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Soft rocks in Argentina

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ABSTRACT

Soft rocks are a still fairly unexplored chapter in rock mechanics. Within this category are the clastic sedimentary rocks and pyroclastic volcanic rocks, of low to moderate lithification (consolidation, cementation, new formed minerals), chemical sedimentary rocks and metamorphic rocks formed by minerals with Mohs hardness less than 3.5, such as limestone, gypsum, halite, sylvite, between the first and phyllites, graphitic schist, chloritic shale, talc, etc., among the latter. They also include any type of rock that suffered alteration processes (hydrothermal or weathering). In Argentina the study of low-strength rocks has not received much attention despite having extensive outcrops in the Andes and great impact in the design criteria. Correlation between geomechanical properties (UCS, deformability) to physical index (porosity, density, etc.) has shown promising results to be better studied. There are many studies and engineering projects in Argentina in soft rock geological environments, some cited in the text (Chihuído dam, N. Kirchner dam, J. Cepernic Dam, etc.) and others such as International Tunnel in the Province of Mendoza (Corredor Bioceánico), which will require the valuable contribution from rock mechanics. The lack of consistency between some of the physical and mechanical parameters explored from studies in the country may be due to an insufficient amount of information and/or non-standardization of criteria for testing materials. It is understood that more and better academic and professional efforts in improving techniques will result in benefits to the better understanding of the geomechanics of weak rocks.

1. Introduction

The soft rocks in Argentina have not received the deserved attention despite being present in a great part of the territory. Many hydroelectric dams, roads and railways have been built in this type of rocks.

In order to encourage the study of the geomechanics of soft rocks in Argentina for its application in engineering, the petroleum industry has made a compilation of studies published in conferences and journals.

This work is a synthesis presented by the commission of soft rocks as a preliminary report to the ISRM International Symposium in Poland, in September 2013.

2. What are soft rocks?

From the point of view of the intact rock or rock matrix, there has been a deep debate as regards soft rocks or weak rocks because it is not easy to define this concept [1]. They have used different criteria to define them: criteria for strength deformability, durability, weathering degradation, strength-stress relationship, etc.

Finally it seems that an "agreement" has been reached between major International Associations (ISRM, IAEG and ISSMFE) and researchers to use the simple compressive strength as a criterion to separate soft rocks from hard soils at the lower limit and from hard rocks in its upper limit. The simple compressive strength is a property commonly used by professionals involved in the design of engineering projects, although it is understood that it is not possible to use only one of the many geomechanical properties to classify soft rocks [1]. Broader classification systems should be developed.

However, not all this systems agree on the limits that should be adopted to characterize a soft rock as shown in Fig. 1, extracted from the paper recently presented by Professor M. Kanji in the 2nd South American Symposium on Rock Excavations in Costa Rica [2].

Fig. 1 shows the upper limits with hard rock to be between 25 and 30 MPa of UCS (strength, resistance). The lower limit with soils shows a greater divergence between different authors, varying between 1 to 6 MPa of the UCS. The criteria for establishing these limits are varied and in all cases related to geological and geodynamics conditions in the site of projects. The geomechanics

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classification of soft rocks based in only one property like the simple compressive strength seems insufficient considering the complexity of geological factors involved in the formation of this type of rocks (soft rocks).

In general, according to geological evolution, soft rocks can be differentiated in: (a) primary soft rocks, and (b) secondary soft rocks. In the first group the following rocks can be identified.

(1) Sedimentary clastic and pyroclastic rocks of low to moderate compaction and lithification (sandstones, siltstone, shales, tuff, agglomerate, marl, etc);
(2) Chemical sedimentary rocks formed by primary minerals of Mohs hardness <3.5 (gypsum, sylvinite, halite, carnallite, some limestones etc);
(3) Metamorphic rocks formed by primary minerals of Mohs hardness < 3.5 such as phyllites, schists, cloritecs schists formed by chlorite, muscovite sericite, graphite with talcum powder, in low grade metamorphic phase.

The second group includes all types of rock that have suffered physical–chemical alteration due to weathering and/or hydrotermalism.

For clastic and pyroclastic rocks, the geological criteria that can be used to set the difference between soft rocks and hard rocks, is the degree of lithification reached by them. Hoshino [3] studied sandstone and pelitic rocks in two sedimentary basins in Japan from samples obtained from deep drilling, up to 3000 m deep. From the correlation between petrographic characteristics, petrophysics (porosity) and mechanical properties (uniaxial compressive strength, module of elasticity, cohesion and propagation speed of P waves) it was defined three stages of consolidation in pelitic sediments: dehydration, framework and cementation (Fig. 2).

In the first stage of lithification, the sediment suffers a process of compaction with dehydration as a predominant phenomenon. This stage is characterized by drastic reduction of pore spaces and mineral transformation (smectite to illite). The rock porosity varies between 30% and 80% and the UCS between 1 and 30 MPa. The process occurs at a confining pressure that reaches 30 MPa, at a temperature of 55–60 °C for 1–2 million years (Tables 1 and 2). The study concludes that the higher the temperatures and pressures they suffer for millions of years, the higher the strength the rocks can reach. It is important to highlight here that the separation between two different geomechanic compartments (low strength vs high strength) in pelitic rock occurs by a change in the mechanisms of sediment lithification.

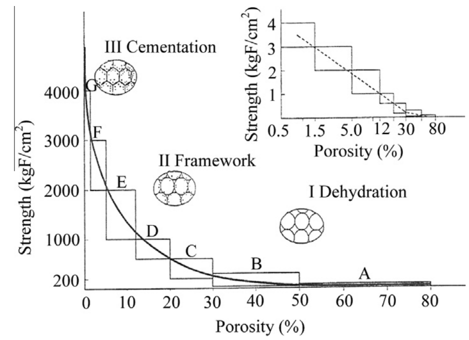

Fig. 2. Porosity–strength relation with compaction stages in the standard sedimentary basins and the textures of lithification [3].

For metamorphic and chemical sedimentary rocks, the geological criteria that can be used to separate soft rocks from hard rocks is the proportion of primary minerals with Mohs hardness less than 3.5. Among the primary minerals that formed the soft rocks are: the sulphatic minerals (gypsum), chloride (halite, silvinite, and carnallite), phosphate, some carbonate, phyllosilicates (biotite, muscovite), clay minerals, chlorite, talc, graphite, vermiculite, serpentinite, etc) all of them with Mohs hardness less than 3.5. These rocks could be considered soft rocks: salt (gypsum, carnallite, halite, etc), some phosphorites, some calcareous rocks, phyllites, schists, serpentinites, etc.

On the other hand, the weathering phenomena, hydrothermal alteration and retrograde metamorphism, are processes that transform the hard rock into rocks of less strength. In these cases the newly formed minerals are minerals with Mohs hardness less than 3.5. An excellent work on the mechanical properties of pyroclastic rocks (tuffs) altered by hydrothermal process, shows that in the dry state, argillic altered rocks (clays group) have strengths <25 MPa, while rocks with propylitic, potassium, Laumontite group and Mordenite alteration, can reach strength up to 90 MPa [4]. It is

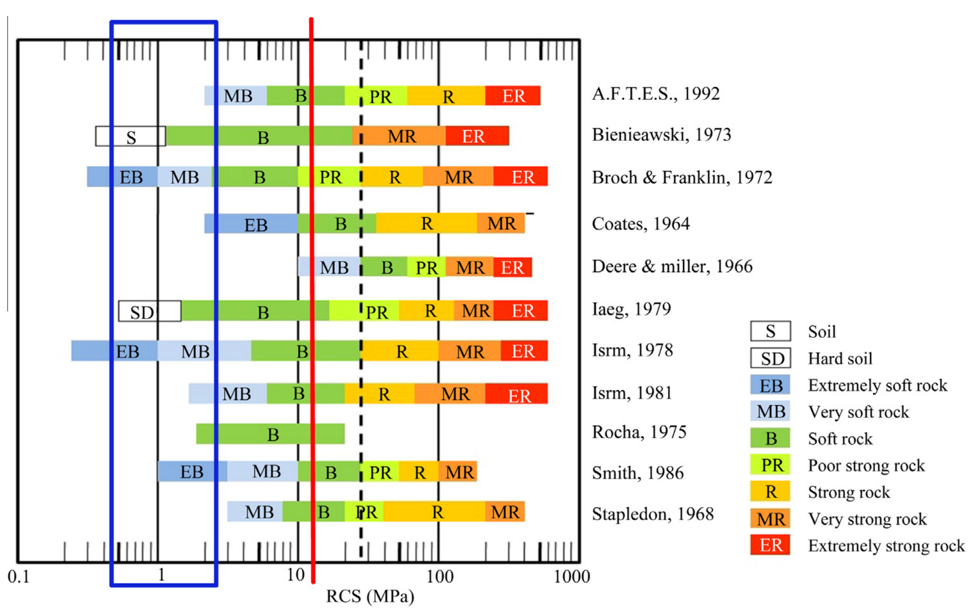

Fig. 1. Uniaxial compressive strength (UCS) for soft rocks [2].