Properties of Basalt Rock in Jordan Using Ultrasonic Pulse Velocity Test. *Geotechnical and Geological Engineering*, 36 (6), 3511–3525.

Bhowmick S., Ram B. K., Mondal T. K. 2022. An experimental approach to evaluate the role of rock failure modes in mechanical characterization of metabasalts. *Geotechnical and Geological Engineering*, 40 (5), 2867-2880.

Cowie S., Walton G. 2018. The effect of mineralogical parameters on the mechanical properties of granitic rocks. *Engineering Geology*, 240, 204-225.

Gomes R. L., Rodrigues J. E. 2007. Quality ranking of twelve columnar basalt occurrences in the northern portion of the Paraná basin - Brazil. *Engineering Geology*, 91 (2-4), 265-278.

Goodman R. E. 1989. *Introduction to Rock Mechanics*. New York, USA. 562 p.

Goulart D. 2019. *Análise e correlação de propriedades físicas e mecânicas de rochas da Formação Botucatu e Grupo Serra Geral*. Completion of course work, Federal University of Santa Catarina.

Gupta A. S., Seshagiri Rao K. 1998. Index properties of weathered rocks: inter-relationships and applicability. *Bulletin of Engineering Geology and the Environment*, 57(2), 161–172.

IBRAM – Instituto Brasileiro de Mineração. 2022. *Mineração em Números*. https://ibram.org.br/mineracao-em-numeros/

ISRM – International Society for Rock Mechanics and Rock Engineering. 2007. *The Complete ISRM Suggested Methods for Rock Characterization, Testing and Monitoring: 1974-2006.*

Karakuş A., Akatay M. 2013. Determination of basic physical and mechanical properties of basaltic rocks from P-wave velocity. *Nondestructive Testing and Evaluation*, 28 (4), 342–353.

Ündül Ö. 2016. Assessment of mineralogical and petrographic factors affecting petro-physical properties, strength and cracking processes of volcanic rocks. *Engineering Geology*, 210, 10-22.

Vale. 2023. *Vale no Pará*. https://www.vale.com/pt/para

Yaşar E., Erdoğan Y. 2004. Estimation of rock physicomechanical properties using hardness methods. *Engineering Geology*, 71 (3-4), 281-288.