Assessment of durability and deterioration of rocks from western Iraq

Abbas J Al-Taie¹

¹ Civil Engineering Department, Al-Nahrain University, Baghdad, Iraq

al.taiegeo@gmail.com

Abstract. The behavior of rocks in water can be expressed in terms of their ability to resist slaking when exposed to water. This ability to withstand durability and deterioration from weathering affects both the effectiveness of the engineering project and its cost. Durability and deterioration of rock from the west of Iraq are little studied, and there is little confidence in these properties to be utilized in engineering works. This study is emphasized on the information obtained from the slaking durability test, specific gravity, and absorption tests performed to evaluate durability and deterioration properties of the rock samples taken from the stratum of the Rutba-Jezira Zone, western Iraq. An examination of the statistical relationship between water content, slake durability index, specific gravities and absorption was also included. The results show that the durability and deterioration of the investigated rock are variable due to the occurrences of a different secondary constituent. Such rock can deteriorate rapidly upon exposure or slake and soften when in contact with water. As a result, the rock of the study area is problem material in several phases of geotechnical engineering.

1. Introduction and objective
The sedimentary rocks form an outer skin on the Earth’s crust, covering three-quarters of the continental areas. The composition of these rocks depends partly on factors such as the composition of the parent material and the stability of its component minerals [1]. Sedimentary rocks are frequently cemented by more than one material, they consist of more than a type of rock and always form alternately laminated because of the natural forming process and also exposed to tectonic effect and pressure. Something like about one-fifth of all sedimentary rocks is carbonate rocks [1-3].

As for degradable materials, sedimentary rocks are the most common rock types which degrade rapidly. These materials decompose when exposed to air, as they take on water [4-5]. In geotechnical practice, durability is an important property of rock-mass and rock-materials [6]. Differing rock durability requires a variety of design parameters and construction techniques. This property, however, can be assessed by different methods based on several indices. Some indices are based on chemical or mineralogical-petrographical or engineering properties. These indices, however, have been devised for quantifying the changes in the properties of rocks from different points of view. Researchers, like Ceryan et al. [7], related these indices to the engineering properties of weathered rocks. Ceryan [8] stated that indices based on key engineering properties generally have more applicability than those based on chemistry and mineralogy and are also simpler and less time-consuming. Quick absorption index, water absorption by weight, abrasion resistance, hardness index, slake durability index, dry density, Schmidt hammer rebound value, porosity, effective porosity, and void ratio are among those indices that based on engineering properties.
The effectiveness of the engineering project constructed on a rock foundation and its cost is highly affected by the ability of the rock to resist slaking when exposed to water. The slake durability of rock is one of the important properties that influence geological hazards and engineering safety. Investigation of the importance of the slaking of soft rock is necessary especially when encountered in underground engineering [4, and 9]. The behavior of rocks in water can be expressed in terms of their ability to resist slaking when exposed to water, using the slake durability test [10-11].

The deterioration of rocks samples (limestone) selected from Mosul city, north of Iraq, investigated by Khattab and Othman [12]. In their investigation, the selected samples subjected to cycles of wetting and drying through slake and durability tests. They were found that the loss of weight of rock samples increased and reached a value of 14%, due to subjection to the durability test, and as a result, a 15% to 25% reduction in strength was recorded. Durability and slake Nineveh weak rocks (northern Iraq) studied experimentally by Khattab et al. [13]. According to this study "very weak, medium-weak, and weak" are the classifications of the durability of the selected rocks samples. Such classifications give an indication of the strength reduction of rock samples. Saleh [14] attributed the weak strength of the rock samples from Nineveh, northern Iraq, to the high void ratio in these samples. Thin sections of rocks studied using microscopic study supported this conclusion. The rock (clastic and carbonate) from the geological formation of Fat’ha and Injana has been studied by Jawadi et al. [15]. They found that the engineering properties for investigated formations in the study areas are low. Unfortunately, durability and deterioration of rock from the west of Iraq are little studied, and there is little confidence in these properties to be utilized in engineering works. It was shown that some of the rock in this area of Iraq is described as "very poor", RQD values for the core specimens of these rocks are less than 21 [3]. Such a situation necessitates an investigation of the rock of this region.

In this study, two laboratory tests were selected from several existing classification systems and performed on rock samples taken from the stratum of the Rutba-Jezira Zone in the west of Iraq. Tests included: slake durability, specific gravity and absorption. The information obtained from these tests was used to evaluate the durability and deterioration properties of the rock samples. A study of the effect of the water content of the specimen at the time of the preparation of the samples on the slake durability index was also included. Furthermore, an examination of the statistical relationship between (water content, slake durability index, specific gravity, and absorption), was carried out using regression analysis.

2. Geological setting

Tectonically, the studied area is located in the Rutba-Jezira Zone of the Stable Shelf area and according to geography it is located in the west of Iraq. The Rutba-Jezira Zone is an inverted Palaeozoic basin with a Syn-Hercynian basin and dominated by the Rutba Uplift. Its basement ranges from 5 km in the Jezira area to 11 km S of Rutba, was relatively stable during Mesozoic-Tertiary time and more mobile during Infracambrian and Palaeozoic times [16]. The general geology of the area consists of limestone with textures ranging from oolitic to chalky, which locally contain corals and shell coquinas; they are often recrystallized and siliceous. Beds of green marls, argillaceous sandstones, breccias, conglomerates, and conglomeratic limestones also occur, see Figure 1.
3. Samples and experimental work

The rock samples used in the experimental study were taken from the stratum of the Rutba-Jezira Zone in the west of Iraq. The specimens of rock are pieces taken from both surface exposure and core samples obtained from different depths. Specimens were selected for the rock samples and subjected to testing for slake durability, water content, and specific gravity and absorption tests. All tests were conducted in accordance with applicable ASTM standards. The slake durability testing was carried out for the mentioned rock pieces. This test was conducted using lab equipment consists of one drum, so one test could be run at a time as shown in Figure 2. The testing methodology was based on the standard procedure as described in ASTM D4644 standards [17]. In this test method, the slake durability index of rock was determined after two drying and wetting cycles with abrasion. The tap water has been used as a slaking fluid through the testing. The test has been carried out on a total number of rock samples of 43.

On the other hand, the ASTM standards, precisely, the procedure described by ASTM D 6473 [18] have been followed to determine the specific gravity and the absorption of the tested rock specimens. According to this procedure, the rock specimens were submerged in tap water for 24 hrs. to examine the sensitivity of these specimens to the damage of water (i.e. water destabilization effect)
4. Results and discussion

The main purpose of this study is to estimate qualitative durability and assign quantitative durability of rock samples from the west of Iraq. To achieve this purpose, the slake durability test was used. The tested specimens have been presented in Figure 3. This figure shows some of the retained specimens after the second cycle of drying and wetting, also, it is showing the typical specimens presented by ASTM standards as a comparison. Based on the shape of the retained specimen, and according to ASTM specification, the rock specimens have been categorized into three groups. The first group is "type I" at which the rock specimens reveal virtually unchanged. In the second group, the ASTM classification is "type II", here the remained specimens are both small and large fragments. While exclusively small fragments have remained in rock fragments of the third category, this is the "Type III" as per ASTM D4644 [17].

![Figure 2. Slake durability test apparatus.](image)

![Figure 3. Retained specimens from slake durability test.](images)
On the other hand, as described in ASTM D4644 [17], the slake durability index of each tested rock samples was determined after two drying and wetting cycles with abrasion. Based on the second cycle results, the durability index (Id) was calculated and the values of Id were plotted as shown in Figures 4. According to the durability index values, and based on the classification of Chandra [19] (Table 1), the investigated rock specimens have been classified into different groups as shown in Figure 4. It can be noticed that the durability descriptor of about 10% of the tested rock is low to medium, the durability of 20% of the specimens are high, while the 70% of specimens have high to very high durability descriptor. This difference in the slake durability index values may be due to the occurrences of different "secondary constituent" with investigated rock such as clay, sand, dolomite, shell, marl, and chalk.

| Id  | Durability Descriptor |
|-----|----------------------|
| 0-25 | Very low             |
| 25-50 | Low                  |
| 50-75 | Medium               |
| 75-90 | High                 |
| 90-95 | Very high            |

The bulk specific gravity, bulk specific gravity (saturated surface dry), and the apparent specific gravity of the tested rock specimens have been calculated from the results of the procedure of ASTM D6473–99. The results of bulk specific gravity have ranged from 1.28 to 2.59, and the bulk specific gravity (saturated surface dry (SSD)) ranged from 1.78 to 2.61, while apparent specific gravity ranged from 2.21 to 2.83. It has observed that after 24 hrs. of submerging in water, some rock specimens were totally collapsed. Such observation indicates the sensitivity of rock specimens to the water's damage or the water's destabilization effect, such effect leads to the softening of rock and as a result, collapsing the rock specimens. On the other hand, the effect of soaking on the mass of rock specimens has been investigated. The increase of rock mass due to filling the rock pores with water has been recorded and
the absorption of rock specimens was calculated. The results showed that the absorption values of the studied specimens were ranged from 1% to 39%.

In the second part of this paper, an examination of the statistical relationship between (water content, slake durability index, specific gravity, and absorption), was carried out using regression analysis. The effect of the water content of the specimen at the time of the preparation of the samples on the slake durability index was also studied. To achieve such examination, computer specialized software named "Number Cruncher Statistical System (NCSS)" has been used. Figures 5 and 6 show the results of the analysis. The results have shown that the variation of the initial water content below 15% has little effect on the values of slake durability index Id, while the slake durability index decreases with increasing the initial water content of rock specimen above the mentioned value. Regression analysis was used to examine the statistical relationship between absorption and bulk specific gravity of the rock specimens. A high correlation has been shown in Figure 6.
5. Conclusions
This paper presents the information obtained from the experimental investigation (including slaking durability test, specific gravity, and absorption tests) on the ability of rock (from Rutba-Jezira Zone, western Iraq) to resist slaking durability and deterioration. A statistical study has been included to examine the relationship between water content, slake durability index, specific gravities, and
absorption. The results reveal that the investigated rock has variable durability and deterioration due to the occurrences of a different secondary constituent. Such rock can deteriorate rapidly upon exposure or slake and soften when in contact with water. The moisture content of the specimen at the time of the preparation of the sample can have a significant effect on the durability and deterioration characteristics of the rock. As a result, the rocks of the study area are problem materials in several phases of geotechnical engineering. The properties of the rock under consideration necessities special considerations to be taken with the engineering works activities like excavation to constructed underground structures. Also, protection of the exposed rock surface when constructed engineering projects in the area like the current study area using suitable blinding materials is important.

References
[1] Bell FG 2007 Engineering Geology (Elsevier, Waltham).
[2] Kassim A and Mohammad ET 2007 Laboratory study of weathered rock for surface excavation works (Faculty of Civil Engineering, UT).
[3] Al-Taie A J 2017 Dynamic deformation modulus of weak rock measured from laboratory and field tests Association of Arab Universities Journal of Engineering Sciences 14 1 1-11.
[4] Klein S 2001 An approach to the classification of weak rock for tunnel projects Rapid Excavation and Tunneling Conference (RETC), In San Diego.
[5] Look B G 2007 Handbook of Geotechnical Investigation and Design Table Taylor and Francis 12-78.
[6] Dhakal G, Yoneda T, Kato M and Kaneko K 2002 Slake durability and mineralogical properties of some pyroclastic and sedimentary rocks Engineering Geology 65 1 31.
[7] Ceryan S, Ceryan N and Aydin A 2005 Determination of weathering in engineering time using interaction matrices Proc. of 1st International Symposium on Travertine Pamukkale University Denizli Turkey 297-304.
[8] Ceryan S 2012 Weathering Indices for assessment of weathering effect and classification of weathered rocks: a case study from ne Turkey Chapter from (Imran Ahmad Dar, Earth Sciences, InTech).
[9] Qi J, Sui W, Liu Y and Zhang D 2015 Slaking process and mechanisms under static wetting and drying cycles slaking tests in a red strata mudstone Geotech Geol Eng 33 4 959-72.
[10] Franklin JA, Broch E and Walton G 1971 Logging the mechanical character of rock Trans Inst. Min. Metall. 80 1–9.
[11] McLean AC and Griibble CD 2005 Geology for Civil Engineers (Taylor & Francis e-Libraries).
[12] Khattab S I A and Othman H M S 2013 Durability and strength of limestone used in building Al-Rafidain Engineering 21 3 1-14.
[13] Khattab S I A, Khalil A A and Faris M K 2014 Durability of some weak rocks selected from Nineveh Eng. & Tech. Journal 32 4 908-21.
[14] Saleh D G 2012 The suitability of limestone of Fat'ha formation for building and road aggregates in Nineveh governorate / North Iraq Journal of university of Anbar for pure science 6 3 146-158.
[15] Al-Jawadi A, Salih D and Adeeb H 2018 Evaluation of engineering properties of rocks and soils Iraqi National Journal of Earth Sciences 18 2 1-14.
[16] Jassim S Z and Goff J C 2006 Geology of Iraq (Dolin, Prague and Moravian Museum, Brno).
[17] ASTM D4644 2003 Standard practice for slake durability of shales and similar weak rocks Book of Standards 04.08.
[18] ASTM D6473 2003. Standard practice for specific gravity and absorption of rock for erosion control Book of Standards 04.08.
[19] Chandra R 1970 Slake durability test for rocks M.S. Thesis, University of London, Imperial College, Rock Mechanics Research Report, 55.