DOI: https://doi.org/10.68732/60accfd3d518d67b

ISBN: 978-9989-2053-6-1

Using Blanco Mera granite as standard reference and benchmark material

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Abstract

In geotechnical engineering, researchers frequently rely on well-known reference soils such as Toyoura sand, Ottawa sand, or London clay. These materials are widely used because of two essential characteristics: reproducibility and comparability. Reproducibility ensures that experiments can be repeated under nearly identical conditions, yielding results consistent across time and location. Comparability makes it possible to benchmark results between testing methods, laboratories, and equipment. Together, these attributes allow such soils to serve as reliable materials for validating numerical models, constitutive laws, and experimental techniques.

In contrast, rocks present a more complex situation. Unlike soils, commonly treated as homogeneous and isotropic materials, rocks are intrinsically heterogeneous and anisotropic, which strongly influence their behaviour. Consequently, establishing typical or reference rocks is less straightforward. Nevertheless, several candidates have gained recognition in the literature, including Lac du Bonnet granite, Berea sandstone, and Westerly granite. These rocks have been extensively tested and are frequently used in studies of fracture mechanics, hydraulic conductivity, and strength characterization. A key challenge is defining the threshold at which a rock can be considered a standard reference material, given the variability observed even within a single quarry.

Based on an extensive experimental campaign on Blanco Mera granite, this study examines the criteria for defining a benchmark rock. More than twenty tests per property were performed, including uniaxial compressive strength (112.71 MPa), tensile strength (9.32 MPa and 5.64 MPa). Results show low standard errors, indicating good repeatability. These findings support considering Blanco Mera granite as a potential reference rock and establish requirements for standardization in geotechnical research. Additional analysis also highlights consistent wave velocity measurements, supporting the mechanical stability of the material across different test conditions and reinforcing its suitability as a reference material for laboratory comparisons and model validation purposes in future applications.

Keywords

Testing, Reference Rock, Benchmark.

1 Introduction

Although soils can often exhibit complex behaviour, they can frequently be described as CHILE-type material, meaning they are *Continuous, Homogeneous, Isotropic, Linear-Elastic*.These properties make them relatively easier to characterize and allow results to be extrapolated in a way that is easier than on rocks. This facilitates the identification of patterns or what we might call "reference soils." Such soils are highly useful in geotechnical engineering because they are employed to calibrate and compare results among testing machines or laboratories, helping to meet rigorous international testing standards.

Rocks, on the other hand, rarely display this behaviour and are almost always better described as DIANE-type solids, meaning they are *Discontinuous, Inhomogeneous, Anisotropic, Non-linear-Elastic*. which, in practical terms, implies that even when using the same rock extracted from different locations within the same quarry, there can be significant differences that affect their mechanical properties

Unlike soils, only a few rocks can be considered "standard" due to their specific applications. For example, Lac du Bonnet granite has been widely studied in laboratories for its thermo-mechanical and mechanical properties (Annor and Jackson, 1986). Another example is a rock extensively analysed for permeability and hydraulic fracturing, the Berea sandstone, primarily in the petroleum industry (Oak et al., 1990). Lastly, Westerly Granite has been widely used in permeability studies under varying temperatures (Summers et al., 1978). These examples illustrate that only a limited number of rocks could be considered as standards. Therefore, in rock mechanics, it is important to establish a framework for defining and using standard reference rocks in specific fields, where the lack of such references makes it difficult to obtain reliable test results and, ultimately, to interpret them within a consistent rock mechanics context.

Through this document, we aim to try to open a debate in this issue by using a type of rock widely employed in different laboratories to propose a tentative framework—or at least to try to define minimum characteristics required—to classify a rock as a standard reference material.

2 Framework of characteristics

In this section we will try to establish a tentative framework in which we can define minimum requirements in order to establish a rock type, based on four different parameters, that means focus on number of tests, fields of studies, laboratories which has performed the studies, and lastly the types of tests.

2.1 Number of tests

In this case, we can establish a minimum number of tests, ensuring that each individual test represents less than 1% of the total dataset. Based on this criterion, at least 100 tests should be performed to adequately characterize the rock. This approach guarantees that the collected data provides a robust representation of its mechanical behaviour, including strength and fundamental elastic properties such as the Elastic Limit and Poisson's ratio. By increasing the number of tests, we reduce the influence of any single measurement and improve the reliability of the overall characterization, which is essential for assessing a rock to be considered as Rock type.

2.2 Number of studies

In this case, at least two independent studies should be available, even if they adopt different methodological approaches, provided that they include the same type of tests. This requirement ensures that meaningful comparisons can be made to determine whether the studies can be considered part of the same group. Furthermore, to strengthen the reliability of the conclusions, it is recommended to include at least three distinct studies, each based on different datasets but containing comparable types of data. This approach enhances the robustness of the analysis and reduces the risk of bias associated with relying on a single source.

2.3 Laboratories

To classify a rock type, it is essential to establish repeatability in the tests performed. This is particularly important because each laboratory, even when following the same procedures or standards, may use different equipment and testing conditions. Such variations can introduce

discrepancies in the results. Therefore, to ensure that a rock can be considered a standard reference material, at least two independent sets of tests should be conducted—either in different laboratories or using different testing machines within the same laboratory. This requirement helps confirm that the results are consistent and belong to the same group, even when obtained under varying conditions. By validating repeatability across different setups, we strengthen the reliability of the characterization and minimize the influence of equipment-specific biases.

2.4 Test type

Regarding the types of tests that should be performed, although the minimum requirements depend on the ultimate purpose for which the rock characterization will be used, the most relevant parameters are typically those related to the rock's strength and elastic properties, as well as the characteristics of its joints. These parameters are essential for accurately establishing the mechanical behaviour of the rock under different loading conditions. Therefore, in order to define a rock type, priority should be given to tests that provide data on these aspects.

3 A Spanish example of

The rock presented here is the Blanco Mera Granite. Blanco Mera is a bright white granite characterized by a mineral composition of 35% plagioclase feldspar, 27% alkali feldspar, and 20% quartz. Accessory minerals include muscovite (7%) and biotite (5%), with trace amounts (under 5%) of chlorite and sericite. As illustrated in Fig. 1, the grain distribution is somewhat irregular, with quartz crystal sizes ranging from 1 to 6 mm and feldspar crystals ranging from 1 to 3 mm along with various mica minerals.This rock is mainly used for ornamental purposes, such as kitchen countertops and as large blocks for fencing plots of land.

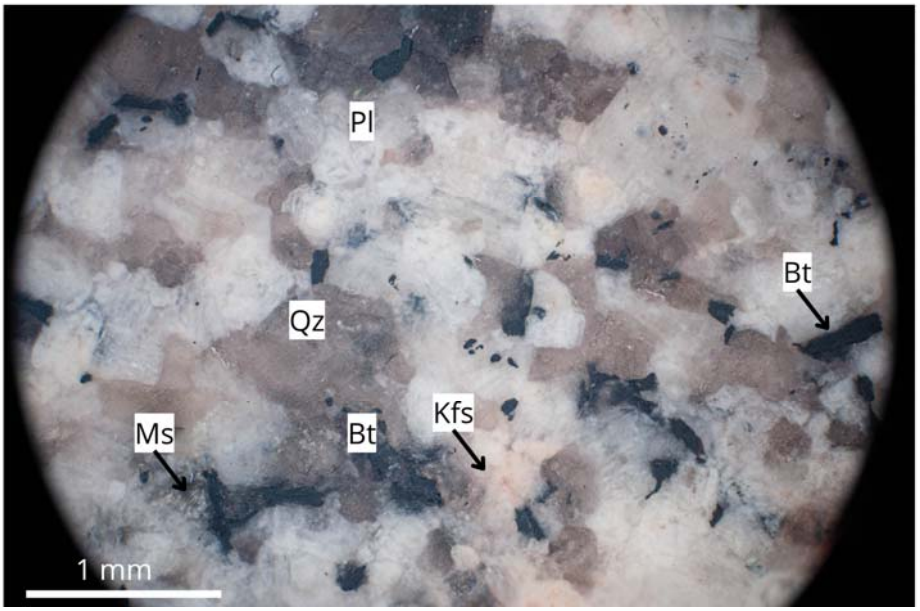


Fig. 1 Details of a surface of Blanco Mera Granite, where the different minerals are observed. Qz refers to Quartz, Kfs Alkali feldspar, Pl Plagioclase feldspar, MS Muscovite and Bt Biotite.

3.1 Available data

During various studies, a database was compiled on Blanco Mera described on the previous section. Although more than 25 studies have been published on this rock in different areas—such as scale effects, jointed rocks, fracture toughness, and permeability—we present here results of the main properties derived from those studies, performed through compressive tests, and its posterior analysis (Alejano et al., 2017 and 2021; González-Fernández et al.,2023, 2024a and 2024b, Quiñones et al, 2017), as well as direct and indirect tensile strength tests (Pérez-Rey et al., 2023 and 2024). Readers can refer to the extended database provided in these studies, which contains more than 100 UCS and triaxial tests performed on NX diameter, having these studies a total of near 400 tests, along with approximately 40 direct tensile tests.

To analyse the data, we will apply different strategies. First, all data of the same type will be grouped, and basic statistical parameters such as the mean, standard error will be calculated. These metrics will

serve as indicators of strength consistency and variability within each dataset. By examining these values, we can obtain an initial assessment of the quality and reliability of the experimental results, providing a solid foundation for subsequent interpretation and deeper statistical analysis.

Finally, we will generate Hoek–Brown failure envelopes along with confidence bounds to compare all strength data from the three studies. This approach will allow us to visualize variability and establish a more robust interpretation of the mechanical behaviour of the rock.

Results of the principal parameters derived from data collected from compressive and tensile tests are presented on Table1.It should be noted that only Nx diameter tests were used for this brief study, although different sizes and types of samples are presented on the studies, and deformability data are available, due to the limit extension of the document we decided to use only NX data.

Table 1. Values of the basic parameters collected through different studies. Alejano et al (2017, 2021), González et al (2023, 2024a, 2024b), Quiñones et al (2017) Perez-Rey (2023, 2024).

Test type	**Average Value**	**Standard Error**	**Number of test**
UCS [MPa]	112.71	3.15	23
DTS [MPa]	5.64	0.21	24
ITS [MPa]	9.32	0.19	10
K_{IC}^{pCT} [MPa m$^{1/2}$]	1.02	0.03	5
E_{UCS} [GPa]	52.72	2.35	5
E_{DTS} [GPa]	23.36	1.34	24
ν_{UCS} [-]	0.26	< 0.01	5
ν_{DTS} t [-]	0.11	< 0.01	17
V_p[km s^{-1}]	5.28	0.02	22
V_s [km s^{-1}]	2.89	0.05	22
γ [kN m^{-3}]	25.63	< 0.01	22
k_n[GPa m^{-1}]	1734.58	189.70	7

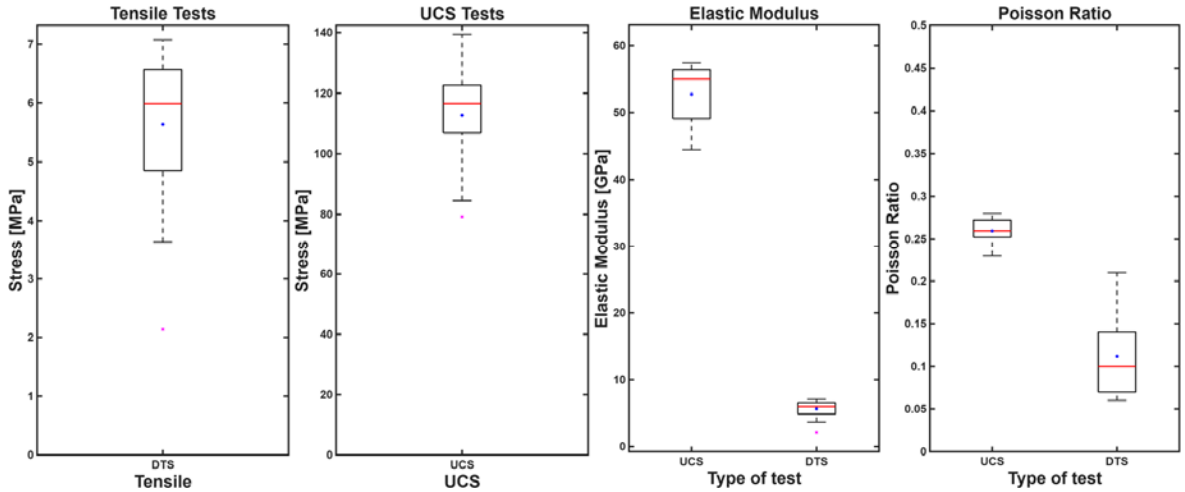


Fig. 2 Box plots of all data used to compute basic statistical data. Left , for tensile tests, middle for UCS tests and right for triaxial compressive tests.

The remaining compressive strength values demonstrate a high degree of agreement across the different confining pressure levels, reflected in their low or assumable dispersity displayed on boxplots of Figure 2. Such low dispersity indicate a strong level of consistency and reliability in the experimental results, suggesting that the material behaviour is stable and that the testing procedures were carried out under well-controlled conditions. In practical terms, this implies that the measured strength values cluster closely around the mean, reducing the likelihood of significant outliers and supporting the statistical robustness of the dataset.

The fitted curves and the corresponding plotted datasets presented on Figure 3 and Table 2 reveal a clear and consistent alignment across all test conditions. The close similarity in both the shape of the curves and the estimated fitting parameters demonstrates strong agreement between the experimental

measurements and the selected fitting models. This concordance indicates that the chosen fit adequately captures the underlying mechanical response of the material over the tested range.

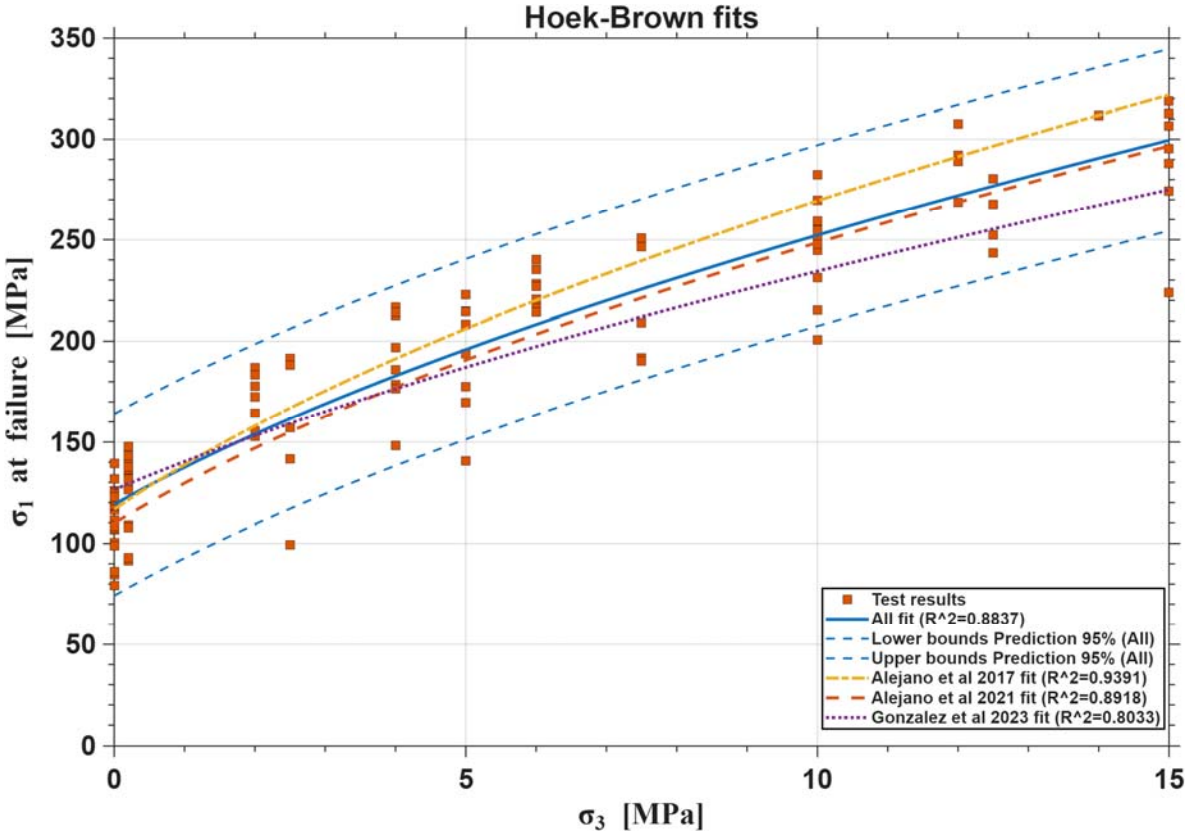


Fig. 3 Hoek-Brown fits for, indiviual studies and all data together.

Such consistency is further reinforced by the overlapping trends observed across the different tests, suggesting that the datasets exhibit comparable statistical and mechanical characteristics. This uniform behaviour supports the interpretation that the results originate from the same material group, or at least from specimens with sufficiently similar properties to justify their joint analysis. The coherence across fits is therefore an important indicator of data reliability, as it reduces the likelihood that the observed patterns are caused by sample-specific anomalies or uncontrolled testing conditions.Although some results, particularly those reported by Gonzalez et al. (2023), show a lower correlation coefficient compared to the others, the authors attribute this to the natural variability of the rock. Even when obtained from the same quarry, the samples may exhibit inherent variability.

Table 2. Values of the Hoek-Brown parameters obtained through different sets of studies.

Study	**Tests**	**H-B parameter**		**Coefficient of correlation R^2**
		m_i [-]	**σ_{ci} [MPa]**	
Alejano (2017)	59	46.02	116.66	0.94
Alejano (2021)	22	40.83	109.84	0.89
Gonzalez-Fernandez (2024)	24	27.20	126.39	0.80
All data	111	37.38	119.06	0.88

4 Conclusions

This document aims to establish a framework for defining when a rock can be considered a standard. Within this framework, it is essential to set a minimum number of tests to ensure statistical robustness and reliability of the results. A sufficient sample size reduces variability and increases confidence in the characterization. Additionally, at least two independent studies should be available, analyzing the same parameters but conducted in different laboratories or using different testing equipment. This requirement guarantees that, after performing statistical analyses, the results are consistent and reproducible across different conditions. Furthermore, the minimum set of parameters to be studied must include those related to strength and elastic properties, as these are fundamental for understanding the mechanical behavior of the rock.

In order to establish a framework for defining a typical rock, we present Blanco Mera Granite as a possible candidate for 'standard rock'. Although the primary dataset includes approximately 150 tests performed exclusively on intact specimens with a diameter of 54 mm, the overall number of tests exceeds 600. These additional tests encompass a wide range of investigations, including scale effects, fissured specimens, tensile strength, fracture toughness, and permeability, among others. Beyond providing fundamental parameters such as strength and elasticity, these tests also deliver specific data relevant to each specialized study. Importantly, the experiments were conducted in different laboratories or, when performed in the same facility, using different machines. This diversity enhances the robustness of the dataset and ensures repeatability and comparability across varying conditions. Therefore, given that the proposed framework is satisfied, we can reasonably conclude that Blanco Mera rock meets the criteria to be considered a standard rock type.

Acknowledgements

The first author acknowledges the Spanish Ministry of Science, Innovation & Universities for financing his research through a grant contract PTA2024-025163-I.

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