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Article

Evaluation of the relationships between compression resistance, point load and indirect traction of aggregates of the built heritage in San Francisco de Campeche

Evaluación de las relaciones entre las resistencias a compresión, carga puntual y tracción indirecta de agregados del patrimonio edificado en San Francisco de Campeche

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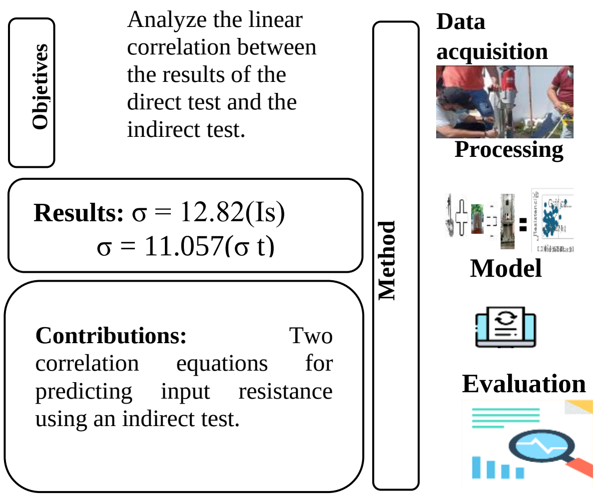
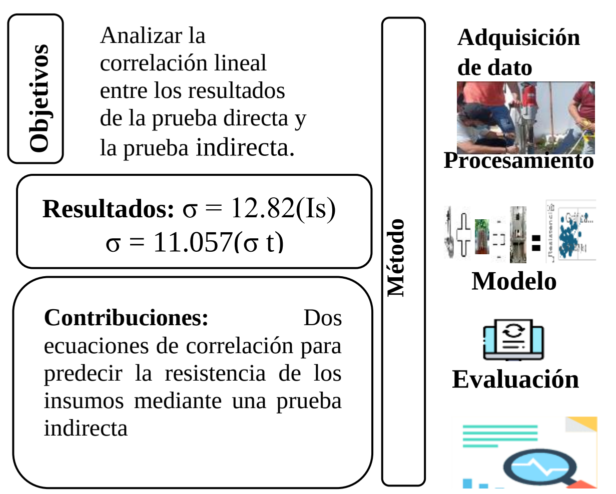
Abstract

This research work analyzed the properties of stone aggregates, focusing on uniaxial compressive strength, point load strength tests and indirect tensile test. Seybaplaya, a port in Campeche, Mexico, was the site of sample collection from an active bank. The results showed that the compression varied between 8.6 - 84.7 MPa, the point load between 0.52 - 7.12 MPa, and the indirect tension between 0.672 - 10.839 MPa. These properties are essential for designers and builders, providing guidance on the importance of aggregates in structures.

Resumen

Este trabajo de investigación analizó las propiedades de los agregados pétreos, centrándose en la resistencia a la compresión uniaxial, pruebas resistencia a la carga puntual y prueba de tracción indirecto. Seybaplaya, es un puerto en Campeche, México, fue el lugar de recolección de muestras de un banco activo. Los resultados mostraron que la compresión varió entre 8.6 - 84.7 MPa, la carga puntual entre 0.52 - 7.12 MPa, y la tracción indirecta entre 0.672 - 10.839 MPa. Estas propiedades son esenciales para diseñadores y constructores, proporcionando una guía sobre la importancia de los agregados en las estructuras.





Simple uniaxial compressive strength, rock point load index and indirect tensile in rocks

Resistencia a la compresión uniaxial simple, índice de carga puntual de roca y traccion indirecta en rocas

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Introduction

All built heritage is based on soil or rock, rocks being the essential raw material for construction. Therefore, it is crucial to consider their characteristics, as they guarantee stability from the foundation. The predominant rocks in our environment are mainly limestones, which are economical and have good physical-mechanical properties for construction. However, they can suffer chemical and physical alterations that affect their appearance and mechanical behaviour (Espinosa Morales *et al*. 2020; Stelfox 2021). It is essential to know the physical and mechanical properties of the rock banks from which materials are extracted for the construction and conservation of built heritage.

The strength of rocks is crucial for our buildings (Naal-Pech *et al*., 2023). These rocks are hard and compact natural aggregates formed by mineral particles with permanent cohesive bonds. Geological classification is based on characteristics such as mineral proportion, granular structure, texture and origin of the rock (González, 2002).

In the State of Campeche, there is an important built heritage of baroque architecture built with limestone masonry, exposed to the humid tropical climate. These materials suffer alterations due to weathering, so it is essential to understand the characteristics of stone materials. The variety of structures, rock types and their spatial distribution have a significant influence on the structural damage of built heritage in the State. It is essential to identify these phenomena in order to adapt land use and reduce the vulnerability of buildings. This research focuses on the characterisation and mitigation of geological hazards associated with geomorphology, especially in karst areas in the state of Campeche (Palacio *et al*., 2013).

Knowing the distribution of the rock bank facilitates the grouping and characterisation of rocks by means of mechanical behaviour parameters obtained from tests on representative samples. The resistance to simple compression of a rock (RCUS) is fundamental to classify it according to its strength, being a key parameter in the most commonly used fracture criteria (Delgado, 2013).

Aggregates are classified into two groups according to their size: fine and coarse. Fine aggregates are natural or manufactured sands with particles from 60 µm to 5 mm, while coarse aggregates have particles from 5 mm to 125 mm (Neville, 1999).

Aggregates are classified according to their density as light, normal and heavy, which influences the unit weight of concrete (Alatorre and Uribe, 1998). Other relevant physical properties include particle shape and texture, porosity, absorption, density, bond and strength. The particle size and maximum aggregate size, such as gravel, are crucial for the behaviour of concrete in its plastic and hardened states.

In tests of concrete with limestone aggregates in the Yucatan Peninsula, failure often occurs in aggregates, especially with water/cement ratios below 0.5. In addition to strength, characteristics such as aggregate size, shape, surface texture and mineralogy also affect concrete strength to varying degrees (Ezeldin & Aitcin, 1991).

It is essential to know the behaviour of stone aggregates, since all concretes in our country use aggregates from two sources: natural deposits (rivers, beaches, etc.) and rock crushing products.

The correlations were derived from numerous tests and analyses of rock cores, which allow characterising and relating specific rock parameters. Researchers have developed correlation equations, evaluated in the laboratory and in the field, which relate the uniaxial compressive strength (RCUS) and the point load index. See **Table 1**:

Box 1

Table 1
Correlation equations between simple uniaxial compression (RCUS) in MPA and point load index.

Year	Autors	Correlation Equation
1972	Broch and Franklin	$RCUS=24*Is_{(50)}$
1975	Bieniawski	$RCUS=23*Is_{(50)}$
1980	Hassani et al.	$RCUS=29*Is_{(50)}$
1981	Singh	$RCUS=18.7*Is_{(50)}-13.2$
1984	Gunsallus and Kulhawy	$RCUS=16.5*Is_{(50)}+51.0$
1992	Grasso et al.	$RCUS=25.67*[Is_{(50)}]^{0.57}$
2001	Kahraman	$R=8,41*Is_{(50)}+9.51$

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Year	Autors	Correlation Equation
2003	Quane and Russel	$RCUS=3.86*[Is_{(50)}]^2+5.62*Is_{(50)}$
2004	Tsiambaos and Sabatakakis	$RCUS=7.3*[Is_{(50)}]^{1.71}$
2005	Fener et al	$RCUS=9.08*Is_{(50)}+39.32$
2007	Akram, M. y Bakar, M.Z.A.	RCUS=22.7921*Is(50)+13.295
2007	Akram, M. y Bakar, M.Z.A.	RCUS=11.076*Is(50)
2008	Cobanoglu, I. y Celik, S,B.	RCUS=8.66*Is(50)+10.85
2010	Altindag and Guney	$RCUS=12.38*[BTS]^{1.0725}$
2011	Tahir et al	RCUS= 7.53 * BTS
2012	Kahraman et al.	RCUS=10.61*BTS
2013	Nazir et al.	$RCUS=9.25*[BTS]^{0.947}$
2015	Kahraman et al.	RCUS=24.30+4.87*BTS

Studio area

Seybaplaya is located on the 'Yucatan Platform', an expanse of sedimentary rock formed by marine sediments millions of years ago, with a depth of approximately 200 metres. Its soil is composed mainly of limestone and clay, and the area contains deposits of oil and natural gas, which are essential to the local economy. It is essential to analyse the rock characteristics of the bench at Seybaplaya, known as Mary Carmen, where there is a quarry. **Figure 1** shows the geographic location of the bedrock bench, and **Table 2** details the type of material and its volume.

Box 2

Figure 1
Seybaplaya rock bank location in Campeche state, Mexico
Source: *http://b.materiales.siac.gob.mx/*

Box 3

Table 2
Characteristics of the Bank in seybaplaya called Mary Carmen

State:	Campeche		
Name of the bank:	Mar y Carmen		
Kilometre:	1000		
Location:	PAYUCAN		
UTM coordinates	X 741570.00		Y 2174740.00
Deviation:	Right	Metres:	0
Type of property:			
Type of material:	TEZONTLE		
Treatment:			
Volume x 1000 (m³):	500	Clearance thickness (m):	0.2
Likely uses:			
Use of explosives:	Unrestricted		There are no
Economic aspects:	Convenient	Quality report:	Report

Methodology

The most common indirect destructive tests on rocks are the point load test (PLT) and the indirect tensile test (BTS). On the other hand, the most commonly used direct destructive test is the simple uniaxial compressive strength test.

A systematic framework is presented to analyse the relationship between uniaxial compressive strength and indirect destructive tests (point load index and indirect tensile test or BTS) on rocks from the Mary Carmen bench in Seybaplaya, Campeche. The steps to be followed to achieve a structured and logical process are detailed.

- Bench exploration and exploitation
- Sample extraction and preparation
- Indirect test (point load index)
- Indirect tensile test (Brazilian method)
- Compressive strength test (compression test)
- Simple uniaxial compressive strength test (RCUS).

Each phase is broken down in this section:

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Exploration and bench mining.

In soil exploration, methods such as open pit, post hole and auger are used. For rock benches, on the other hand, more expensive drilling methods are used.

Although rock benches should be sampled randomly, some institutions determine the number of boreholes according to the volume of material to be exploited, without taking into account the homogeneity of the formation. **Figure 2** shows the Mary Carmen bench.

Box 4

Figure 2
Mary Carmen Rock Bank located at Seybaplaya Campeche, Mexico

Sample extraction and preparation A standard procedure is established for the preparation of rock core samples according to ASTM 2008 D4543.370238-1. Samples should be straight circular cylinders with a length to diameter ratio of 2.0 to 2.5 and a minimum diameter of 47 mm. In addition, the ends must be polished and flat, with a maximum tolerance of 0.001 inch, in this research 50 samples of 53.0 mm were worked. Figure 3 sample preparation

Box 5

Figure 3
Sample preparation for the test

Indirect test (point load test)

The Point Load Test (PLT), according to ASTM D5731-05, also known as the Franklin test, is one of the most widely used indirect methods for determining rock strength. It is performed by applying a point compressive load along the diameter of a cylindrical rock sample until failure, using two truncated metal cones in coaxial and opposite positions. The cone dimension is standardised, as shown in **Figure 4**.

Box 6

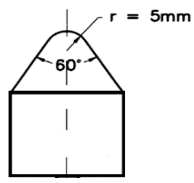

Figure 4
Standardised truncated cone for point load index test

The uncorrected point load index is calculated with equation 1

$$Is = P*1000/(D_e)^2 \quad (1)$$

Where:

P= Load applied in (kN).

D_e = Distance between load-bearing conical tips (mm).

Is = Point load index, uncorrected (Mpa).

Indirect tensile test (BTS)

The Brazilian test (ASTM D3967-08) is a simple indirect method for determining the tensile strength of brittle materials such as rocks. It consists of applying a compressive load along the diameter of a cylindrical rock sample until it breaks. There are several types of load plates, as shown in Figure 5.

Box 7

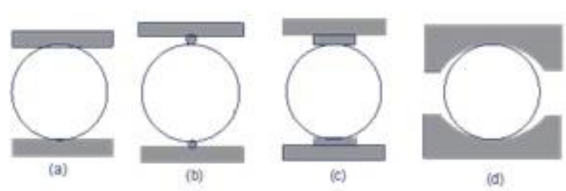

Figure 5
Typical loading configurations for the Brazilian tensile test: (a) flat load plates, (b) flat load plates with two small diameter steel rods, (c) flat load plates with cushion and (d) curved load jaws

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The indirect tensile strength shall be calculated by equation 2

σ_t=2P/(π*L*D) =0.6366*P/(L*D) (2)

Where:

P= Load applied in (N).

L= Thickness of sample in (mm).

D=Diameter of sample in (mm).

σ_t = Indirect tensile strength (Mpa).

Simple uniaxial compressive strength test (RCUS)

The uniaxial compression test is performed according to the standard (ASTM D7012-10). This method allows the calculation of the uniaxial compressive stress, Poisson's ratio and Young's modulus of a rock core (Peng and Zhang, 2007). The simple uniaxial compressive strength is determined using **the equation (3).**

σ=RCUS = P/A (3)

Where:

σ = RCUS = resistance to simple uniaxial compression in Mpa.

P = Axial load N.

A = Cross-sectional area mm^2.

Simple compression test procedure.

Note the dimensions to assess the cross-sectional area.

Ensure that the universal machine is calibrated correctly and in optimum condition, with the reading at zero before starting any measurements.

Position the specimen so that it is perfectly centred between the compression platens of the universal machine.

Use the control software to program the machine and run the compression test properly.

Carry out the test until failure of the specimen is detected, watching carefully for cracks. see **Figure 6**.

Box 8

Figure 6
Compression test with the universal machine

Remove the load from the flask. Remove the specimen from the machine and proceed to place a new sample, repeating the procedure described above. (Nieto & Avendaño, 2015).

Results

In this investigation, 50 single uniaxial compressive strength tests (RCUS), 50 point load tests (PLT or Is) and 50 indirect tensile tests (BTS) were carried out, obtaining the results presented in **Table 3**.

Box 9

Table 3
Results of the 50 samples: where ID is the sample identification number, Rcus in MPA, PLT in MPA and BTS in Mpa.

ID	Point loading rate (PLT or Is) in MPA	Brazilian Test σt=0.6366*P*1 000/(D*L)	RCUS simple uniaxial compressive strength at MPA
1	3.248	3.829	31.6
2	1.283	1.150	28.6
3	0.888	4.239	46.8
4	0.772	2.732	15.2
5	1.912	1.631	18.3
6	2.964	2.374	11.7
7	1.743	1.907	22.7
8	3.143	0.972	42.1
9	1.797	1.859	53.4
10	0.969	0.672	14.9
11	4.339	4.373	68.6
12	1.486	2.386	8.6
13	1.817	3.722	23.2
14	3.548	4.222	40.7
15	3.468	4.149	43.5
16	3.590	1.702	28.7
17	1.949	2.893	43.6
18	1.119	5.562	55.5

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ID	Point loading rate (PLT or Is) in MPA	Brazilian Test σt=0.6366*P*1 000/(D*L)	RCUS simple uniaxial compressive strength at MPA
19	1.880	2.057	32.3
20	0.854	2.285	61.3
21	0.960	3.125	78
22	3.459	3.192	61.9
23	1.051	2.746	42.4
24	5.468	3.464	49.1
25	7.117	10.839	84.7
26	3.167	4.788	72.8
27	2.616	6.858	38.1
28	4.477	5.475	33.2
29	2.469	3.906	58
30	3.109	3.865	23.9
31	0.522	2.246	21.3
32	1.424	2.435	40
33	3.519	5.101	34.8
34	2.145	2.501	43.6
35	2.833	1.586	18.5
36	2.836	3.154	54.1
37	3.345	1.333	45.5
38	2.985	3.872	44.1
39	2.298	1.459	22.4
40	3.635	1.951	35.1
41	0.551	2.915	43.4
42	2.563	3.767	37.4
43	3.007	2.280	31
44	4.305	4.435	36.5
45	4.461	1.612	63.7
46	3.086	0.711	15.7
47	2.557	1.643	57.6
48	3.601	2.065	40.5
49	4.032	3.633	65.1
50	3.731	1.404	23.3

The correlation between RCUS and PLT or Is tests on Seybaplaya rocks is significant, with an R2 of 0.7649. This indicates a strong linear relationship, explaining 76.49% of the variability in compressive strength, which is statistically acceptable to see. **Fig. 7**

Box 10

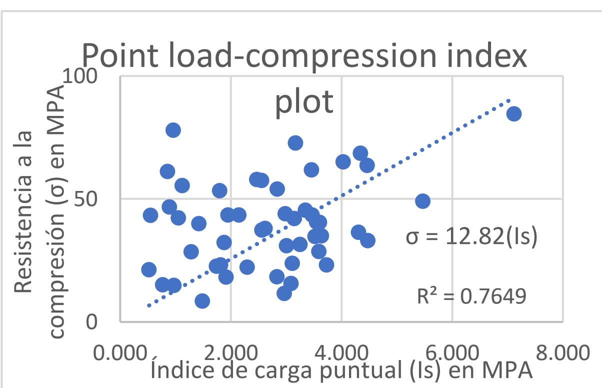

Figure 7
Correlation plot between RCUS and load index value (PLT) in rock samples

The correlation between RCUS and BTS in the Seybaplaya rocks is significant, with an R2 of 0.7885. This indicates a strong linear relationship, explaining 78.85% of the variability in compressive strength, which is statistically acceptable. **Fig. 8**

Box 11

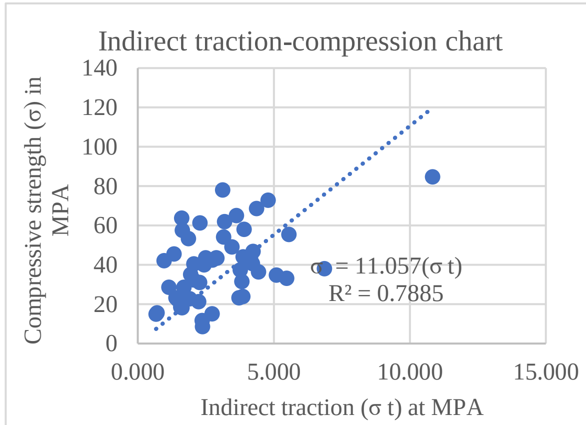

Figure 8
Correlation graph between RCUS and indirect tensile strength (BTS) in rock samples

Discussion

With the help of an expert, explosives were used to blast the bench and large rock fragments were selected at random to extract samples. It was observed that the drilling rate varied with the hardness of the rocks, confirmed by compression tests and identification of samples by their ID. In addition, when water was injected into the drill hole, a white liquid was produced, indicating the presence of limestone. Three samples were extracted from each fragment: one for point load test, indirect tensile test and one for compressive strength assessment.

The compression test specimens were measured with a vernier caliper and subjected to cross-sections. Some specimens disintegrated, preventing them from meeting the length ratio of 2 to 2.5 times their diameter, which required drilling new specimens. The point load index specimens, also measured with a vernier caliper, met the length to diameter ratio of 1 according to the standard. Likewise, the indirect tensile specimens met the length-to-diameter ratio of 0.5, according to the standard.

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For the load index test on rock samples, diametric tests were performed on cylindrical samples to determine the uncorrected point load resistance index (Is). This index was obtained by applying a concentrated point load with truncated conical plates until the sample was fractured. In addition, compression tests were carried out on a universal machine with dry samples, obtaining consistent results throughout the process.

- It is observed that the rocks show numerous discontinuities.

- When examining the RCUS-PLT graph, it can be seen that there is an acceptable relationship.

- When examining the RCUS-BTS graph, it is seen that there is an acceptable relationship.

- It is shown that the dynamite bench mining method also creates micro-cracks that continue to damage the resistors.

- It was observed that the bench material is of limestone type.

Conclusion

This study represents a significant advance in rock mechanics in Campeche, providing a better understanding of rock behaviour, crucial for the construction and rehabilitation of built heritage. Several key considerations stand out as general conclusions.

The data obtained from the aggregates of this bank have allowed the design of blocks used in the construction of confined masonry walls and ramparts, as well as perimeter walls for the reconstruction, rehabilitation and conservation of the built heritage, complying with a structural requirement of average strength of f'c=3.92266 Mpa (40 kg/cm²).

Compression tests of the stone aggregates show an average strength of 40.14 MPa (409.31 kg/cm²). Although this does not allow obtaining high strength concretes for the built heritage, the maximum strength achieved in the region is f'c=29.42 MPa (300 kg/cm²). Knowing the characteristics of this bench, more informed decisions can be made to construct or rehabilitate the built heritage.

The aggregates of the rock bank studied excellently meet the necessary characteristics for use in the restoration and conservation of the façades of the historic centre of San Francisco de Campeche, due to their similarity. This is evidenced in **Figures 9 and 10**.

Box 12

Figure 9
Restoration of the façade of the historic centre of San Francisco de Campeche, Mexico

Box 13

Figure 10
Rehabilitation of the façade of the historic centre of San Francisco de Campeche, Mexico

This study represents a significant advance in rock mechanics in Campeche. The regression models presented are applicable to rocks with similar characteristics to those studied. Among the conclusions, we highlight the determination of the physical-mechanical parameters of the rock samples, whose ranges are summarised in Table 4.

Box 14

Table 4
Range of RCUS, PLT and BTS values in rock samples from the Seybaplaya bench

Concept	Rango	Mean value	Standard deviation	units
RCUS in MPA	8.6 <> 84.7	40.14	17.9977663	Mpa
Value PLT	0.52<>7.12	2.68	1.35	Mpa
Value BTS	0.672<>10.839	3.062	1.768	Mpa

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Statements

Incompatibility

The authors and co-authors declare that they have no conflicts of interest. They have no competing financial interests or personal relationships that could influence the content of this article.

Availability of data and materials

The data obtained from this research are available for consultation at any time as needed.

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Contribution of the authors

The contribution of each researcher in each of the points developed in this research was defined on the basis of the following:

Naal-Pech, José Wilber: He contributed significantly to the conceptualisation of the project, as well as to the development of the research method and technique. He supported the design of the field instrument and carried out the data analysis, systematising the results. She was also in charge of writing the article.

Palemón-Arcos, Leonardo: Carried out the background research for this article and provided support in the design of the field instrument. He also contributed to the drafting of the article.

El Hamzaoui, Youness: Contributed to the data processing and generation of the correlation graphs, as well as to the development of the approach, method and writing of the article.

Gutiérrez-Can, Yuriko: Contributed to the research design, defining the type and focus of the study, as well as developing the method and writing the article.

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Abbreviations

ASTM American Society for Testing and Materials.

RCUS Compressive Strength Uniaxially Simple Compressive Strength.

PLT Point Load Test

References

Background

Alatorre, J., & Uribe, R. (1998). Agregados para concreto: cada cual por su nombre. Construction and Technology (Mexico), 10(121), 13-14.

C. Delgado, Evaluation of a Technological Change for the Processing of High Hardness Minerals. Thesis. University of Chile: 2013.

Espinosa-Morales, Y., Alarcón, A. L., Domínguez-Carrasco, M., Martínez-Miranda, V., Arteaga-Arcos, J. C., Silva-León, I., & Reyes, J. (2020). An Approach to Identify and Understand the Main Processes of Weathering that Suffer the Pre-Hispanic Stelae Located in the CALAKMUL Biosphere Reserve in Campeche, Mexico. Archaeometry, 1-17.

Ezeldin, A. S., & Aitcin, P. C. (1991). Effect of coarse aggregate on the behavior of normal and high-strength concretes. Cement and Concrete Aggregates (U.S.A.), 13(2), 121-124.

González de Vallejo L. I., Ferrer M., Ortuño L., Oteo C., (2002) Ingeniería Geológica, Editorial Pearson Educación, Madrid, ISBN84-205-3104-9.

Naal-Pech, José W., Palemón-Arcos, Leonardo, El Hamzaoui, Youness and Gutiérrez-Can, Yuriko. 2023. Study of the relationship between uniaxial compressive strength, water content, porosity and density in bank rocks in Seybaplaya Campeche. Doi: 10.35429/JME.2023.20.7.9.16. Vol.7 No.20 9-16.

Neville, A. (1999). Concrete technology. Mexico: IMCYC, p. 163.

Palacio Aponte A. G., 2013. Identification and Characterization of Subsidence and/or Collapse of Karstic Soils. P. 169-181. In: Posada Vanegas G., B.E. Vega Serratos, and Silva Casarín (eds), Peligros Naturales en el Estado de Campeche. Quantification and Civil Protection. Universidad Autónoma de Campeche, cenecam-Gobierno del Estado de Campeche, cenapred.

Stelfox, D. (2021). Natural Stone Database. Online information for the stone-built heritage of Northern Ireland.

Basics

ASTM 05 Standards, Standard: D 5731-05. Test Method for Determination of the Point Load Strength Index of Rock.

ASTM 2008. Standard Practices for Preparing Rock Core as Cylindrical Test Specimens and Verifying Conformance to Dimensional and Shape Tolerances. D4543.370238-1.

ASTM 08 Standards D3967-08 Standard test method for splitting tensile strength of intact rock core specimens, 2008, 4p.

ASTM 2010a. Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures. D7012-10.

Nieto, G. C., & Avendaño, D. P. (2015). Resistance of Materials Laboratory Guide. Bogota D.C: Inimagdalena.

Peng, S. and Zhang, J., Rock properties and mechanical behaviors. Engineering Geology for Underground Rocks. Springer Berlin Heidelberg, 2007.

Supports

Çobanoğlu and S. B. Çelik (2008): Estimation of uniaxial compressive strength from point load strength, schmidt hardness and P-wave velocity, Bulletin of Engineering Geology and the Environment, 67: 491-498.

Bieniawski ZT (1975) Point load test in geotechnical practice. Eng Geol 9(1):1-11.

Broch E, Franklin JA (1972). Point-load strength test. Int J Rock Mech Min Sci 9(6):669-697.

Fener M, Kahraman S, Bilgil A, Gunaydin O (2005) A comparative evaluation of indirect methods to estimate the compressive strength of rocks. Rock Mech Rock Eng 38(4):329-343.

Grasso P, Xu S, Mahtab A (1992) Problems and promises of index testing of rocks. In: Tillerson JR, Wawersik WR (eds) Proceed ings of the 33rd US symposium on rock mechanics. Balkema, Rotterdam, pp 879-888.

Gunsallus KL, Kulhawy FH (1984) A comparative evaluation of rock strength measures. Int J Rock Mech Min Sci 21:233-248.

Hassani FP, Scoble MJ, Whittaker BN (1980) Application of point load index test to strength determination of rock and proposals for new size-correction chart. In: Summers DA (ed) Proceedings of the 21st US symposium on rock mechanics. University of Missouri Press, Rolla, pp 543-564.

Kahraman S (2001) Evaluation of simple methods for assessing the uniaxial compressive strength of rock. Int J Rock Mech Min Sci 38:981-994.

K. Karaman, F. Cihangir, B. Ercikdi, A. Kesimal, S. Demirel. 2015. Utilization Of The Brazilian Test For Estimating The Uniaxial Compressive Strength And Shear Strength Parameters. Journal of the Southern African Institute of Mining and Metallurgy. 115(3): 185-192.

ISSN: 2444-4987
RENIECYT-CONAHCYT: 1702902

M. Akram and M. Z. A. Bakar (2007) Correlation between Uniaxial Compressive Strength and Point Load Index for Salt-Range Rocks Pak. J. Engg. & Appl. Sci. Vol. 1 July 2007.

M. Tahir, N. Mohammad, F. Din. 2011. Strength Parameters And Their Inter-Relationship For Limestone Of Cherat And Kohat Areas Of Khyber Pakhtunkhwa. Journal of Himalayan Earth Sciences. 44(2): 45-51.

Quane SL, Russel JK (2003) Rock strength as a metric of welding intensity in pyroclastic deposits. Eur J Mineral 15:855-864.

R. Altindag, and A. Guney. 2010. Predicting the Relationships between Brittleness and Mechanical Properties (UCS, TS and SH) of Rocks. Scientific Research and Essays. 5(16): 2107 - 2118.

R Nazir, E. Momeni, D. Jahed Armaghani and M. F. Mohd Amin. 2013. Correlation Between Unconfined Compressive Strength And Indirect Tensile Strength Of Limestone Rock Samples. Electr J GeotechEng. 18 (I): 1737-1746.

S. Kahraman, M. Fener, and E. Kozman. 2012. Predicting the Compressive and Tensile Strength of Rocks from Indentation Hardness Index. Journal of the Southern African Institute of Mining and Metallurgy. 112(5): 331-339.

Singh DP (1981) Determination of some engineering properties of weak rocks. In: Akai K (ed) Proceedings of the international symposium on weak rock. Balkema, Rotterdam, pp 21-24.

Tsiambaos G, Sabatakakis N (2004) Considerations on strength of intact sedimentary rocks. Eng Geol 72:261-273.

ISSN: 2444-4987
RENIECYT-CONAHCYT: 1702902