GEOTECHNICAL INVESTIGATION OF SOUK ALKHAMIS QUARRIES; VIEW OF SLOPE STABILITY

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الملخص

تهدف هذه الدراسة لإلقاء الضوء حول تأثير كل من التركيب المعدني ومسامية صخور الأحجار الجيرية والجيرية الدولوميتية المتكشفة، بمحجر سوق الخميس والمحاجر القريبة من نفس المنطقة، على مقاومة الكتل الصخرية ومن تم تقييم حالة استقرارية تلك الكتل الصخرية. الدراسات الجيوتقنية والجيوميترية والتركيب المعدني أوضحت أن حالة الكتل الصخرية بتلك المحاجر هي بين المعقولة والجيدة. كما تبين أن تواجد عنصر الماغنيسيوم في تركيبة الحجر الجيري لها تأثير على سلوك الأحجار الجيرية من حيث مقاومتها. ووجد أن مقاومة الصخور لها علاقة مباشر مع المسامية نتيجة لعملية الدلمتة التي تعرضت لها الأحجار الجيرية بمنطقة الدراسة. أما بالنسبة لاستقرارية الكتل الصخرية بمحاجر المنطقة التي تمت دراستها فقد أرجعت إلى حالة الكتل الصخرية المعقولة والجيدة بالإضافة إلى صغر زاوية ميل مستوى الانهيار.

ABSTRACT

This investigation is intended to shed some light on the effect of mineral composition and porosity of the limestone and dolomitic limestone rocks, at Souk Alkhamis and nearby quarries, on the strength of the rock masses, and to evaluate the stability of these rocks in the quarries. The geotechnical, mineral composition and geometrical studies indicate that the rock masses are of good to fair type. The magnesium content in the limestone composition is controlling the behavior of the strength in limestone. It has also been found that the strength is related directly to the porosity which resulted from the dolomitization processes. The stability analysis showed that the rock masses are stable due to the good to fair quality of the rocks and the low angle of plane failure.

KEYWORDS: porosity; Mineral Composition; Rock Mass Classification; Geotechnical Parameters; slope stability; Factor of Safety; Dolomitization; Discontinuity Surfaces

INTRODUCTION

Slope stability problems are arising in open pit mines, road cuts, waste dumps and vicinities of dams and reservoirs. The height and slope angle at which a slope will stand is of the major economic importance to open pit operator [1]. The stability of rock slopes is evaluated through fundamental approaches such as rock mechanics, geoengineering, and any other related properties that may affect the rock mass strength. Thus this investigation is dependent on rock mass classification, the composition of slope materials and the porosity of these materials. Rock material strength is different from specimen to another.

In general, the strength of large rock masses is controlled by discontinuity surfaces, such as faults, fractures, fissures or joints that intersect the rock masses. [2]. Previous work done by Snonez [3], Pierc [4] and Hoek [5] proved that, the stability of rock slopes is a function of geotechnical and geometrical parameters. However this study is carried to classify the rock masses in souk Al-Khamis and nearby quarries, on the bases of the parameters controlling the stability of slopes in the quarries, which are located 65 Km southeast of Tripoli Libya, at latitude (30° 31´40´´) N and longitude (13° 12´ 54´´) E [6], and to investigate the effect of mineral composition and porosity on the rock strength.

METHODOLOGY

In order to study the geotechnical and geometrical parameters, six locations have been selected in Souk Elkhamis quarry and other quarries in the vicinity area. The study was based on site investigation of the rock masses and laboratory testing of 18 samples of size (30-40) centimeters are gathered from the selected locations. The site investigation and the results of the testing have been used to determine cohesive strength (C), the friction angle (Ø) for the rock mass and the effect of mineral composition and porosity on the rock strength, consequently to evaluate their effects on the stability of the quarry slopes.

The rock mass classification is based on determination of the following parameters,.

- Rock Quality Designation (RQD), which is defined as the percentage of intact core pieces longer than 100 mm (4 inches) in the total length of core. The rock quality designation is based on modified core recovery which depends indirectly on the number of joints, fractures, fissures and the amount of softening or alteration [7].
- Spacing of discontinuities. This is defined as the perpendicular distance between adjacent discontinuities. It tends to correlate linearly with the (RQD)
- Condition of discontinuities. Which describe the state of adjacent rock walls of discontinuity either open or filled
- Groundwater condition. In rock mass classification the rock mass is assumed either dry or wet depending on existence of the amount of water
- Unconfined compressive strength.

RESULTS AND DISCUSION

The RQD values which are estimated from photographs ranged between (73-88%), this means that the rock mass quality is fair to good [8].

The spacing between adjacent discontinuities determines the size of blocks making the rock mass. It has been found, the values of spacing ranges between (13-50) centimeters. Also the spacing per meter has been evaluated and its values are ranged between (2-7) spaces. The separation between adjacent rock walls of discontinuity in which the intervening space is open or filling materials have been measured directly in the field or from photographs Figure (1).

The values of filled separation lies between (2-25) centimeters and the open ones have values between (0.50-15) centimeters. Eighteen samples have been tested to determine the uniaxial compressive strength of the intact rock, porosity, and chemical composition. The compressive strength is determined by loading core samples of (4.7cm) diameter and length of (10 cm).

Figure 1: open and filled joints in Souk Alkhamis quarry

The values of compressive strength ranged between (25-125) MPa. Nine samples were tested to determine the porosity of the intact rocks. The porosity values lie between (3-16%). The chemical composition of eight samples is determined using the atomic absorption techniques, is illustrated in Table (1)

Table 1: The chemical composition of the studied rock samples (wt.%)

Sample No.	Mineral composition					
	Co_2	CaO	MgO	Fe_2O_3	Al_2O_3	SiO_2
1	44.30	27.75	21.1	0.75	0.61	5.85
2	43.80	54.25	1.30	0.19	0.09	0.31
3	40.10	46.30	3.50	0.75	2.55	6.85
4	43.02	52.49	1.60	0.28	0.48	2.90
5	44.3	25.70	22.40	1.71	1.29	4.40
6	41.50	54.07	1.08	1.21	0.87	1.17
7	42.30	47.40	3.30	1.88	2.20	2.90
8	44.70	26.80	23.10	1.40	1.29	2.40

Upon the chemical analysis of samples and the calculation of the proportions of calcite and dolomite in the carbonate phase (mole %) the rock masses may be separated in three distinct groups samples (1,5,8) categorized as dolomite, samples (3,7) are dolomitic limestone and samples (2,4,6) are limestone.

Geotechnical analysis

Based on geomechanics classification of jointed rock masses, the rock masses in the study area can be classified as fair to good rock masses [9]. The strength composition relationships indicated, that the strength decreases with the increasing percentage of calcite in limestone, and dolomite Figure (2), this strength behavior may be related to the replacement of calcite by dolomite in dolomitization process, in which decrease in the crystals interlocking in calcite is occurred [2].

Also it has been found that the increase of silica% tends to decrease strength of either limestone or dolomite samples Figure (3). This can be interpreted by the increasing of heterogeneity within the structure of rock minerals [3-4].

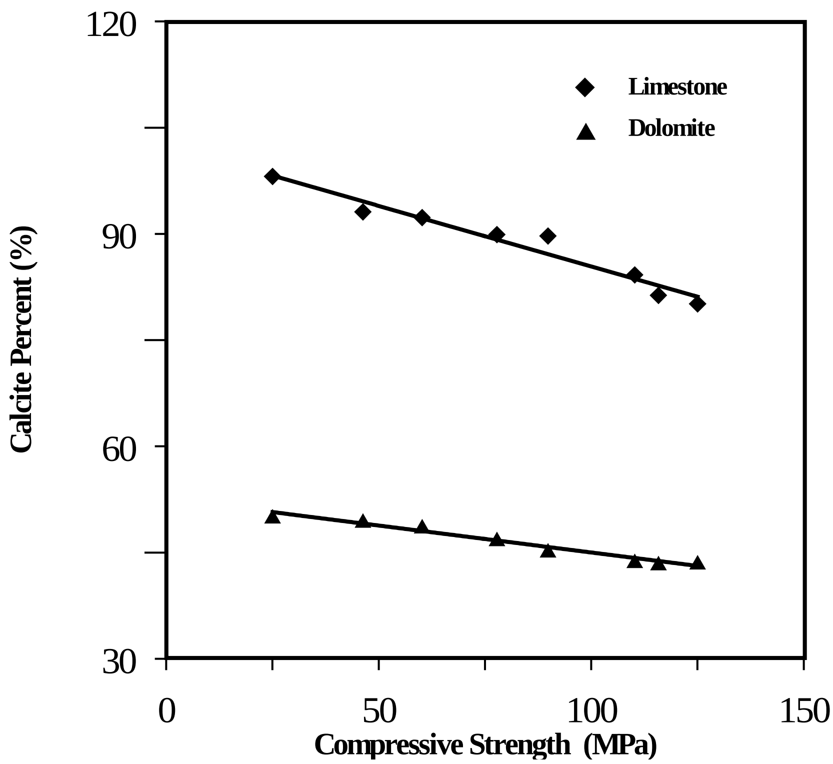

Figure 2: Compressive strength and calcite weight percent relationship

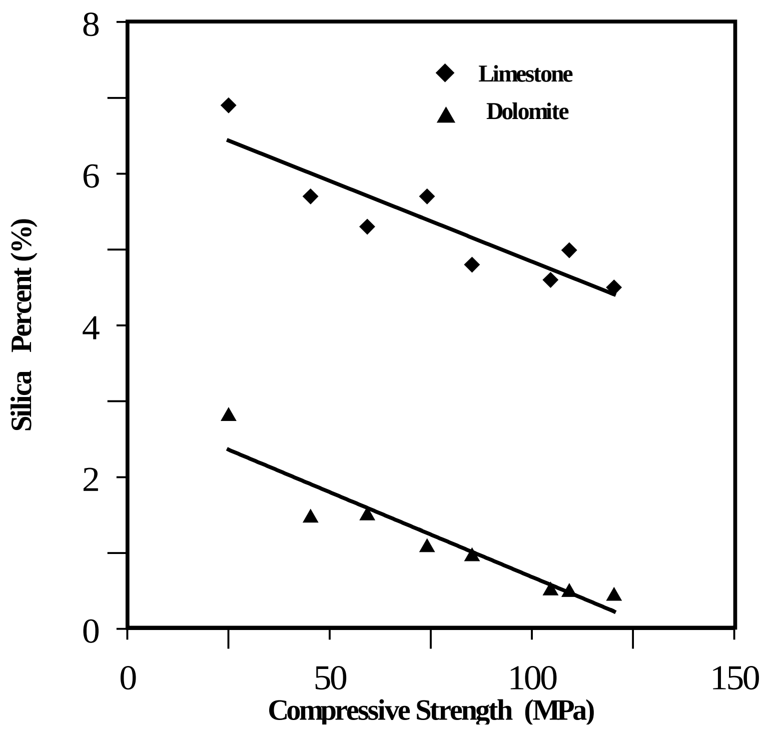

Figure 3: Compressive strength and silica weight percent relationship

On the other hand the increasing of iron and aluminum oxides amount causes strength increasing this may be due to the cementing forces created by their presence Figures (4a & 4b)

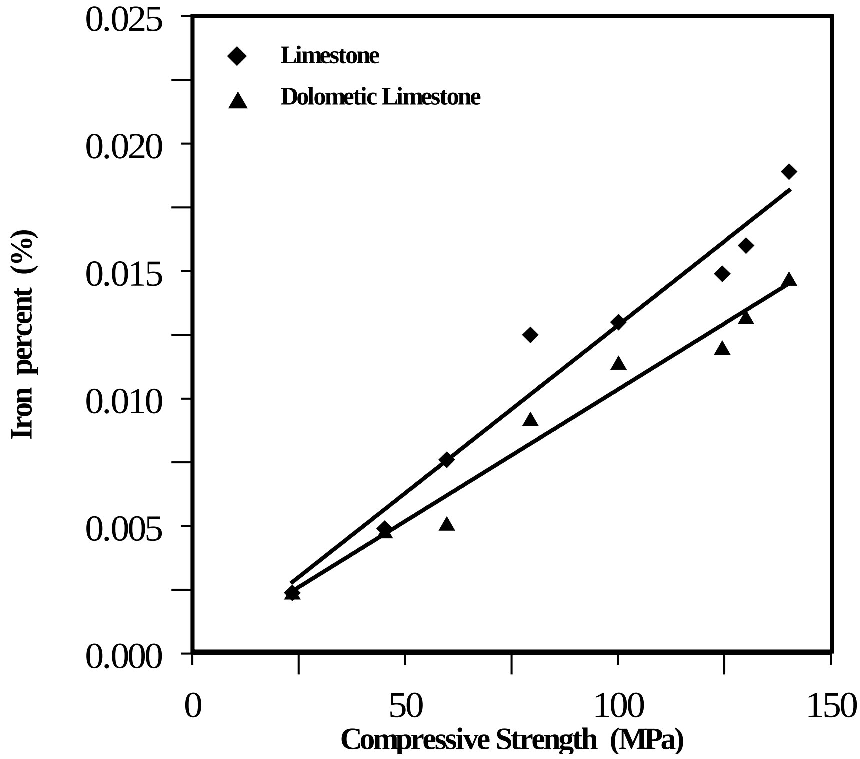

Figure 4a: Compressive strength and iron weight percent relationship

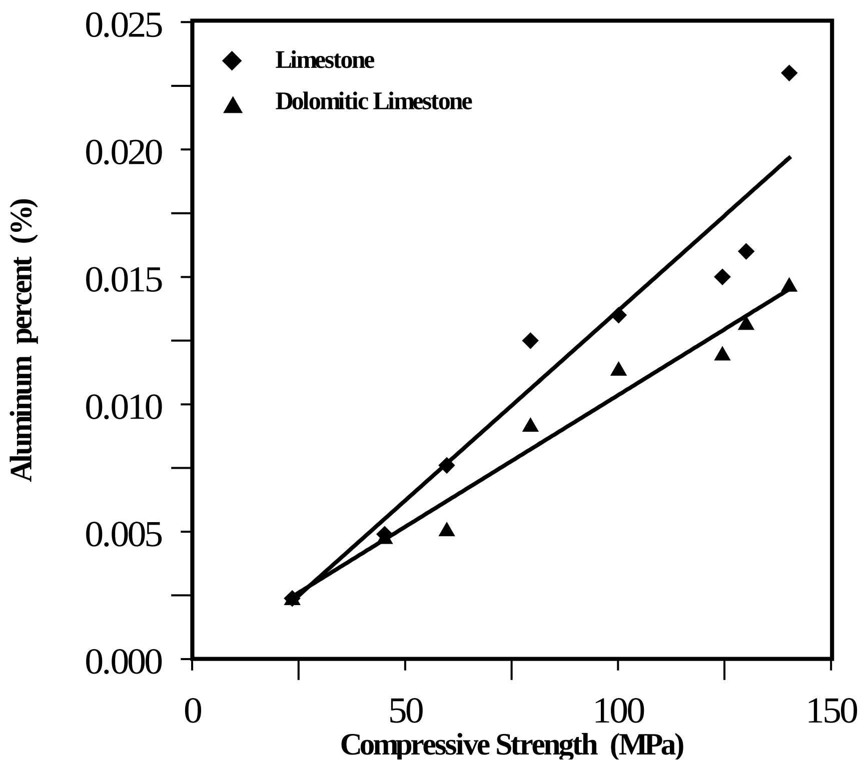

Figure 4b: Compressive strength and aluminum weight percent relationship

The effect of porosity on the compressive strength is determined by plotting the obtained porosity values against the compressive strength values. It is clear from Figure (5), the strength decreases when the porosity increases. This relationship was clear in the samples containing high percentage of magnesium, and this can be related to the replacement of calcite during dolomitization processes, in which an extra space obtained due to the different crystal size of magnesium and calcium atoms. This space increased the pores, and tends to weaken the rock, consequently a reduction in the rock strength occurred.

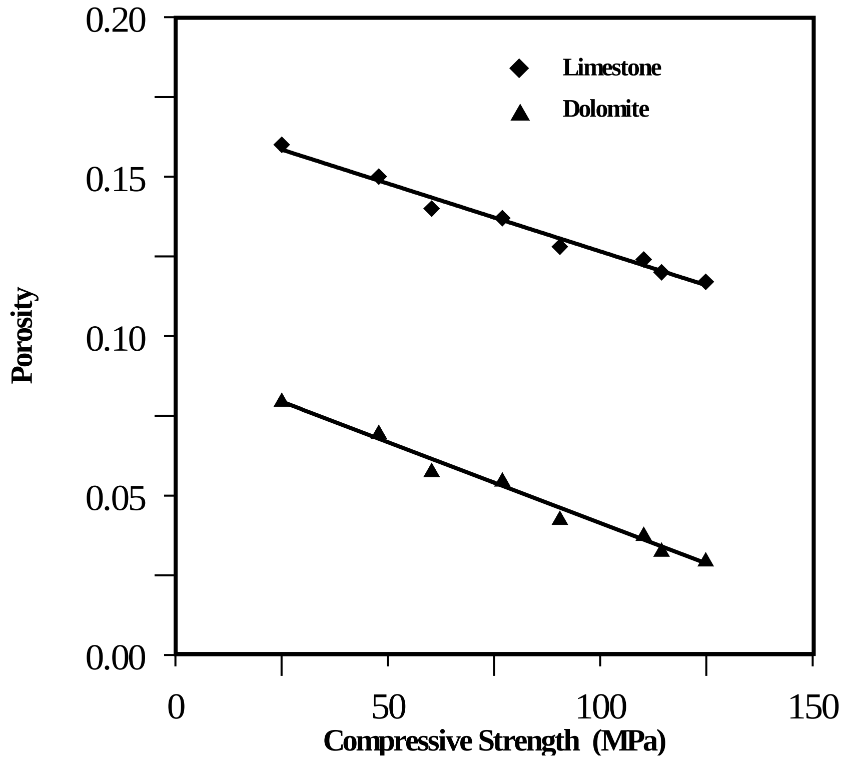

Figure 5: Compressive strength and porosity relationship

Rock Slope Analysis

Based on nature and the type of the rock masses in the study area, the possible mode of failure that can occur is plane failure type. In regularly bedded rocks there are possibilities for block movement along the planes of weakness such as bedding, joints, fractures etc.[10] Generally plane failure forms due to gravity action when a rock rest on inclined weak plane which daylight in to free face with dip angle greater than the friction angle [11]. In order to study the stability of slopes in the study area, the cohesion and friction angle of the rock types should be evaluated, however shear tests are preformed on twelve samples representing the fair and good rock masses as determined by geomechanics investigation preformed on the different locations. The cohesion and friction angel values for fair and good rock mass quality respectively are 2.2 MPa, 5.8°, and 5.3 MPa, 23°. The factor of safety of the investigated quarries is calculated under a value of cohesive strength starting from 2.2 MPa up to 5.3 MPa, and in such a way the friction angle is started from 5.8° to 23°. Both are under two water conditions, completely dry and wet slope, in which the (water height/ slope height) ratio which denoted as (Z_w/Z) = 0 in dry case and the ratio = 0.1 in moisture case. Table (2) displays these results.

Table 2: The factor of safety of slopes in the investigated quarries

Compressive strength MPa	Factor of safety (Z_w/Z) = 0		Factor of safety (Z_w/Z) = 0.1	
	Good rock	Fair rock	Good rock	Fair rock
25	-	0.85	-	0.8
77	2	0.62	1.9	0.6
115	2.5	1.2	2.32	1.1

According to obtained factor of safety values It is clear the slopes are generally stable even though the slope angles of all quarries are very high, this is due to the fair to good rock quality, and low plane angle of discontinuities.

CONCLUSIONS

From the results obtained this study the following conclusions can be drawn:

- The rock masses in Souk Alkhamis area are characterized by medium to high strength and classified as fair to good rock types
- The strength behavior is honored to chemical composition of the rocks in which the increase of dolomite percentage in calcite rocks decreases its strength slightly. Also the presence of silica affects the strength negatively, whereas the strength increases with increasing of iron and aluminum oxides.
- The porosity is found to be higher in dolomite rather than in limestone samples, this is related to dolomitization processes consequently the strength decreases with increasing the porosity.
- Stability investigations indicated that the slopes in the quarries are stable even at high slope angle; this is due to the rock quality and low discontinuity plane angle.

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