doi: https://doi.org/10.47460/minerva.v3i7.54

Rock material particle size and its correlation with the point load test index

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Recibido (11/01/2022), Aceptado (09/020/2022)

Abstract: This work proposes the methodology to obtain a correlation between the particle size of the rock material and the point load test index (Is 50), in order to characterize the materials, present in mining projects in terms of resistance. For a correct development of mining activities, both open pit (quarries) and underground (mines), it is important to determine the compressive strength of the rocks, since, through it, geomechanical classifications are obtained, and thus calculate safety factors to define stabilization and/or fortification systems for mining operations. This work was developed on the basis of samples from a geological formation and subsequent preparation of specimens, then they were subjected to physical tests, which can be carried out without problem in the field and finally the respective relationships were obtained. The results are encouraging and the equations are proposed to characterize the rock and achieve the proposed objective.

Keywords: Rock, Crushing, Classification, Compression.

Tamaño de partícula del material rocoso y su correlación con el índice de prueba de carga puntual

Resumen: Este trabajo propone la metodología para obtener una correlación entre el tamaño de partículas del material rocoso y el índice de carga puntual (Is 50), con la finalidad de caracterizar los materiales presentes en proyectos mineros en términos de resistencia. Para un correcto desarrollo de actividades mineras, tanto a cielo abierto (canteras) como subterráneo (minas), es importante determinar la resistencia a compresión de las rocas, ya que, mediante la misma, se obtiene clasificaciones geomecánicas, y así calcular factores de seguridad para definir sistemas de estabilización y/o fortificación de las labores mineras. Este trabajo se lo desarrolló sobre una base de muestras de una formación geológica y posterior elaboración de probetas, luego, se las sometió a ensayos físicos, los cuales pueden ejecutarse sin problema en campo y finalmente se obtuvieron las relaciones respectivas. Los resultados son alentadores y se proponen las ecuaciones para caracterizar la roca y conseguir el objetivo propuesto.

Palabras Clave: Roca, Trituración, Clasificación, Compresión.

I.INTRODUCTION

In mining projects, when they are in the advanced exploration and/or exploitation phases, it is important to define various properties or parameters of the materials to be extracted, since this information will allow the optimization of development processes. There are several analyzes that must be carried out in order to know and diagnose the reservoir, but one of those properties, and undoubtedly one of the most important, is the simple compressive strength or uniaxial compression of the rock (UCS).

The UCS allows classifications to be developed for rock masses and in this way, together with other additional parameters, the safety measures of mining structures are established, since the geomechanical classifications provide values of safety factors and in many cases, even the types of fortification that must be implemented in mining operations, whether open pit or underground.

In many mining projects, due to their location and/or cost, it is not possible to send samples to the laboratories to determine the UCS of the materials, because the equipment used for the aforementioned evaluation is high cost and does not count with its availability, so an alternative that can be used is the Point Load Test Index, better known as Is 50.

The field determination of this parameter is easier, the equipment is of accessible construction and its handling is feasible for a worker. Therefore, the UCS can be known through the Is 50 and avoid the permanent sending of samples to laboratories.

This paper proposes, from the theoretical basis used for this purpose, the methodology to obtain the proposed objectives, describing a clear and statistical procedure, which can be used in other cases, generating a strategy to obtain the appropriate instruments of evaluation; It should be emphasized that in this work the results obtained have generated a very important expectation about its application.

II.MATERIALS AND METHODS

The objective of rock crushing is to reduce the particle size of solid samples, always bearing in mind that their homogeneity must be preserved. The main tool used to reduce the particle size of solids is a jaw crusher, is a machine used in primary crushing. The field that most uses jaw crushers is mineral and industrial production [1].

Once the samples have been crushed, the classification of the fragmented elements is usually continued, different systems for classifying the particles have been developed. The separation of a soil into different fractions, according to their sizes, is necessary to know its competence and efficiency, from the geotechnical perspective. This action includes sieving tests, the objective of which is to distribute the different sizes of rock material particles through the use of a series of sieves arranged in decreasing shapes with reference to the aperture diameter. This classification comprises two parts: by sieving for coarse particles (gravel and sand) and by sedimentation for the fine fraction of the soil (silts and clays) 2.

One way to graphically represent the results obtained from the sieving tests is by means of the granulometric curve, where the percentage of the passing sample is plotted on the ordinate and the diameter of the particles on the abscissa. From the particle size curve, characteristic diameters such as D50, D60, D70, D80, D90, etc. can be obtained. D refers to the apparent diameter of the particle and the subscript (50, 60, 70, 80, 90) denotes the percentage of finer material 3.

One of the important properties that must be known about rock material is the simple compressive strength or uniaxial compression of the rock (UCS), and to obtain this parameter, rock samples must be obtained that emerge in the reservoir, prepare suitable specimens and send them to laboratories for the determination of the burst pressure. This work must be permanent since the geology of the mining projects varies in the progress of the exploitation and by nature the rocks are anisotropic and heterogeneous □ 4□ .

Simple compressive strength or also called uniaxial compressive strength is the ability of a rock to withstand a specific stress or load, this allows us to classify and characterize the rock matrix. If the rock fails by breaking a fracture it can be defined as an independent property. In short, it is the value obtained when a load is applied in one direction without applying another effort in any other direction [5]. Simple or uniaxial compressive strength is one of the most common parameters because it allows us to define the failure criteria and the geomechanical behavior of a rocky matrix [6].

There are two ways in which rock rupture can occur, which are:

1.Fragmentation: it occurs when the crack is homogeneous and there is no interaction between them.

2.Fracture: it is caused by the concentration and mixture of microscopic cracks that generate a macroscopic crack during the application of the specific load [7].

It is important to determine this resistance in order to be able to classify the rock masses, and with which the stability of the mines can be determined, whether open pit or underground mines [8]. But in mining projects it happens very often that it is not possible to send samples to laboratories, due to their location and/or the cost it represents for the mining company, so the point load test index or Is 50 can be used as an alternative.

The index of resistance to point load test (Is 50), of a rock, is defined as the value of Is that would be obtained for the same sample with an equivalent diameter of 50 mm, that is, it is the correlation that is applied when the test point loading is carried out on a 50-millimeter diameter test piece. For diameters other than this, is must be multiplied by a correlation factor F [9].

The point load test index is presented as an alternative to evaluate in a determined and indirect way the value of the simple compressive strength. It is a test of easy execution and low cost, this test consists of placing a rock sample between two points in a standard way and a force is applied, increasing until it fractures.

The resistance index for point load (Is) is determined by the relationship between the measurement of the height between the two points and the measurement of the force applied at the moment of rupture. The results of the test will depend on the shape, volume and preparation of the sample, in addition to other factors such as the direction of the load, the relationship between the height and diameter of the sample and the speed of application of the load, therefore consistent application is recommended [10].

This test has two advantages, the main one is that few requirements are needed with respect to the samples to be tested, such as the geometric minimums and that the break is produced by a fracture plane that consists of the two points of application of the load, the second advantage is that the machine can be easily moved or transported, this means that its use is not only limited to the laboratory but it can also be used in the field.

In this work, 30 samples of andesite rock were analyzed, obtained from the sector called Cojitambo, which is a volcanic formation located in the province of Cañar, Ecuador. These samples had dimensions of approximately 9 cm x 10 cm x 10 cm.

Fig. 1. Rock samples.

To determine the resistance to simple compression, each one of the samples was introduced in the point loading machine, the same one that is a Humboldt press that subjects the materials to tension and compression tests [11]. The pressure is given by means of plates or jaws that are actuated by screws or by a hydraulic system. Its main function is to determine the resistance of different materials through a system that applies loads on the sample and graphically measures the load at the moment of its rupture, with this procedure the point load test index, Is 50 was obtained.

Fig. 2. Humboldt compression machine

The samples are then subjected to the crushing process in a jaw crusher to obtain fine particles of material.

Fig. 3. Crushing the specimens in the R22 jaw crusher

Next, a representative number of the samples were taken and weighed on a balance. Subsequently, this quantity was placed in the different sieves to obtain the granulometry, ordering them from largest to smallest opening and was subjected to vibratory and rotational movements, with the help of a mechanical vibrator or sieve.

Fig. 4. Classification process by electric sieve

Finally, the sieves were removed and the material retained on each of them was weighed separately. With these data and with the initial known weight of the sample, it was possible to determine the percentage of material that was retained on each sieve. Therefore, the maximum size of the particles constituting the 20%, 50% and 80% portion was calculated.

Fig. 5. Weight of each sieve and sample

III.RESULTS AND DISCUSSION

The results obtained in the statistical evaluation show in a general way the relationship between the distribution of particles in rock material with the point load test index, Is 50. Table 1 shows the results of the relation of the opening diameters of the particle with the Is 50 of the 30 samples treated. The proposal presented refers to the fact that the lower D is obtained, the greater resistance presented by the rock material, since it is proposed that the greater number of particles generated in the crushing process, it implies that the rock has a greater resistance to compression, the inverse represents that, the lower the compressive strength of the rock, the amount of particle production decreases.

Table 1. Results of the particle size distribution and Is 50

TEST	D80 mm	D50 mm	D20 mm	Is 50 MPa
1	8,483	5,367	2,214	3,037
2	8,509	5,036	1,824	3,190
3	8,478	4,997	1,821	3,220
4	8,452	4,966	1,749	3,324
5	8,386	4,891	1,738	3,415
6	8,370	4,863	1,708	3,458
7	8,338	4,852	1,694	3,486
8	8,316	4,852	1,689	3,514
9	8,255	4,839	1,676	3,572
10	8,254	4,820	1,672	3,715
11	8,236	4,788	1,665	3,865
12	8,221	4,776	1,651	3,914
13	8,218	4,740	1,650	3,933
14	8,217	4,732	1,631	3,937
15	8,205	4,705	1,631	3,976
16	8,194	4,703	1,606	3,979
17	8,158	4,700	1,586	3,996
18	8,146	4,697	1,585	4,031
19	8,132	4,690	1,582	4,106
20	8,125	4,660	1,575	4,187
21	8,107	4,657	1,573	4,200
22	8,095	4,642	1,571	4,289
23	8,082	4,636	1,570	4,311
24	8,041	4,636	1,547	4,379
25	8,038	4,600	1,539	4,526
26	8,036	4,588	1,524	4,733
27	8,033	4,533	1,484	4,760
28	7,98	4,493	1,475	4,833
29	7,957	4,472	1,446	4,956
30	7,698	4,200	1,289	4,992

To determine the correlation of the rock material, between the particle size distribution and the point load test index Is 50, we place the particle diameters D80, D50 and D20 on the abscissa axis and Is 50 on the ordinate axis. This can be seen in Figures 6, 7 and 8.

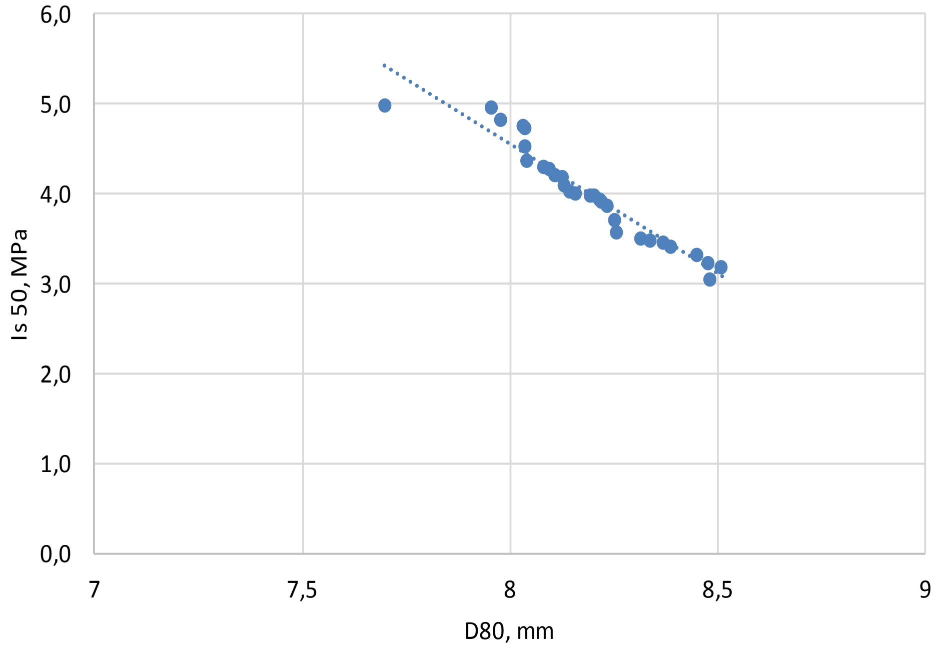

Fig. 6. D80 values and point load test index Is 50

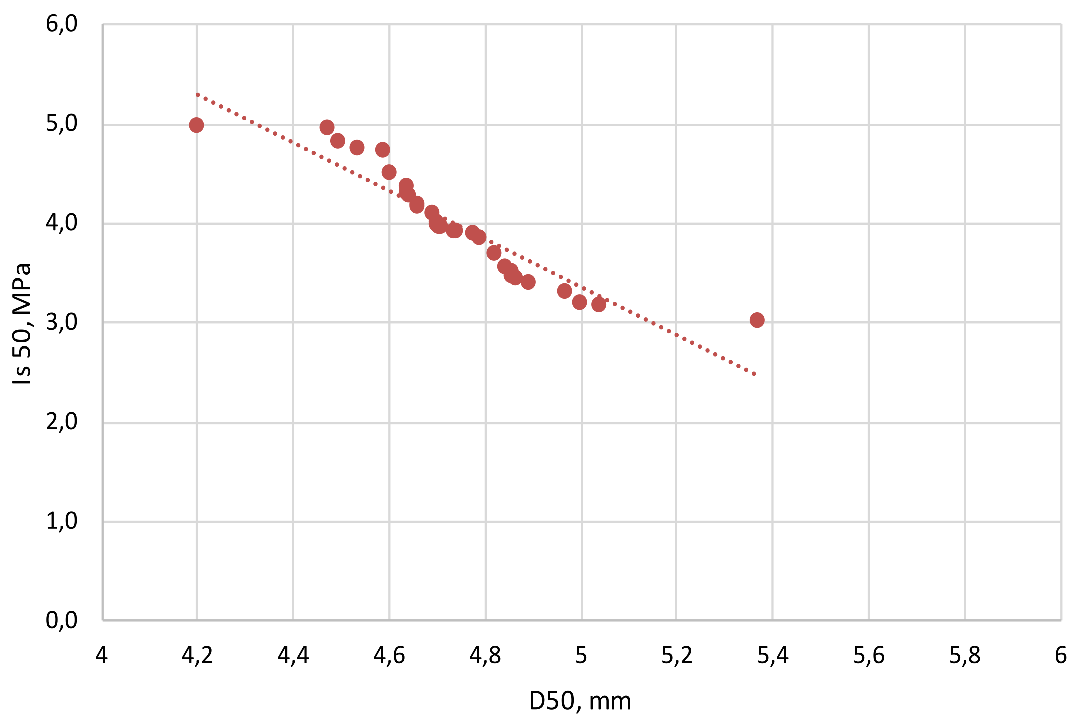

Fig. 7. D50 values and point load test index Is 50

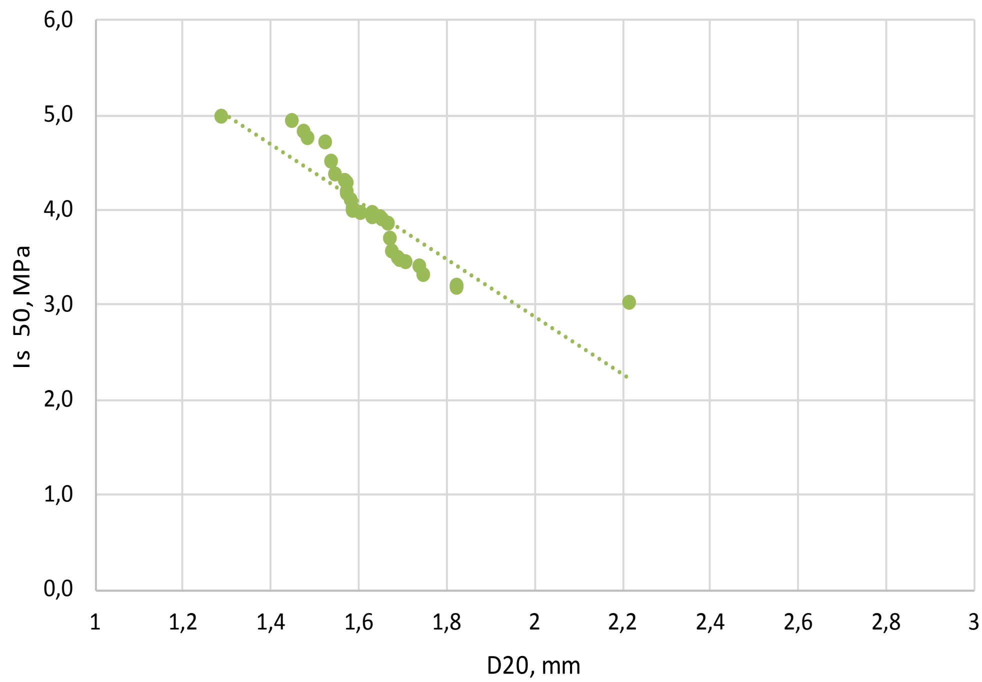

Fig. 8. D20 values and point load test index Is 50

Finally, in Figure 9 you can see the results of the correlations between the D80, D50 and D20 and the Is 50.

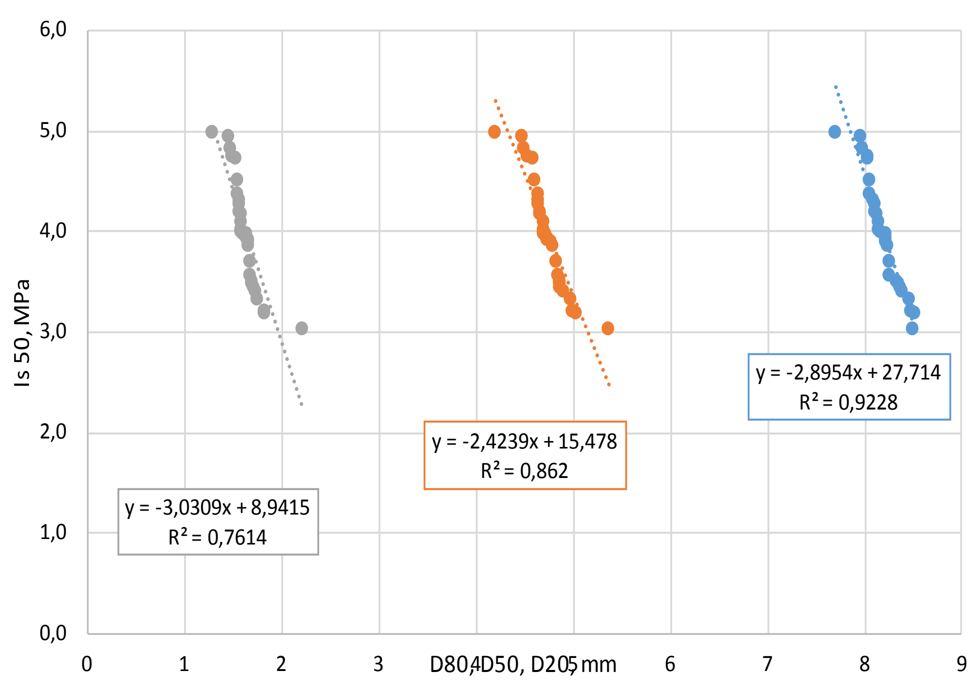

Figure 9. Correlation between D80, D50 and D20 and Is 50

After analyzing the data of the three correlations, it was established that the correlation given by the D80 is adequate to be used, due to its R2. Therefore, the equation is the following:

$$Is\ 50 = -2.8954 \cdot D80 + 27.714 \tag{1}$$

It should be noted that these equations are exclusive for the rock material of the Cojitambo sector, which is an amphibolic andesite, which presents a typical and apollonian variety in its light gray microcrystalline mass, the amphibole, black mica and fairly large fragments of white plagioclase.

The correlation equation obtained can be used to determine the point load test index Is 50, only knowing the D80 of a sample and consequently establishing the simple compressive strength using the equation:

$$UCS \approx 23 \cdot Is\ 50 \tag{2}$$

IV.CONCLUSIONS

The execution of the crushing and classification tests on rock specimens for the determination of the particle size, as well as the Is 50 tests are feasible to be carried out in situ, since most mining companies have the appropriate equipment to these essays.

It was found that there is a relationship between the D80 and the Is 50, of the analyzed rock samples, which provides a fast and inexpensive way to determine an approximate value of the simple compressive strength of the rock.

A correlation between the D80, Is 50 and UCS is proposed, which allows characterizing the rock material present in the area, consequently, D80 values have been obtained ranging from 7.698 mm to 8.483 mm and the value of Is 50 for this material ranges from 3.037 MPa to 4.992 MPa.

This proposal allows finding the UCS of the rock and it is between 69.85 MPa and 114.82 MPa, that is, the rock is considered to be of medium to high resistance.

If the D80 values, obtained in other rock samples, are not within the range obtained in Table 1, it is necessary that these materials be sent to the laboratory for the determination of the UCS.

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CURRICULUM SUMMARY

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