Journal of Engineering Applications December 2024 Vol.11 No.32 36-42
Article

Study of the relationship between uniaxial compressive strength and the point load index test in rocks from the bank in Seybaplaya Campeche Mexico

Estudio de la relación entre la resistencia a la compresión uniaxial y el ensayo de índice de carga puntual en rocas del banco de Seybaplaya Campeche México

Naal-Pech, José Wilber*[a], Palemón-Arcos, Leonardo [b], El-Hamzaoui, Youness[c] and Gutiérrez-Can, Yuriko[d]

[a] ROR Universidad Autónoma del Carmen • KHW-2538-2024 • 0009-0006-2955-0382 • 1231951
[b] ROR Universidad Autónoma del Carmen • KHW-2160-2024 • 0000-0001-9743-0434 • 49334
[c] ROR Universidad Autónoma del Carmen • AFN-6960-2022 • 0000-0001-5287-1594 • 292367
[d] ROR Universidad Autónoma del Carmen • KHW-2340-2024 • 0000-0001-6358-2130 • 798108

CONAHCYT classification:

Area: Engineering
Field: Engineering
Discipline: Mechanical Engineering
Subdiscipline: Materials Mechanics

https://doi.org/10.35429/JEA.2024.32.11.36.42

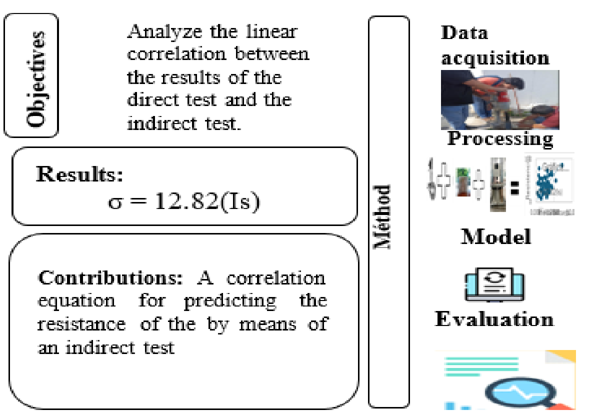
History of the article:
Received: September 11, 2024
Accepted: December 24, 2024

* ✉ [222524@mail.unacar.mx]

Check for updates

Abstract

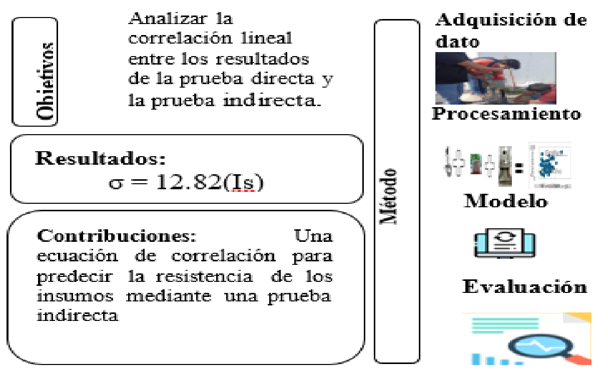
The present research focuses on analyzing the uniaxial compressive strength of rocks and its relationship with point load index testing. It is important to note that Seybaplaya, located in Campeche Mexico, is recognized for its fishing, industrial and commercial activities and where a rock bench is located from which samples were obtained to carry out the study. As a result, equations were developed that allow predicting the simple uniaxial compressive strength based on the values obtained from the point load index test. It is relevant to highlight that these relationships are valid only for rocks with lithological characteristics similar to those used in this study. The analysis results and conclusions demonstrate the linearity of the relationships between the simple uniaxial compressive strength and the point load index test.



Simple uniaxial compressive strength and rock point load index

Resumen

La presente investigación se enfoca en analizar la resistencia a la compresión uniaxial de las rocas y su relación con ensayo índice de carga puntual. Es importante señalar que Seybaplaya se ubicado en Campeche México, es reconocido por sus actividades pesqueras, industriales, comerciales y en la que se localiza un banco de roca de la que se obtuvieron muestras para llevar a cabo el estudio. Como resultado, se desarrollaron ecuaciones que permiten predecir la resistencia a la compresión uniaxial simple basándose en los valores obtenidos ensayo índice de carga puntual. Es relevante destacar que estas relaciones son válidas únicamente para rocas con características litológicas similares a las utilizadas en este estudio. Los resultados del análisis y las conclusiones demuestran la linealidad de las relaciones entre la resistencia a la compresión uniaxial simple y el ensayo índice de carga punctual



Resistencia a la compresión uniaxial simple e índice de carga puntual de roca

Citation: Naal-Pech, José Wilber, Palemón-Arcos, Leonardo, El-Hamzaoui, Youness and Gutiérrez-Can, Yuriko. Study of the relationship between uniaxial compressive strength and the point load index test in rocks from the bank in Seybaplaya Campeche Mexico. Journal of Engineering Applications. 2024. 11-32: 36-42.

Journal of Engineering Applications December 2024 Vol.11 No.32 36-42
Article

Introduction

Every construction project is based on a soil or rock terrain, with rocks being the fundamental raw material. It is crucial to assess their strength when analysing and designing structures, as this ensures stability from the foundation. In summary, the strength of rocks is a key factor in structural design, as they are natural, hard and compact aggregates, consisting of mineral particles with permanent cohesive bonds. The proportion of different minerals, the granular structure, the texture and the origin of the rock serve for its geological classification (González, 2002).

The behaviour of a block or mass of rock at its place of origin differs from a sample of rock material, which shows significantly higher strength. In addition, blocks of rock often exhibit structural weaknesses, known as cleavages, which include fractures, fissures, joints and other discontinuities. Virtually all of the rocks that make up the kilometres of the earth's crust are traversed by fissures and cracks of short extent (Iriondo, 2006). The diversity in structure, rock types and their geographical distribution affects structural damage in engineering works. Therefore, it is essential to identify these factors in advance, adapt land use according to their impact and reduce the vulnerability of constructions. This problem is the subject of this research focused on the characterisation and mitigation of geological risks caused by geomorphology, specifically in karst areas, such as those found in the state of Campeche (Palacio, 2013).

Due to the high cost and complexity associated with performing the Resistance to Uniaxial Simple Compression (RCUS) test to evaluate the behaviour of rocks, it is recommended to use tests that allow classifying the physical properties of the rocks involved (Naal-Pech et al., 2023). This classification will allow subsequent grouping and characterisation of the rocks by assigning mechanical behaviour parameters that are obtained from tests on representative samples. Determining the simple compressive strength of a rock is important because it allows the rock to be classified according to its strength; it is an important parameter in the most commonly used fracture criteria (Delgado, 2013). Sometimes, it is necessary to ignore the normative recommendations due to discontinuities in the rock mass, which make it difficult to obtain rock cylinders of adequate length.

In addition, for rocks with grains larger than one centimetre, such as granites or pegmatites, obtaining adequate samples may be impossible, and if they are obtained, they cannot be broken with conventional presses. To address these difficulties, researchers such as (Galván, 2011) have developed an experimental correlation between rock compressive strength and indirect test results or physical characteristics of the rock under study, allowing indirect estimates of rock strength to be obtained cheaply and quickly. Equations based on test results relating parameters have been developed using statistical methods of correlation and linear regression. To estimate the simple compressive strength of a rock, there are methods and tests applicable both in the field and in the laboratory, with variations ranging from subjective estimates to indirect measurements. One of the methods used is to obtain the Compressive Strength at Uniaxial Simplex (RCUS) through the index properties of the rock (Galván, & Restrepo, 2016).

These correlations were derived from numerous tests and analyses of rock cores, which allows characterising and relating specific rock parameters. Several researchers have worked hard to obtain these correlation equations in rocks, which were evaluated both in the laboratory and in the field, allowing to relate the uniaxial compressive strength (RCUS) and the point load index. See **Table 1**.

Box 1

Table 1

Correlation equations between compression uniaxial simplex (RCUS) in MPA and point load rating.

Year	Authors	Correlation Equation
1964	D'Andrea et al.	$RCUS=15.3*Is_{(50)}+16.3$
1966	Deere and Miller	$RCUS=20.7*Is_{(50)}+29.6$
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	$RCUS=16.5*Is_{(50)}+51.0$
1990	Cargill and Shakoor	$RCUS=23*Is_{(50)}+13$
1992	Grasso et al.	$RCUS=25.67*[Is_{(50)}]^{0.57}$
1994	Ulusay et al.	$RCUS=19*Is_{(50)}+12.7$
2001	Kahraman	$R=8,41*Is_{(50)}+9.51$
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.	S,B. RCUS=8.66*Is(50)+1 0.85

ISSN: 2410-3454.
RENIECYT-CONAHCYT: 1702902

Naal-Pech, José Wilber, Palemón-Arcos, Leonardo, El-Hamzaoui, Youness and Gutiérrez-Can, Yuriko. Study of the relationship between uniaxial compressive strength and the point load index test in rocks from the bank in Seybaplaya Campeche Mexico. Journal of Engineering Applications. 2024. 11-32: 36-42
https://doi.org/10.35429/JEA.2024.32.11.36.42

Study area

The main wealth of the state of Campeche comes from important hydrocarbon deposits on its marine shelf, as well as significant deposits of non-metallic minerals such as limestone, gypsum, clays, salt and stone aggregates (Servicio Geológico Mexicano, 2021).

Seybaplaya is located on the 'Yucatan Platform', an extension of sedimentary rock on the Yucatan Peninsula, which was formed by the accumulation of marine sediments millions of years ago and reaches a depth of approximately 200 metres. Its soil is composed mainly of limestone and clay, and the area is home to oil and natural gas deposits, which are critical to the local economy.

It is essential to analyse the rock characteristics of the bench located in and around Seybaplaya, known as Mary Carmen, where a quarry is located. **Figure 1** shows the geographic location of the rock bank, while **Table 2** details the type of material and its volume.

Box 2

Figure 1

Seybaplaya rock bank location in Campeche state, Mexico**.**

Box 3

Tabla 2

Characteristics of the Bank in seybaplaya called Mary Carmen

State:	Campeche		
Name of the bank:	Mar and Carmen		
Kilometre:	1000		
Location:	PAYUCAN		
Coordinates UTM	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:	Reporte

Methodology

The most commonly used indirect destructive test on rocks is point load index and the most commonly used direct destructive test is simple uniaxial compressive strength. A systematic framework is presented to analyse the relationship between the uniaxial compressive strength and the indirect destructive test (point load index) on rocks from the Mary Carmen bench at Seybaplaya, Campeche. To achieve this objective and to ensure a structured and logical process, the steps to be followed are detailed below:

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

Each phase is broken down in this section:

Exploration and bench mining

For soil exploration, methods such as open pit, post hole and auger are commonly used. However, in rock bank exploration, drilling methods are used which are often very expensive. Rock benches must be sampled randomly; however, some institutions set the number of drill holes according to the volume of material to be exploited, without considering the homogeneity or heterogeneity of the formation.
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 investigation 50 samples of 53.0 mm were used.

Indirect test (point load index)

The Point Load Test (PLT) is performed according to ASTM D5731-05. This test is also known as the Franklin test and was introduced in 1970. It is one of the most widely used indirect tests to determine the strength of rock. This test is performed by applying a point load of compression along its diameter to a cylindrical rock sample until failure. The load is applied by means of two truncated-metallic cones in coaxial and opposite position to each other and the cone dimension is standardised as shown in **Figure 2.**

ISSN: 2410-3454.
RENIECYT-CONAHCYT: 1702902

Box 4

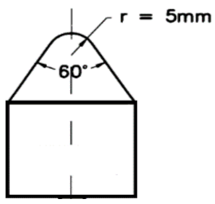


Figure 2
Standardised truncated cone for point load index test.

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).

Resistance to simple uniaxial compression test (RCUS). The uniaxial compression test in accordance with ASTM D7012-10. The method used to calculate 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 calculated with equation (2).

$$\sigma=RCUS = P/A \quad (2)$$

Where:
σ = RCUS = simple uniaxial compressive strength in Mpa.
P = axial load N
A = Cross-sectional area ^{mm2}
Simple compression test procedure.

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

Results

In this research, 50 single uniaxial compressive strength tests (RCUS) and 50 point load index tests (PLT or Is) were carried out, and the following results were obtained (see **Table 3)**

Box 5

Table 3
Results of the 50 samples: where ID is the identification number of the sample, Rcus in MPA, Is in MPA.

ID	Point loading rate (PLT or Is) in MPA	RCUS single uniaxial compressive strength in MPA
1	3.248	31.6
2	1.283	28.6
3	0.888	46.8
4	0.772	15.2
5	1.912	18.3
6	2.964	11.7
7	1.743	22.7
8	3.143	42.1
9	1.797	53.4
10	0.969	14.9
11	4.339	68.6
12	1.486	8.6
13	1.817	23.2
14	3.548	40.7
15	3.468	43.5
16	3.590	28.7
17	1.949	43.6
18	1.119	55.5
19	1.880	32.3
20	0.854	61.3
21	0.960	78
22	3.459	61.9
23	1.051	42.4
24	5.468	49.1
25	7.117	84.7
26	3.167	72.8
27	2.616	38.1
28	4.477	33.2
29	2.469	58
30	3.109	23.9
31	0.522	21.3
32	1.424	40
33	3.519	34.8
34	2.145	43.6
35	2.833	18.5
36	2.836	54.1
37	3.345	45.5
38	2.985	44.1
39	2.298	22.4
40	3.635	35.1
41	0.551	43.4
42	2.563	37.4
43	3.007	31
44	4.305	36.5
45	4.461	63.7
46	3.086	15.7
47	2.557	57.6
48	3.601	40.5
49	4.032	65.1
50	3.731	23.3

ISSN: 2410-3454.
RENIECYT-CONAHCYT: 1702902

Naal-Pech, José Wilber, Palemón-Arcos, Leonardo, El-Hamzaoui, Youness and Gutiérrez-Can, Yuriko. Study of the relationship between uniaxial compressive strength and the point load index test in rocks from the bank in Seybaplaya Campeche Mexico. Journal of Engineering Applications. 2024. 11-32: 36-42
https://doi.org/10.35429/JEA.2024.32.11.36.42

Using information from **Table 3** to correlate RCUS and (PLT or Is), in rock samples from the Seybaplaya bench, we obtain the graph, see **Figure 3**. It is observed that the load and compression index test value, there is an acceptable ^{R2} of 0.7649.

Box 6

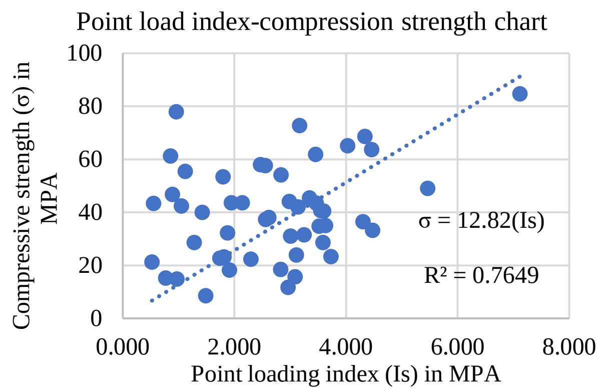


Figura 3

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

Discussion

With the assistance of an expert, explosives were used to mine the bench and rock fragments of considerable diameter were randomly selected for sampling. During the extraction phase, it was observed that the drilling rate varied according to the hardness of the rocks, a fact that was confirmed by compression tests and the identification of the samples by their ID. In addition, it was noted that when water was injected into the borehole, a white liquid was generated, indicating the presence of limestone in the rock. Two samples were extracted from the same fragment: one for the point load test and one to assess the compressive strength.

The compression test specimens were measured with a vernier caliper and cross-sections were made. This process was complicated in some cases due to the disintegration of the specimens, which led to the length ratio of 2 to 2.5 times their diameter not being met, forcing another specimen to be drilled to satisfy the requirements. On the other hand, the samples tested for the point load index were also measured with a vernier caliper, complying with the length - diameter ratio of 1, as established in the standard.

For the load index test on rock samples, diametrically shaped tests were carried out on cylindrical samples.

The uncorrected point load resistance index (Is) was determined. This index was obtained by subjecting a rock sample to a concentrated point load, applied through a pair of truncated conical plates, until fracture occurs in the sample. Compression tests were carried out in the universal machine using dry samples, obtaining the expected results, allowing to observe consistent results throughout the process.

a) It is observed that the rocks present numerous discontinuities.
b) When examining the RCUS-PLT graph, it can be seen that there is an acceptable relationship.
c) When analysing the RCUS-PLT graph, it is observed that the correlation is linear.
d) It is shown that the dynamite bench mining method also creates micro-cracks that continue to damage the resistors.
e) It was observed that the bench material is of limestone type.

Conclusion

The results obtained in this study represent a significant advance in rock mechanics in the state of Campeche. It is fundamental to take into account that the regression models presented in this document are applicable and representative for rocks with similar characteristics to those used in this research. Among the general conclusions, the following considerations stand out: the physico-mechanical parameters of the rock samples analysed in the study were determined. A summary of the ranges of these values is presented below. See **Table 4**.

Box 7

Table 4

Range of RCUS values and PLTen rock samples from the Seybaplaya bench

Concept	Rango	Mean value	Standard deviation	Units
RCUS en MPA	8.6 <> 84.7	40.14	17.9977663	Mpa
Value PLT	0.52<>7.12	2.68	1.35	Mpa

Declarations

Conflict of interest

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.

ISSN: 2410-3454.
RENIECYT-CONAHCYT: 1702902

Availability of data and materials

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

Funding

No internal or external funding was provided for this research project; however, it was possible thanks to the scholarship for postgraduate studies and thanks to the stimulus for belonging to the National System of Researchers and the Programme for the Professional Development of Teachers through the Autonomous University of Carmen (UNACAR).

Authors' contribution

Naal-Pech, José Wilber: Contributed significantly to the conceptualization of the project, as well as to the development of the research method and technique. Supported the design of the field instrument and carried out the data analysis, systematizing the results. In addition, he was 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. In addition, he contributed to the writing of the article

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

Acknowledgements

The authors José Naal-Pech, Leonardo Palemón-Arcos and Youness El Hamzaoui are grateful for the support of the Consejo Nacional de Humanidades, Ciencias y Tecnologías (CONAHCYT) provided through the Universidad Autónoma del Carmen (UNACAR). Yuriko Gutiérrez-Can acknowledges the support of the Programa para el Desarrollo Profesional Docente (PRODEP), through the Universidad Autónoma del Carmen and the Grupo Disciplinar de Ingeniería Civil of the UNACAR. All authors are grateful to the Universidad Autónoma de Campeche for the facilities provided to carry out the tests in its structure laboratory.

Abbreviations

ASTM American Society for Testing and Materials.

RCUS Compressive Strength Uniaxially Simple Compressive Strength.

PLT Point Load Test

References

Background

C. Delgado, Evaluación de un cambio Tecnológico para el Procesamiento de Minerales de Alta Dureza. Tesis. Universidad de Chile: 2013.

Galván, M., Correlación entre la resistencia a compresión simple y el índice a carga puntual Is (50) en calizas de la Comunidad Valenciana (España). Tesis Doctoral, Universidad Politécnica de Valencia, España, 2011.

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

M. Galván, I. Restrepo, «Correlación de la resistencia a compresión uniaxial con la humedad y porosidad eficaz en rocas». DYNA. 2016.

M. Iriondo, Introducción a la Geología. Córdova. Argentina: 2006.Editorail Brujas, argentina ISBN-978-987-591-061-4

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.

Palacio Aponte A. G., 2013. Identificación y Caracterización de la Subsidencia y/o Colapso de Terrenos Kásrticos. P. 169-181. En: Posada Vanegas G., B.E. Vega Serratos, y Silva Casarín (eds), Peligros Naturales en el Estado de Campeche. Cuantificación y Protección Civil. Universidad Autónoma de Campeche, cenecam-Gobierno del Estado de Campeche, cenapred.

Servicio Geológico Mexicano (sgm)., 2021 Panorama Minero del Estado de Campeche.

ISSN: 2410-3454.
RENIECYT-CONAHCYT: 1702902

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 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). Guía de laboratorio de Resistencia de materiales. 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

D'Andrea DV, Fisher RL, Fogelson DE (1964) Prediction of compression strength from other rock properties. Col Sch Mines Q 59(4B):623–640

Deere DU, Miller RP (1966) Engineering classification and index properties for intact rock. Air Force Weapons Lab. Technical report, AFWL-TR 65–116, Kirtland Base, New Mexico

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

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

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

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: 2410-3454.
RENIECYT-CONAHCYT: 1702902