DNIPRO UNIVERSITY of TECHNOLOGY 1899

Mining of Mineral Deposits
ISSN 2415-3443 (Online) | ISSN 2415-3435 (Print)
Journal homepage http://mining.in.ua
Volume 13 (2019), Issue 2, pp. 75-81

UDC 622.02 https://doi.org/10.33271/mining13.02.075

ENGINEERING CHARACTERISTICS OF EGYPTIAN LIMESTONE

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ABSTRACT

Purpose. Study of physical properties such as porosity, density and mechanical properties such as compressive strength and tensile strength of Egyptian limestone based on experimental investigations.

Methods. In this paper using physical and mechanical properties to evaluate the Egyptian limestone according to the relationship between their properties especially the degree of water saturation. Samples were obtained from six different locations (Helwan, Minia, Assuit, Qena, Sohag, and Aswan).

Findings. The strong correlation between porosity and density, and good correlations between uniaxial strength and tensile strength. Carried out results indicated that, small porosity results in greater rock strength and vice versa.

Originality. Applying the fitting curve technique to check the best correlation between the different property of limestone to identify the best relationship to apply the prediction to find the limestone property in other location as regards applying conditions.

Practical implications. Results carried out that the strong correlation between porosity and density, and good correlations between uniaxial strength and tensile strength as summarize in the outcome of data interpretation. Highest quality stones, in terms of their hydric behavior and mechanical properties, are the index for the suitability of using limestone.

Keywords: *limestone, rock mechanics, mechanical properties, physical properties*

1. INTRODUCTION

The chemical composition of limestone is $CaCO_3$ (mineral calcite), other form calcium subtitle magnesium to produce dolomite ($CaMg (CaCO_3)$). There are many limestone deposits extended in all governorate in Egypt, which used in building stone, cement industry, highway construction as filling materials, concrete aggregate, etc. (Ahmad, El-Sageer, & Hussein, 1996).

Egyptian limestones are extracted from different places such as quarry in different governorates as shown in Figure 1 (Qena, Helwan, Minia, Assuit, Sohag, and Aswan), which in different physical and mechanical properties. Sayed Ahmed & Abdel Wahab (1983) and Mahrous, El-Beblawy, Mohamed, El-Sageer, & Mostafa (2007) studied the physical and mechanical properties of different eight samples locations and focused on applying new equation to determine the modulus of elasticity as known compressive strength for limestone.

Hussein, El-Beblawy, El-Sageer, Abul, & Tawfik (2004) investigated some of property and specifications of Helwan rock samples: for conservation treatment of Ancient Egyptian limestone monuments Said (1981, 2017), rock strength carried out by Duroscope rebound values (for strength) with all consolidates which up strength of the tested sample. Silica acid ester Wacker-OH were able to penetrate limestone specimens in considerably higher than others, reaching 48.15% up to strength values followed 39.84% strength of specimens with Polymethyl methacrylate.

Teme & Edet (1986), Goodman (1980), Broch & Franklin (1972) carried out that how to classified the limestone area when measured uniaxial compressive strength also concluded that the influence of water on mechanical property regard as the influence time finally recommended approximately 20 – 90% of mechanical property lost when samples immersed totally in water as regard as rock type.

Vasarhelyi had been studied the effective of water content on limestone sample, the final result conclude that over 73% reduction in uniaxial compressive strength and around 53% reduced in modulus related to the saturation factors and other note the uniaxial compressive strength increases exponentially with rock density (El-Sageer, Sayed, & Hussien, 1997; Hussein, El-Biblawy, & El-Sageer, 1997).

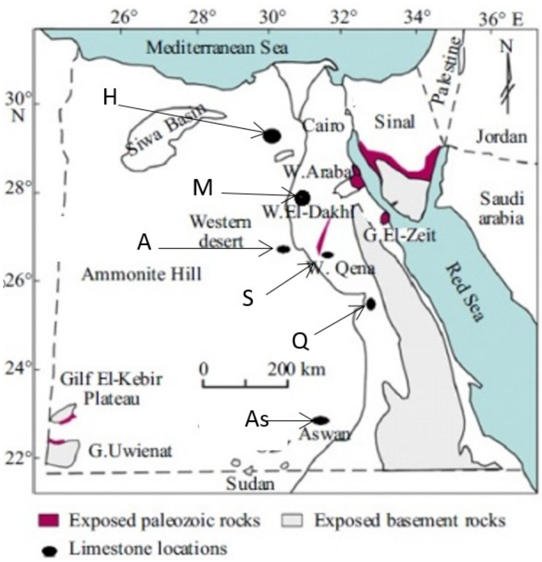

Figure 1. Studied area, Helwan (H), Minia (M), Assuit (As), Sohag (S), Qena (Q) and Aswan (Aw)

There are few researchers studied the limestone samples which totally saturated and results indicated that totally decreased in magnitude of physical and mechanical properties of some limestone samples other locations had been studied Bieniawski & Van Heerden (1975). All data calculated and statistical analysis had been processed.

2. EXPERIMENTAL WORK

All tested rocks as representative samples were collected from six different governorates as Helwan, Mania, Assuit, Sohag, Qena and Aswan. General specification of limestone samples in pure and highly degree of homogeneity, also its usually seen as white to grayish. Samples preparation for studied area and samples after testing are presented on Figures 2 and 3.

Qena samples look like marl limestone which mostly as yellow color concluded by El-Beblawi, Mohamed, El-Sageer, Mostafa, & Mahrous (2009). Core samples were prepared by using drilling machine and following the criteria of ISRM (1979) standard. Test preparation for core samples were applied perpendicular to the bedding planes of stratified Esu, Edet, Teme, & Okereke (1994), Edet (1992) and Hendron (1978).

Kayabaşı, Soypak, & Göz (2018) focused on determined the geological analysis to illustrate chemical contents and give distribution of petrographic also give many details for mechanical peripeties of limestone location at that time it gives good seem to evaluate parameters for mine design.

The suitable properties for aggregate production were checked as regard as water contented, density, whether resistance and abrasion resistance finally carried out the limestone site which more suitable for concrete and asphalt making.

Kamani & Ajalloeian (2019) target to investigating the aggregate degradation (AD) by using rock strength tests to check the relationship between ad properties and rock strength. the final results carried out that good correlation between point load index and aggregate impact value ($R^2 = 0.832$), also, UCS has relative larger effects on the aggregate crushing value (ACV) ($R^2 = 0.812$) under the same loading condition. The weakest correlation occurs between Los Angeles abrasion value (LAAV) and UCS ($R^2 = 0.679$).

Alavi Nezhad Khalil Abad, Yilmaz, Jahed Armaghani, & Tugrul, A. (2016) focused on parameters which effect on properties mainly with resistance conditions. The suitable tests for evaluate durability of aggregates especially in lab. Those property are water absorption and Los Angeles coefficient to specified evaluation of limestone aggregates.

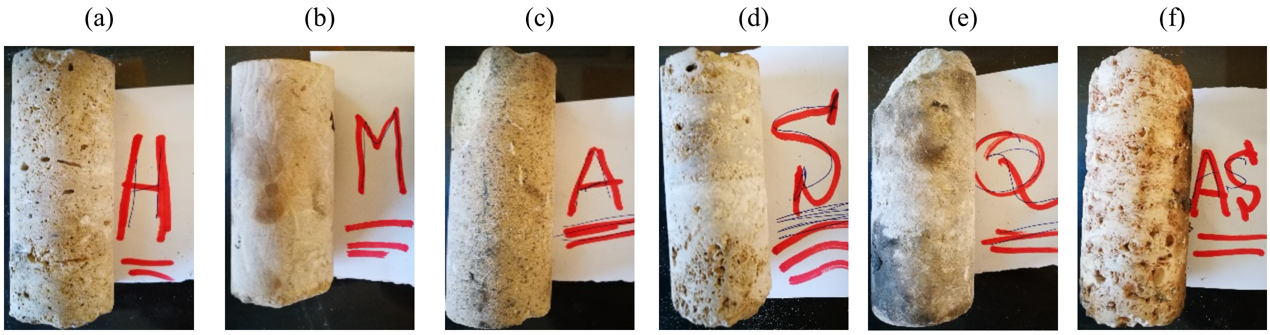

Figure 2. Samples preparation for studied area: (a) Helwan; (b) Minia; (c) Assuit; (d) Sohag; (e) Qena; (f) Aswan

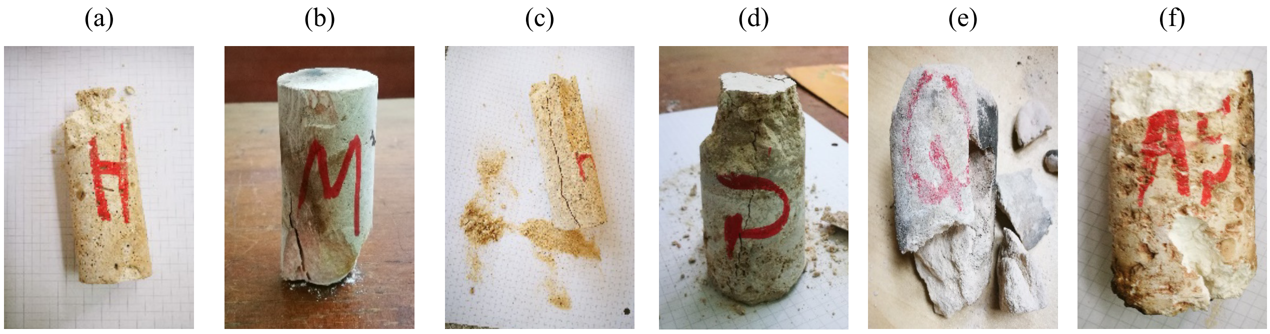

Figure 3. Samples after testing: (a) Helwan; (b) Minia; (c) Assuit; (d) Sohag; (e) Qena; (f) Aswan

They found the correlation coefficient for the relationships between different property. Another variance apply root square error were calculated and compared for two developed model.

Carvalho, Silva, & Simão (2018) carried out that accessing their petrographic and main technological features, that samples were overwhelmed to salt mist test related to European standard, determinations (variation on water absorption and flexural strength after salt mist cycling). That evaluation of limestone depends on investigation of physical and mechanical properties, finally the limestones' suitability for the main types of applications and for specific usage conditions, within each one. Thus, it was possible to set the recommended uses for each limestone, in order to maximize its durability.

Vázquez et al. (2013) they using different type of building and construction materials to examine the quality index for suitability of as building, petrographic specification and physical properties are very important affect its behavior when exposed to agents of decay the highest quality stones, in terms of their hydric behavior and mechanical properties are the crystalline dolostone from Bonar and the travertine from Albox, both of which have relatively low porosity.

Dhir, Limbachiya, McCarthy, & Chaipanich (2007) focus on determine the specification and durability of concrete to produce Portland cement (PC) and limestone. The more specific composition of Portland limestone cement was evaluated. characterization of concrete during establishment, including, initial surface absorption, carbonation resistance, chloride diffusion, freeze/thaw scaling and abrasion resistance, indicate that in general the test concretes followed single relationships with strength for most properties.

Jordá-Bordehore, Martín-García, Alonso-Zarza, Jordá-Bordehore, & Romero-Crespo (2016) explained the host rock is finely bedded and presented a complex network of folds and fractures, this structure controlled the development and the maze-pattern of the cave, as well as its main water routes. The stability of karstic caves can be assessed similarly to man-made excavations, but due to its geological heritage. The *Q* index and the stability graph method have both proven to be useful, but due to the polyhedral shape of the cave.

Physical properties such density and porosity (dried) of all sample were determine, nine samples for every location. Sample weighted using sensitive balance with an accuracy ~0.01 gram. Sample preparation its dried in furnace for 24 hours with around 105°C and cooling after that, next step totally immersed in water then dried wit clothes and weighed. Mechanical properties were measured for limestone samples both compressive and tensile strength beside coefficient dynamic fragmentation were examined for nine samples for every site, beside of preparing the sample to be ready for physical testing. All samples weighted to measure degree of saturation process. Samples will be saturated when the weight constant. The saturation measurement considered care to keep particle before dried and weighted. Another way to obtained the behavior of water distribution the sample stay for 7 days in air inside container which bottom have small water, this experimental give us good way for water distribution. Tables 1 – 6 shown in the result for physical and mechanical properties. All data analysis and the final results concluded that as shown in Table 7.

Table 1. Average physical and mechanical properties (Helwan)

Rock type	S.N.	Porosity, %	Dry density, g/cm^3	Coefficient of dynamic fragmentation	UCS, MPa		Tensile, MPa	
					dry	saturated	dry	saturated
H	1	10.20	2.65	24.53	33.35	30.21	2.68	1.85
	2	11.30	2.45	21.45	36.98	32.52	1.89	1.25
	3	8.90	2.80	22.53	40.01	38.21	3.85	2.41
	4	7.60	2.36	28.93	25.68	21.35	2.63	1.87
	5	9.88	2.63	27.82	27.63	24.36	2.72	2.43
	6	6.77	2.65	22.34	26.91	23.50	2.51	1.72
	7	7.32	2.75	24.53	37.54	30.52	2.34	1.86
	8	7.55	2.88	20.86	26.82	23.54	2.04	1.43
	9	11.86	2.64	24.36	34.65	29.80	3.02	2.08
	Av.	9.04	2.65	24.15	32.17	28.22	2.63	1.88

Table 2. Average physical and mechanical properties (Mina)

Rock type	S.N.	Porosity, %	Dry density, g/cm^3	Coefficient of dynamic fragmentation	UCS, MPa		Tensile, MPa	
					dry	saturated	dry	saturated
M	1	7.85	1.54	27.31	70.63	27.31	5.32	1.87
	2	10.32	2.68	20.12	56.42	28.71	6.45	2.35
	3	9.98	2.41	15.89	61.82	26.42	7.35	3.46
	4	6.99	2.65	24.53	92.31	45.75	5.85	2.75
	5	8.77	2.35	15.83	55.34	21.35	2.43	1.58
	6	6.45	1.98	17.99	70.54	31.55	2.73	2.91
	7	5.89	2.05	26.53	80.36	34.51	2.07	1.89
	8	7.54	2.65	27.38	64.35	28.41	4.03	2.06
	9	5.87	2.86	21.56	71.63	20.63	5.36	2.34
	Av.	7.74	2.35	21.90	69.27	29.40	4.62	2.36

Table 3. Average physical and mechanical properties (Assuit)

Rock type	S.N.	Porosity, %	Dry density, g/cm^3	Coefficient of dynamic fragmentation	UCS, MPa		Tensile, MPa	
					dry	saturated	dry	saturated
A	1	8.90	1.62	26.35	105.36	93.80	8.35	6.86
	2	7.30	2.73	24.35	98.63	77.55	6.53	4.63
	3	5.45	2.46	20.83	87.52	43.87	5.32	3.85
	4	4.56	2.33	18.97	102.45	89.36	9.80	7.63
	5	6.78	2.47	24.80	122.53	111.50	8.96	6.54
	6	5.74	1.98	17.63	113.56	86.53	9.35	6.43
	7	4.66	2.05	15.64	97.82	62.53	5.64	2.89
	8	5.32	2.65	19.55	104.58	89.52	6.35	5.63
	9	4.25	2.40	27.35	88.63	60.35	8.63	6.82
	Av.	5.88	2.30	21.72	102.34	79.45	7.66	5.70

Table 4. Average physical and mechanical properties (Sohag)

Rock type	S.N.	Porosity, %	Dry density, g/cm^3	Coefficient of dynamic fragmentation	UCS, MPa		Tensile, MPa	
					dry	saturated	dry	saturated
S	1	12.35	2.66	21.47	40.86	11.36	4.03	1.05
	2	8.77	2.78	28.63	52.63	14.36	5.03	1.05
	3	7.64	2.91	26.53	50.32	12.35	5.32	1.06
	4	4.66	1.82	16.43	46.93	9.86	3.85	1.87
	5	7.89	1.94	12.48	27.53	8.97	2.63	0.89
	6	5.98	2.04	23.45	25.85	11.53	3.85	0.87
	7	12.33	1.098	18.63	30.56	16.63	3.85	1.02
	8	13.48	2.04	14.56	41.89	17.56	6.3	1.08
	9	10.33	2.01	24.83	45.82	18.92	5.86	1.03
	Av.	9.27	2.14	20.78	40.27	13.50	4.52	1.10

Table 5. Average physical and mechanical properties (Qena)

Rock type	S.N.	Porosity, %	Dry density, g/cm^3	Coefficient of dynamic fragmentation	UCS, MPa		Tensile, MPa	
					dry	saturated	dry	saturated
Q	1	7.60	1.62	16.82	74.66	36.06	5.63	2.86
	2	8.64	2.73	17.63	66.33	40.36	7.35	3.54
	3	7.82	2.46	21.45	54.32	28.97	4.36	1.87
	4	9.71	2.80	24.33	75.03	34.92	6.35	4.35
	5	6.83	1.97	14.32	75.06	30.73	4.18	2.54
	6	4.66	2.04	12.72	80.52	40.36	7.65	3.64
	7	8.66	2.42	16.85	96.35	38.92	3.86	1.86
	8	4.56	2.36	25.21	75.06	28.79	4.36	2.05
	9	7.83	2.81	27.31	71.23	40.36	5.36	2.03
	Av.	7.37	2.357	19.63	74.28	35.50	5.46	2.75

Table 6. Average physical and mechanical properties (location Aswan)

Rock type	S.N.	Porosity, %	Dry density, g/cm^3	Coefficient of dynamic fragmentation	UCS, MPa		Tensile, MPa	
					dry	saturated	dry	saturated
As	1	8.91	2.65	15.63	45.63	22.31	4.32	1.35
	2	12.35	2.73	17.89	50.22	24.35	5.36	1.56
	3	11.45	2.46	22.64	48.96	20.38	4.36	1.98
	4	7.33	1.82	23.81	40.28	21.39	3.87	1.53
	5	5.68	1.73	14.53	38.91	24.36	4.36	1.87
	6	5.32	2.04	21.74	43.82	24.51	4.32	1.83
	7	6.81	1.91	13.22	51.92	23.56	3.93	1.05
	8	8.22	2.06	12.85	40.25	20.15	2.89	1.21
	9	4.63	2.71	18.75	55.36	19.85	3.03	1.23
	Av.	7.86	2.23	17.90	46.15	22.32	4.05	1.51

Table 7. The final average results of physical and mechanical properties of limestone samples

Rock type	Average porosity, %	Average dry density, g/cm³	Average coefficient of dynamic fragmentation	Average UCS, MPa		Average tensile, MPa	
				dry	saturated	dry	saturated
H	9.04	1.78	24.15	32.17	28.22	2.63	1.88
M	7.74	2.01	21.90	69.27	29.40	4.62	2.36
A	5.88	2.65	21.72	102.34	79.45	7.66	5.70
S	9.27	1.65	20.78	40.27	13.50	4.52	1.10
Q	7.37	2.05	19.63	74.28	35.50	5.46	2.75
As	7.86	1.95	17.90	46.15	22.32	4.05	1.51

3. RESULTS AND DISCUSSION

Rock samples were checked for porosity and the relationship illustrated in Figure 3. Sohag limestone illustrates the highest porosity value. It also remarks that Sohag sample has the lowest dry density as shown in Figure 4.

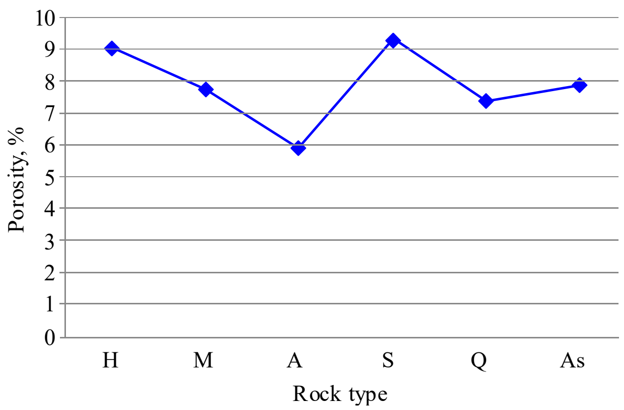

Figure 3. The average porosity for all rock sample related cite

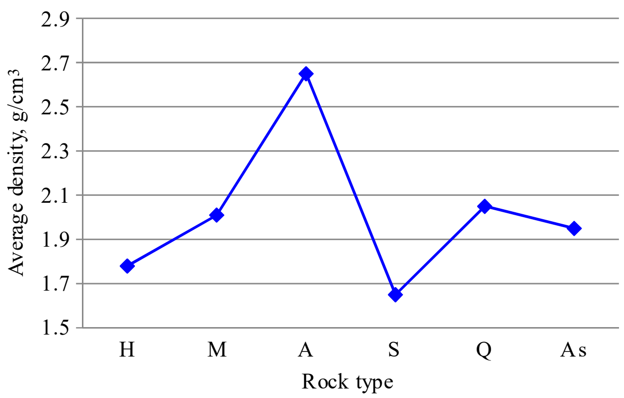

Figure 4. The average density for different locations

Figure 5 shows the value of compressive strength as mean under condition dray and saturated for limestone sample. The results indicated that small porosity greater strength and vice versa. For Sohag samples, final results carried out that great porosity and low strength (tensile and compressive strength).

Regression analysis by using least square method to obtain the best-fit line, and the correlation coefficient ($R^2 = 0.95$), correlation equations applied to check the degree of correlated between different property such as density and porosity. Figure 6 illustrates the good relationship between porosity and density.

Correlation style applied in other property such as uniaxial compressive strength and tensile strength.

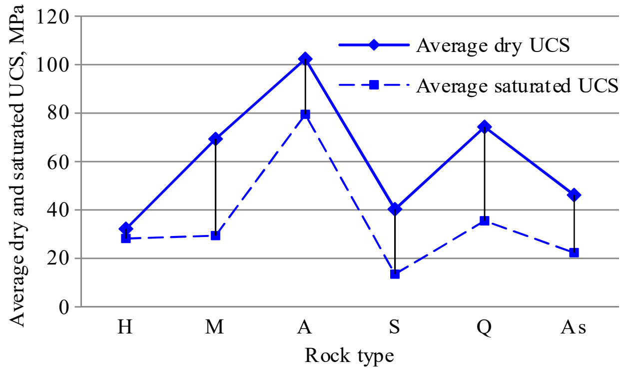

Figure 5. Average dry and saturated UCS with rock type

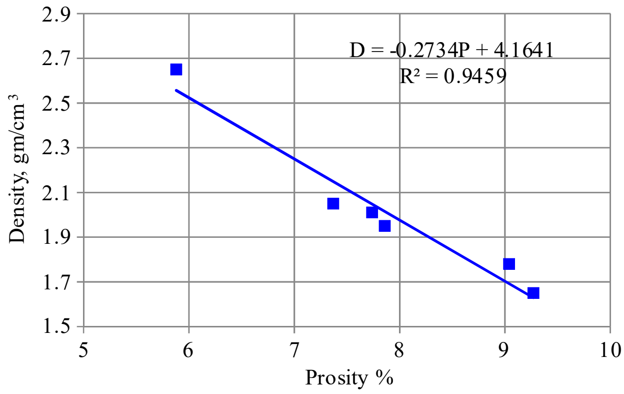

Figure 6. The relationship between density and porosity

Another correlation was made between the uniaxial compressive strength and the tensile strength as shown in Figure 7.

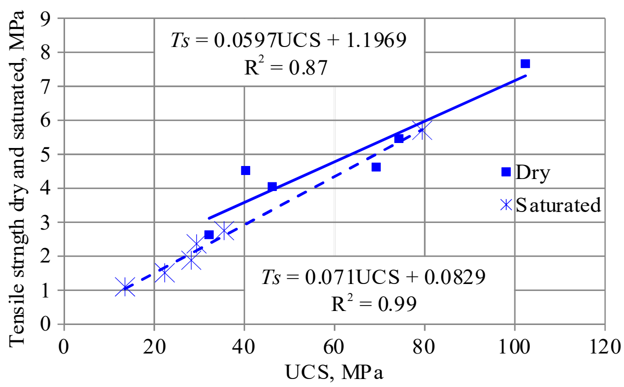

Figure 7. The relationship between tensile strength and uniaxial compressive strength

A good correlation was also obtained as R^2 was about 0.87 dry case and 0.99 Saturated case.

4. CONCLUSIONS

Finally, data analysis for limestone rocks were determined in the laboratory such as density, porosity Brazilian Tensile strength and the uniaxial compressive strength. It was found that rock with small porosity results in greater rock strength and vice versa.

It's clear that limestone sample in Sohag is high porosity which directly depend on the compressive and tensile strength to be lowest. The strength properties were reducing for limestone samples in Sohag than the other samples which fully saturated.

Fitting curve were made for the different property such as uniaxial compressive strength and the tensile strength and good correlation done. On the other hand, correlation between density and porosity were established. All the relationship between the different suing as index of interpretation of the results to identify the behavior of studied area for rock samples which give us clear evidence of the water environment is presence or not.

ACKNOWLEDGEMENTS

This research was partially supported by Mining and Petroleum Engineering Department, Faculty of Engineering Al-Azhar University, Egypt, that provided machines to finish the research.

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ФІЗИКО-МЕХАНІЧНІ ВЛАСТИВОСТІ ЄГИПЕТСЬКОГО ВАПНЯКУ

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Мета. Вивчення фізичних та механічних властивостей вапняку родовищ Єгипту на основі експериментальних досліджень.

Методика. Зразки вапняку відбирались з родовищ шести різних провінцій (Helwan, Minia, Assuit, Qena, Sohag, Aswan). Зразки кернів були підготовлені з використанням бурильного станка відповідно до критеріїв стандарту ISRM. Підготовка до випробування зразків керна проводилася перпендикулярно площинам нашарування. Відповідні властивості для виробництва заповнювача були перевірені з точки зору вмісту води, щільності, стійкості до стирання та стійкості до стирання в кінцевому підсумку на вапняковій ділянці, який більше підходить для виготовлення бетону і асфальту. Фізичні властивості (щільність та пористість) і механічні властивості (міцність на стиск, міцність на розрив і коефіцієнт динамічного дроблення) були досліджені за стандартними методиками для дев’яти зразків вапняку кожної з шести провінцій.

Результати. Для вапняку родовищ Єгипту експериментально виявлено високу кореляцію між пористістю та щільністю, а також хороші кореляції між міцністю на одновісний стиск і міцністю на розрив, що характеризує інженерні вимоги до його використання у цивільному та промисловому будівництві. Проведені результати показали, що низька пористість призводить до більшої міцності порід і навпаки.

Наукова новизна. Полягає у використанні техніки підгонки кривої для перевірки найкращої кореляції між різними властивостями вапняку при встановленні найкращого відношення, застосовуючи цей прогноз для вивчення властивостей вапняку в іншому місці.

Практична значимість. Отримані показники фізичних та механічних характеристик вапняку є корисними для визначення можливої області його застосування в цивільному та промисловому будівництві, тощо.

Ключові слова: *вапняк, механіка порід, механічні властивості, фізичні властивості, кореляція*

ФИЗИКО-МЕХАНИЧЕСКИЕ СВОЙСТВА ЕГИПЕТСКОГО ИЗВЕСТНЯКА

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Цель. Изучение физических и механических свойств известняка месторождений Египта на основе экспериментальных исследований.

Методика. Образцы известняка отбирались с месторождений шести различных провинций (Helwan, Minia, Assuit, Qena, Sohag, Aswan). Образцы кернов были подготовлены с использованием бурильного станка согласно критериям стандарта ISRM. Подготовка к испытанию образцов керна проводилась перпендикулярно плоскостям напластований. Подходящие свойства для производства заполнителя были проверены с точки зрения содержания воды, плотности, устойчивости к истиранию и стойкости к истиранию в конечном итоге на известняковом участке, который больше подходит для изготовления бетона и асфальта. Физические свойства (плотность и пористость) и механические свойства (прочность на сжатие, прочность на разрыв и коэффициент динамического дробления) были исследованы по стандартным методикам для девяти образцов известняка каждой из шести провинций.

Результаты. Для известняка месторождений Египта экспериментально обнаружена высокая корреляция между пористостью и плотностью, а также хорошие корреляции между прочностью на одноосное сжатие и прочностью на разрыв, характеризующие инженерные требования к его использованию в гражданском и промышленном строительстве. Проведенные результаты показали, что низкая пористость приводит к большей прочности пород и наоборот.

Научная новизна. Заключается в использовании техники подгонки кривой для проверки наилучшей корреляции между различными свойствами известняка при установлении наилучшего отношения, применяя этот прогноз для определения свойств известняка в другом месте.

Практическая значимость. Полученные показатели физических и механических характеристик известняка являются полезными для определения возможной области его применения в гражданском и промышленном строительстве и т.д.

Ключевые слова: *известняк, механика пород, механические свойства, физические свойства, корреляция*

ARTICLE INFO

Received: 11 January 2018
Accepted: 10 May 2019
Available online: 7 June 2019

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