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The use of point load test for Dubai weak calcareous sandstones

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ABSTRACT

Intact rock is typically described according to its uniaxial compressive strength (UCS). The UCS is needed in the design of geotechnical engineering problems including stability of rock slopes and design of shallow and deep foundations resting on and/or in rocks. Accordingly, a correct measurement/evaluation of the UCS is essential to a safe and economic design. Typically, the UCS is measured using the unconfined compression tests performed on cylindrical intact specimens with a minimum length to width ratio of 2. In several cases, especially for weak and very weak rocks, it is not possible to extract intact specimens with the needed minimum dimensions. Thus, alternative tests (e.g. point load test, Schmidt hammer) are used to measure rock strength. The UCS is computed based on the results of these tests through empirical correlations. The literature includes a plethora of these correlations that vary widely in estimating rock strength. Thus, it is paramount to validate these correlations to check their suitability for estimating rock strength for a specific location and geology. A review of the available correlations used to estimate the UCS from the point load test results is performed and summarized herein. Results of UCS, point load strength index and Young's modulus are gathered for calcareous sandstone specimens extracted from the Dubai area. A correlation for estimating the UCS from the point load strength index is proposed. Furthermore, the Young's modulus is correlated to the UCS.

1. Introduction

The uniaxial compressive strength (UCS) of rock is the most commonly used parameter in the characterization of intact rock. It is needed for different applications including the design of foundations resting on and/or in rocks and the stability of rock slopes. The UCS is typically determined from the axial loading of unconfined intact rock specimens. The uniaxial compression test should be performed on cylindrical specimens with a length to width ratio of 2–2.5. The standard specimen height should range between 100 mm and 300 mm. The specimen ends perpendicular to the cylinder axis should be flat, smooth and parallel as per ASTM (2008a). Alternatively, the UCS may be estimated using the point load test, which is conducted on specimens in the form of cores, blocks or irregular pieces with a diameter of 30 mm and 85 mm, respectively (ASTM, 2008b). The point load test is especially useful when core specimens cannot be extracted from fractured or weathered rock masses. Furthermore, the point load test is simpler and more economical compared to the UCS test.

2. The point load test

The point load test gradually applies a concentrated compressive force using conical platens on the rock specimen until it fails by splitting. The loading system consists of a loading frame, a hydraulic jack, and a pressure gauge. The test can be conducted in the field or in the laboratory. The failure load is recorded and used to calculate the point load strength index I_s, according to the following equation (ASTM, 2008b):

$$I_s = P_{ult} \Big/ D_e^2 \quad (1)$$

where P_{ult} is the failure load (N), and D_e is the equivalent core diameter (mm).

It has been found that the point load strength index depends on the specimen size (Thuro and Plinninger, 2001). According to ASTM (2008b), the standard specimen diameter D is 50 mm. However, it may not always be possible to obtain specimens having a 50 mm in diameter (Brook, 1980). Therefore, it is common to perform the test on specimens of different sizes and determine the point load strength index I_s. The size is corrected to obtain the value of I_s which would have been measured by a diametrical test with $D = 50$ mm and is

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given the symbol I_{s50} (ASTM, 2008b). Several correction schemes for size have been developed over the years since the beginning of the point load test (e.g. Broch and Franklin, 1972; Brook, 1985; Thuro and Plinninger, 2001; ASTM, 2008b). The specimen size correction proposed by ASTM (2008b) is implemented in this paper.

3. Geology of Dubai in the United Arab Emirates

The near-surface geology of the United Arab Emirates can be divided into two groups: lower formation or 'Solid Geology' and upper formation or 'Superficial Geology'. The Superficial Geology comprises beach dune sands, marine sands and silts. The Solid Geology is composed of alternating beds of calcarenite/calcareous sandstone with some carbonate sand bands, gypsiferous sandstone with cemented sand layers, and calcisiltite and siltstone, from the top down (Beau et al., 2008). A geological map of the general location under investigation is presented in Fig. 1, which shows the expected stratigraphy of the coastal areas of Dubai (Alsharhan and Kendall, 2003). It consists of Quaternary marine, aeolian, sabkha and fluvial deposits that lie on the top of aeolianite and marine calcarenite (Ghayathi formation) which overlay the Barzman formation that is comprised of fluvial sediments characterized by poorly sorted conglomerates (Macklin et al., 2012). The rocks considered in this study belong to the Ghayathi formation described as marine calcarenite.

4. Mechanical and chemical characteristics of Dubai calcareous sandstone

Boreholes were drilled at a number of sites at Dubai in the United Arab Emirates. Rock samples were extracted using a double tube core barrel headed with diamond bit, producing a nominal core diameter of 76 mm. The boreholes extended into the rock at a depth of approximately 8 m (approximately −13 to −21 DMD (Dubai Municipality Datum)). Chemical testing of 21 specimens shows that the calcium carbonate ($CaCO_3$) contents vary between 50.62% and 93.57% with an average of 71.32%.

According to ARGEMA classification of carbonate formations shown in Table 1 (Le Tirant and Nauroy, 1994), cemented formations with carbonate contents higher than 30% are defined as soft to hard carbonate rock. For geomaterials with calcium carbonate contents lower than 30%, the material performs as a silicate. Accordingly, it is warranted to describe such materials as "carbonate rock" (Le Tirant and Nauroy, 1994).

The unconfined compressive strength is generally considered as the reference value for the compressive strength which is typically measured using uninstrumented uniaxial compression tests (ASTM, 2002a). The recorded values of the unconfined compressive strengths varied between 0.13 MPa and 15.75 MPa. Thus, the tested rock specimens were classified as weak to very weak ones according to Mayne et al. (2001).

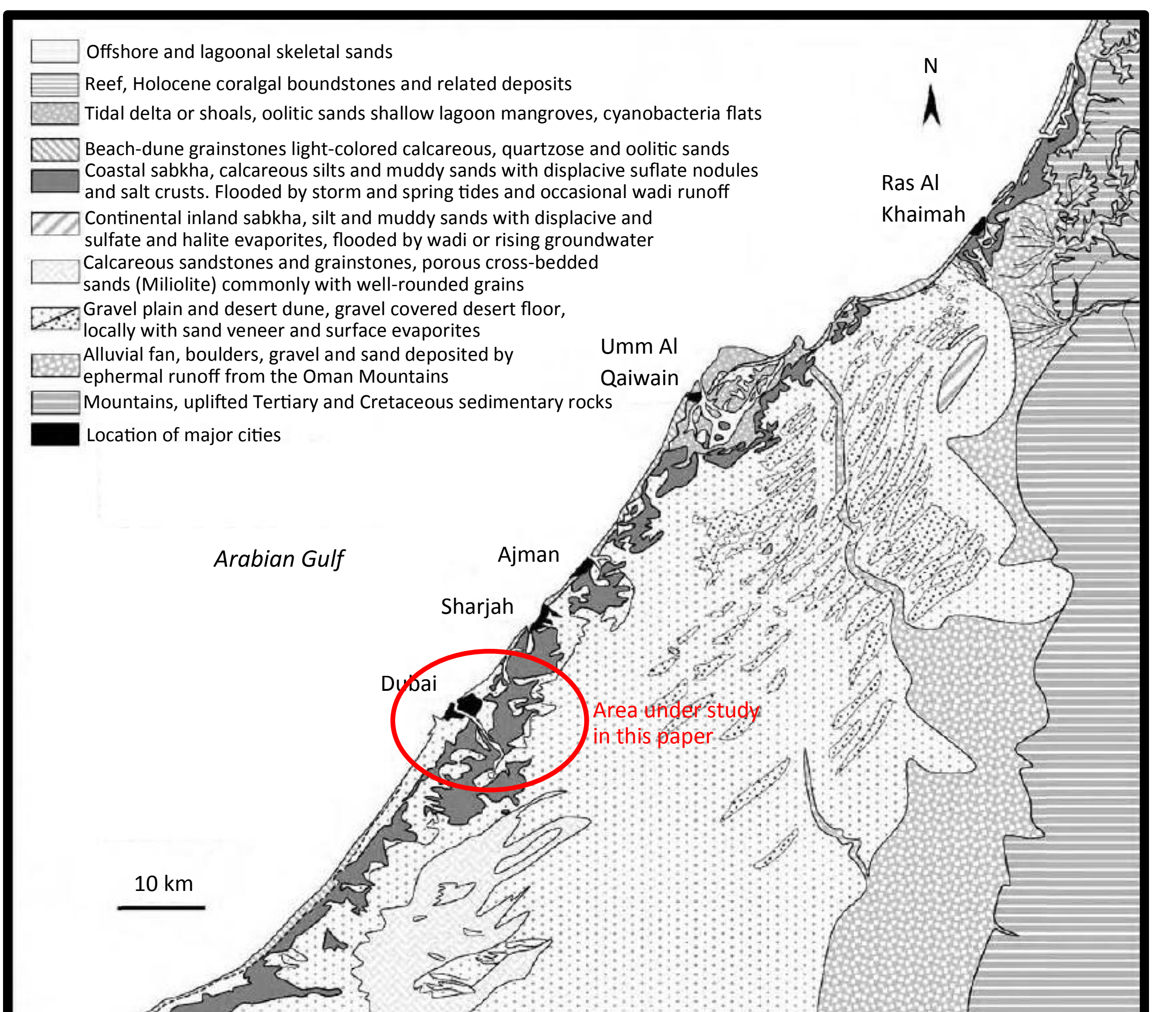

Fig. 1. Geological map of the United Arab Emirates showing the area under study (Alsharhan and Kendall, 2003).