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Critical issues in soft rocks

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ABSTRACT

This paper discusses several efforts made to study and investigate soft rocks, as well as their physico-mechanical characteristics recognized up to now, the problems in their sampling and testing, and the possibility of its reproduction through artificially made soft rocks. The problems in utilizing current and widespread classification systems to some types of weak rocks are also discussed, as well as other problems related to them. Some examples of engineering works in soft rock or in soft ground are added, with emphasis on their types of problems and solutions.

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1. Introduction

Soft rocks are a critical geomaterial since they present several types of problems. First of all, they may present undesirable behaviors, such as low strength, disaggregation, crumbling, high plasticity, slaking, fast weathering, and many other characteristics.

These types of unfavorable behaviors prevent their utilization or tend to avoid the use of the site dominated by soft rocks for important engineering works many times. Dams and hydroelectric power plants look for a better geological condition; tunnels and highways look for a better alignment escaping from weak zones, whenever possible. However, there are entire regions in the world dominated by soft rocks where no good or better rock is encountered, obliging people to accept and to deal with them. This leads to the need of understanding well soft rocks and of developing adequate solutions for the problems they pose.

Secondly, soft rocks have intermediate strength between soils and hard rocks. In some cases, they are too soft to be tested in rock mechanics equipment and too hard for soil mechanics equipment. This indicates that some adjustment in their testing must be developed to well characterize their properties.

The third type of problem is their sampling and site investigation. The percussion boring is prevented when high number of blows for standard penetration tests (SPTs) determination is required. Usually, in practical terms, the ground is considered impenetrable with SPTs greater than 50, and no adequate sampling is possible. On the other side, conventional rotary diamond drillings, even with swivel type double barrels, destroy the sample or bring it in bits and partially destroyed, avoiding to know well the type of subsoil. Even triple barrels, although better, may be inefficient. The most critical and important geological feature is exactly that one not recovered. This leads to the necessity of driving pits or shafts for good reconnaissance of the subsoil.

Last but not least, some types of soft rocks present great difficulty in their geomechanical classification under the usual systems, since these systems were developed mainly for discontinuous media of hard rocks. Therefore, for soft rock masses, it will be necessary to adapt the existing systems or develop new classification systems, which are specific for practically continuous soft rock masses.

Consequently, soft rocks and soft grounds are little studied and understood, and there is little confidence on their properties to be utilized in important engineering works. In this way, conservative parameters are adopted, to guaranty enough safety, but very often against the economy.

All these reasons indicate that the study and understanding of the characteristics of soft rocks are important, mainly because good geological conditions may not be presented in large regions of the world, but mainly the best geological sites have already been used, obliging the present and future engineering works to face and tackle with the available sites dominated by soft rocks.

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It is not the intent of this paper to cover and define the issues here presented, but rather to discuss the main types of problems and shortcomings in the knowledge of soft rocks, hoping to motivate discussion and research, and that the developments made by researchers and institutions be reported as a contribution to the International Society for Rock Mechanics (ISRM) Technical Commission on Soft Rocks.

2. Geotechnical societies' contribution

Besides researches made at universities, research institutes, and some specific investigation carried out by the industry, the main systematic effort for the development of the understanding of soft rocks has been made by the geotechnical societies.

The first known soft rock technical commission was settled by ISSMGE (International Society of Soil Mechanics and Geotechnical Engineering) as TC22 Soft Rocks and Indurated Soils, initially chaired by Prof. Akai, Japan, from 1985 to 1994, followed by Prof. Durville, France, from 1994 to 2001 when the TC was discontinued. It is worth mentioning that the first international symposium on soft rocks was held in Tokyo, in 1985 and that the commission presented a report on Recent Advances on Soft Rock Research at the 12th ISSMGE congress in 1989 in Rio de Janeiro, Brazil.

Meanwhile, some important papers were presented at conferences, among them those of Deere and Vardé (1986) as a general report to an International Association of Engineering Geology (IAEG) conference, where they considered those masses of hard rock as weak rocks but including weakness geological features besides soft or low strength intact rock; a thesis on weak sandstones by Dobereiner (1984) at the University of London; a keynote lecture by Nieto (1982) on soft rock masses at the 1st South-American Congress on Rock Mechanics, at Bogotá and Kanji (1990) at the 3rd South-American Congress on Rock Mechanics, Caracas, on dam foundations on soft rocks. In Brazil, ABGE (Brazilian Association for Engineering Geology) promoted a group study on the geotechnical properties of sedimentary rocks of Brazilian formations, coordinated by Campos (1988).

Some universities and research institutes have also worked on soft rocks. For instance, the sub-society of soft rock engineering (set up in 1996) is very active in China, chaired by Prof. Manchao He, where 13 symposiums on soft rock engineering have been held since 1999, dealing with new concepts regarding soft rocks, soft rock classification and countermeasures for different soft rock engineering problems.

In parallel, Prof. Juan Jose Bosio, from Paraguay, encouraged the geotechnical societies of Argentina, Brazil, Paraguay, and Uruguay, to constitute a Regional Committee on Soft Rocks of the Rio de la Plata Basin, encompassing those countries. The committee worked for some time under his chairmanship, succeeded by this author. The committee was later converted in a regional committee of IAEG, and in 2 or 3 years of existence presented a first report at the end of term of the IAEG President, in 2002, IAEG did not renew the committee.

The first symposium specifically devoted to soft rock at our knowledge was organized by the Spanish geotechnical societies on soils, rocks, and tunnels, and called National Symposium on Soft Rocks, held in Madrid on November 17–18, 1976.

However, the first event at international level was the Tokyo symposium of 1985. It was followed by other international or national ones, although not as a sequence. In 1990, the British Geological Society organized the 26th Annual Conference of the Engineering Group, having published their proceedings in 1993 as a book entitled "The Engineering Geology of Weak Rock". In 1998, the Italian Geotechnical Society organized the International Symposium called "The Geotechnics of Hard Soils–Soft Rocks in Naples". The next one was the 15th European Conference on Soil Mechanics and Geotechnical Engineering (ECSMGE) held in Athens, 2011, under the title "Geotechnics of Hard Soils–Weak Rocks". The 2nd South-American Symposium on Rock Excavation was held in Costa Rica, 2012, with a special lecture given by Kanji (2012) about problems and solutions of soft rocks in engineering works. The next IAEG Congress to be held this year (2014) in Torino, will include a technical session on soft rocks, as well as the Brazilian Rock Mechanics Symposium to be held in Goiania, in next September.

In the academic side, some important theses were prepared. To the author's knowledge, the most outstanding ones were those of Dobereiner (1984) at the University of London, on weak sandstones, Jeremias (1997) at the Laboratório Nacional de Engenharia Civil (LNEC), Portugal, on argillaceous rocks, and Galván (1999) at University of São Paulo, Brazil, on the properties of artificially cemented sands to simulate arenaceous soft rocks.

In 2007, Prof. Pedro Pinto, the ISSMGE president, suggested the sister societies IAEG and ISRM to establish a Joint Technical Committee (JTC) on Soft Rocks, which was accepted, and the JTC-7 on Soft Rocks was constituted, among several other ones. The work was launched but in early 2010 due to institutional problems, all JTCs were extinguished, except JTC-1 on Landslides.

Finally, in 2011 during the ISRM Congress in Beijing, a Soft Rock Technical Commission was proposed, having being accepted by the new president, Prof. Xia-Ting Feng and the ISRM board, with fruitful work up to now. The Specialized Conference on Soft Rocks organized by the Chinese Society for Rock Mechanics and the Chinese Sub-society for Rock Engineering and Deep Disaster Control is an activity of the ISRM Technical Commission.

3. What is considered soft rock?

Several authors have classified intact rocks according to their strength in different scales and terms, as summarized in Fig. 1. However, there is a practical coincidence that the upper limit of the strength of what is considered soft is about 25 MPa as unconfined compressive strength (UCS).

On the other side, the lower limit of the strength of soft rock, distinguishing it from soils, is more difficult to establish. An SPT above 50 and an UCS greater than 0.4 MPa were established by Terzaghi and Peck (1967) for materials behaving more like rock than soil. Dobereiner (1984) considered an UCS value of 0.5 MPa. Rocha (1975) distinguished rock when the piece does not crumble or disaggregate when immersed in water. Baud and Gambin (2011) utilized another criterion, based on the limit pressure in pressuremeter testing, indicating values of 2–10 MPa, and depending on the elastic modulus to the limit pressure ratio.

Notwithstanding, the transition between soft and hard rocks and with soil is problematic. In some studies by Galván (1999) to verify whether all rock types conform to the theoretical relationship between dry density and porosity, it was seen that there is a continuous transition between those materials, without any sharp change in that relationship, as shown in Fig. 2 (Kanji and Galván, 1998). Some dispersion around the theoretical line must be due to differences in testing procedures.

The usual rock types that may be called as soft rocks are mentioned in Table 1.

However, it has to be emphasized that the mention of the geological or lithologic name alone may be misleading. For example, sandstone can be cement in different degrees, being very soft if poorly cemented or extremely hard if well cemented. Therefore, the complementary condition must be also mentioned to allow good definition of the material condition.

Even the geological age may be important. In dealing with sedimentary rocks from the Paraná Basin, Bosio and Kanji (1998)

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