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Evaluation of the physical and mechanical properties of gypsum rocks and assessment of their durability in the quarries of Northwest Kirkuk, Iraq

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Abstract

This study evaluates the physical and mechanical properties of gypsum rocks from quarries in northwest Kirkuk, Iraq, to assess their durability under local environmental conditions. Six stations were selected for sample collection, with seven samples analyzed for porosity, specific gravity, water absorption, moisture content, point load strength, and durability through wet-dry cycles. Results revealed low porosity (1.15–2.70%), minimal moisture content (0.48–1.01%), and moderate water absorption (0.74–1.77%), indicating high cohesion and limited susceptibility to water infiltration. Durability tests classified the rocks as "medium-high" after two cycles, with mass retention exceeding 89%. Point load strength varied significantly (1.24–2.68 MPa), reflecting heterogeneity in mineral composition. This study is concerned with evaluating the gypsum rocks of this area, which helps in determining the uses in engineering and industrial fields. The study fills critical data gaps for regional resource utilization and offers insights for sustainable quarry management.

Keywords: Gypsum rocks, physical properties, mechanical durability, point load strength, Kirkuk quarries, geotechnical assessment

1. Introduction

Gypsum is one of the most common minerals, obtained from sedimentary layers formed in marine basins and with high evaporation. is a key component of sedimentary sequences . Its prevalence in Kirkuk Governorate, Iraq, is particularly notable, where extensive deposits are embedded within the Middle Miocene Fatha Formation and adjacent stratigraphic units (Sissakian & Al-Jiburi, 2014) ^[18]. The Fatha Formation, deposited reflects a dynamic interplay of shallow marine, supratidal, and lagoonal environments, (Al-Juboury & McCann, 2008) ^[1]. These settings fostered cyclical episodes of evaporation, leading to the precipitation of calcium sulfate minerals such as gypsum, often interbedded with marl, clay, and limestone layers-a testament to the region's complex paleo environmental history (Buday, 1980) ^[8] and because of the presence of gypsum rocks in large quantities, it has economic and engineering importance and its important role in urban expansion and medical fields (Carvalho *et al.*, 2008) ^[4], (Othman and Ali, 2023) ^[17]. Six samples were collected from the study area to reach an accurate knowledge of its physical and mechanical properties and the extent of the durability of these rocks. Many studies have focused on the physical properties such as porosity, specific gravity, water absorption and moisture content, as the study (Wei *et al.*, 2020) ^[22] has proven that porosity and density directly affect the resistance of gypsum rocks and their tolerance to mechanical stress (Wong, 2016) ^[23] has proven that the difference in specific gravity, porosity and chemical content affects their mechanical properties ,In addition to the following studies that addressed the relationships between engineering and rock properties (Bell, 1993) ^[7], (Kahraman and Yeken, 2008) ^[13], (Erguler and Ulusay, 2009) ^[10], (Török and Příkryl, 2010) ^[20], (Yilmaz, 2010) ^[24], (Zhou *et al.*, 2011) ^[26], (Kumar *et al.*, 2015) ^[14], (Khanlari and Naseri, 2016) ^[15], (Alyamac *et al.*, 2017) ^[16], (Soroush *et al.*, 2020) ^[15]. Therefore, despite the availability of gypsum rocks in the northwest of Kirkuk, it was noted that there are few studies on the physical and mechanical properties and the extent of rock erosion under local environmental conditions. Therefore, this study provided an evaluation of gypsum rocks in his region.

2. Study area

The study area is located 23.2 km from Kirkuk city center near Dibs-Kirkuk road. The study area includes two gypsum quarries in fatha formation. The area is located between longitudes 44°14'29" and 44°09'23" east and latitudes 35°11'33" and 35°36'29" north, depending on the Universal Transverse Mercator (UTM) coordinate system.

3. Aim of study

This study aims to evaluate the physical (porosity, specific gravity, water absorption, moisture content) and mechanical (point load strength) properties of gypsum rock samples from quarries northwest of Kirkuk, Iraq, for the purpose of assessing their durability under local environmental conditions, to fill the gap in data specific to the region and to benefit from them in industrial and construction uses.

4. Materials and Methods

Rock samples were collected from six stations, with one sample taken from each station. In addition, two samples were taken from the sixth station, one very pure and the other mixed, resulting in a total of seven samples taken within the study area. The samples were also selected based on the apparent differences in the gypsum rocks in order to represent a comprehensive representation of the different types and properties. Care was taken to select rock samples that were not affected by weathering factors and were free of cracks or discontinuities. After the samples were collected, they were broken into smaller samples for distribution to other tests. The samples were prepared for testing, where physical tests were performed, namely rock porosity according to specifications (ASTM.C-97-09, 2010) [4], moisture content according to (ASTM.D22-16, 2004) [5], specific gravity according to (ASTM-C-127-2004) [3], and water absorption according to specifications (ASTM-C-01-127, 2004). A durability test was then conducted to measure the strength of the rocks according to (ASTM D-4644-87, 2004) [6], Using the device shown in(Figure 1).The point load index test was also used to provide information about

how the materials behave under specific stresses according to (ISRM, 2007) [12], Take measurements as shown in (Figure 2).

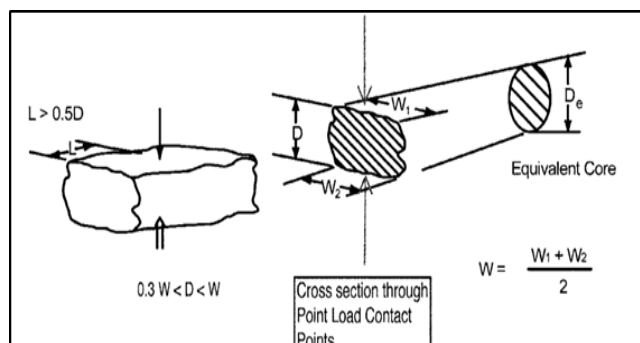


Fig 1: Irregular sample dimensions for point load testing (ISRM)

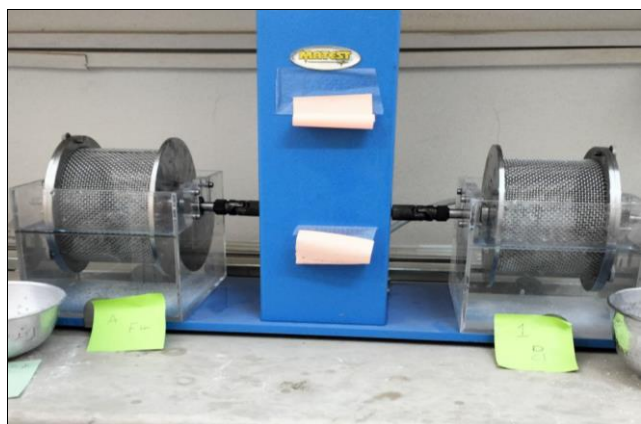


Fig 2: Durability testing device (Matest)

5. Results and Desiccation

The laboratory tests of the rock samples were as follows (Table 1), (Table 2) (Table 3)

Physical Properties including (Porosity, Moisture content, Absorption water, specific gravity)

Table 1: Physical properties

No. Station	Sample	Porosity	Moisture content	Absorption water	Specific gravity
Station 1	1	2.34%	0.874%	1.529%	2.274
Station 2	1	2.73%	1.010%	1.767%	2.267
Station 3	1	1.33%	0.481%	0.841%	2.294
Station 4	1	2.70%	0.965%	1.688%	2.229
Station 5	1	1.15%	0.423%	0.740%	2.296
Station 6	1	1.32%	0.484%	0.847%	2.265
	2	1.78%	0.529%	0.925%	2.302

Durability test rates and classification according to (Gamble, 1971) [11]. (Table 2)

Table 2: durability test

No. station	Sample	First cycle (Id1)	Classification (Gamble, 1971)	Second cycle (Id2)	Classification (Gamble, 1971)
Station 1	1	95.12%	Medium High	90.72%	Medium High
Station 2	1	96.87%	Medium High	93.96%	Medium High
Station 3	1	95.82%	Medium High	91.99%	Medium High
Station 4	1	95.07%	Medium High	90.61%	Medium High
Station 5	1	94.31%	Medium High	89.14%	Medium High
Station 6	1	95.03%	Medium High	90.41%	Medium High
	2	95.69%	Medium High	91.40%	Medium High

Point load test values in rock samples after calculating the resistance index I_s (50) as follows (Table3)

Table 3: point load test

No. station	Sample	Point load strength (MPa)	Point load strength index, $I_{s(50)}$ /MPa
Station 1	1	1.243	0.48
Station 2	1	2.020	0.91
Station 3	1	1.846	0.72
Station 4	1	1.310	0.91
Station 5	1	2.680	1.15
Station 6	1	2.495	0.828
	2	2.425	1.045

5.1 physical properties

In these physical tests, the porosity showed percentages ranging between (1.15%-2.70%), which indicates few voids and reflects high cohesion, and this is due to the difference in the constituent minerals, and the moisture content percentage (0.481%-1.010%), which indicates very little water trapped inside the pores or between the grains. This may be an indication of a dry environment or a rock that has been exposed to dehydration. Water absorption (0.740%-1.767%) is also a low amount and the rock is unable to absorb large amounts of water. The specific gravity also varied between (2.229-2.302), and this difference indicates the difference in the percentages of impurities present in the rock samples (Maqsood, Anis-ur-Rehman and Gul, 2003) [16].

5.2 The durability test

The durability test was conducted to evaluate the resistance of rocks to erosion through second cycles of drying and wetting, and the results were classified according to (Gamble, 1971) [11]. The remaining mass percentages after the first cycle were determined between (94.31%) and (96.87%) for all the samples tested under the experiment in the first cycle and were classified as medium high durability except for a sample from the first site in the third station which was classified as medium due to a slight loss in its mass. These results mean that most of the rocks showed a good degree of corrosion resistance in the first cycle which reflects the good cohesion of the samples. The remaining mass percentages after the second cycle were between (89.14%-93.96%) and all samples were classified as medium high durability. This indicates that the rock is resistant to corrosion even during two cycles.

5.3 Point Load Strength

The point load strength values showed differences in the results, where the highest value was recorded in the fifth sample at (2.680 MPa) and the lowest value in the first station (1.243 MPa). This variation reflects the extent of the difference in the structural composition of the samples (Tugrul and Zarif, 1999) [21].

6. Conclusion

The results confirm that this study of the characteristics of the rocks of the region makes them important and promising in engineering and industrial applications. The analyses of the physical properties showed a low percentage of porosity ranging between (1.15-2.70%), which reflects a high internal cohesion due to the nature of the compact crystalline structure of gypsum. The values of the specific

gravity differed due to the presence of impurities within the rock samples, ranging between (2.229-2.302). The moisture content was low (0.48-1.01%) and the water absorption rate was limited (0.74-1.77%) indicating good resistance to water corrosion, which is good and important in dry areas as the region fluctuates between dry and seasonal rains. In terms of durability, the samples were classified as (medium-high) after the two cycles of testing, i.e. the mass retention was (more than 89%), which confirms their ability to withstand repeated stresses from the environment such as drying and wetting. A large variation was observed in the values of point load strength (1.24-2.68 MPa), where the fifth sample recorded the highest value (2.68 MPa), while the first sample appeared weaker with a value of (1.24 MPa). The reason for this variation is due to geological differences during the stratigraphic formation, such as the presence of impurities such as marl deposits and the degree of crystallization, which directly affect the mechanical behavior of rocks. The results are consistent with research that linked the variation between porosity values and specific gravity to increased mechanical resistance. However, the higher classification of gypsum rock durability compared to other areas is due to the sedimentary conditions during the Middle Miocene, which led to the formation of gypsum layers that were more homogeneous. This study provided an evaluation of its engineering properties, degree of resistance and mass retention rate during local environmental conditions, which helps in determining appropriate uses in engineering and industrial fields.

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