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GEOTECHNICAL STUDY OF CARBONATE ROCKS ON THE AREA BETWEEN ALEXANDRIA AND EL-ALAMEIN ALONG THE MEDITERRANEAN SEA COAST OF EGYPT

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ABSTRACT:

To accommodate the rapid increase of population and avoide the construction on green lands, it is necessary to construct on desert areas. For that reason the area between Alexandria and El Aamein in the north western coastal plain of Egypt was the subject of detailed geotechnical investigation. This area comprises four longitudinal carbonate ridges extending parallel to the Mediterranean Coast with broad interdunal area that covered by Lagoonal Sabkha Soil.

Geotechnical investigation of carbonate rocks have shown that these rocks can be classified as oolitic Limestone that have a wide range of density and porosity. They are of low to very low strength and high failure strain due to low cementation forces and weak coherence of carbonate strains grains.

INTRODUCTION:

The Mediterranean Coastal plain is considered one of the most important areas in Egypt suitable for tourism and recreation activities. Although many recreation villages were constructed, however several engineering problems were faced that make construction difficult in these areas, not only that, but also many buildings have been partly and/or completely damaged. Such problems are encountered in many developed areas in northern coastal plain of Egypt were the present area lies. The most of these are subsidence and settlement problems that related to collapsing of-soil, landslides and the presence of covernous structures due to dissolution of carbonate rocks. Several foundation and construction problems can be solved related to geotechnical problems to minimize expect potential damage of buildings which is important in planning for new urban areas. The area under study occupies the northern part of the Mediterranean Coastal plain that lies midway between Alexandria and El-Alameian. The total distance along the coast is approximately 100km and the area extends in land for a distance of about 20 km covering about 2000 km^2 (Fig. 1).

The coastal plain in the area is distinguished by a series of at least eight elongated parallel carbonate ridges. These ridges run parallel to the coast and are separated by longitudinal interdunal depressions. They are named from the most seaward to-landward as. The first

ridge, the second ridge, the third ridge, .. etc. and known by coastal ridge, Mex Abu sir ridge, Gabel Maryt ridge, Khashm.

El-Eish-ridge Alam El-Khadern ridge, Mikheirta ridge, Ragqbet El-Halibridge and Alam shaltut ridge. The area under study is easily accessible for Cairo and Alexandria by both railway and asphaltic high ways. The asphaltic Alexandria-Matruh highway lies at the first depression between the first and second ridges, while the Alexandria Matruh railway Lies at the third depression between the third and fourth ridges.

AIM OF THE RESEARCH:

The main purposes of their work are to solve some of geotechnical problems and minimize potential damage of buildings, and then developing the area. And study the geotechnical characteristics of carbonate rocks based on their physical and mechanical properties.

BACKGROUND:

1-Geological Stetting:

The northern part of the Western Desert is covered mainly by thin blanket of Miocene rocks forming a vast persistent limestone plateau. It extends from the western side of the Nile valley and delta in the east to El-Salum in the west and by the Mediterranean costal plain in the north to the Qattara and Siwa depression in the south. Salem (1976) student the Miocene rocks in the northern part of the western desert and concluded that, during lower Miocene thick deltaic sequence of terrigenous clastic sediments were deposited in the central and eastern parts of the northern western desert and a carbonate plate form was developed toward the western desert and a carbonate plate form was developed toward the west. In the Middle Miocene, there was a shift in locus of deltaic sedimentation that was dominant in western and central parts and onlapped parts of deltaic sediments.

The coastal zone to the north of the Miocene plateau is covered by quaternary deposits which rest with conformable and or unconformable relation of the Tertiary deposits. These deposits are mainly represented by the Holocene deposits of coastal sand dunes, lagoonal and alluvial deposits and the pleistocene oolitic limestone ridges and old lagoonal deposits.

The quaternary carbonate ridges in the present area are cemented into moderately hard limestone except the coastal ridge which is-mostly less cemanted. (Fig. 2).

2-Chemical analysis:

The chemical analysis was made for 20 representative sample collected from the first four ridges with the aim of determining the percentage of $CaCO_3$ and $MgC0_3$ (Table 1).

The data showed that calcium carbonate is the main component of these rocks. Although a slight decrease is noted southward toward the oldest ridge. This is related to increase content of insoluble residue in the direction and to leaching processes that took place after deposition of these rocks (Kronay, 1975).

In contrast to calcium carbonate, magnesium carbonate shows a marked increase toward the oldest ridge which is attributed to dolomitization of calcite by aging. This process may be entanced by groundwater movement and due to leaching process by rain water.

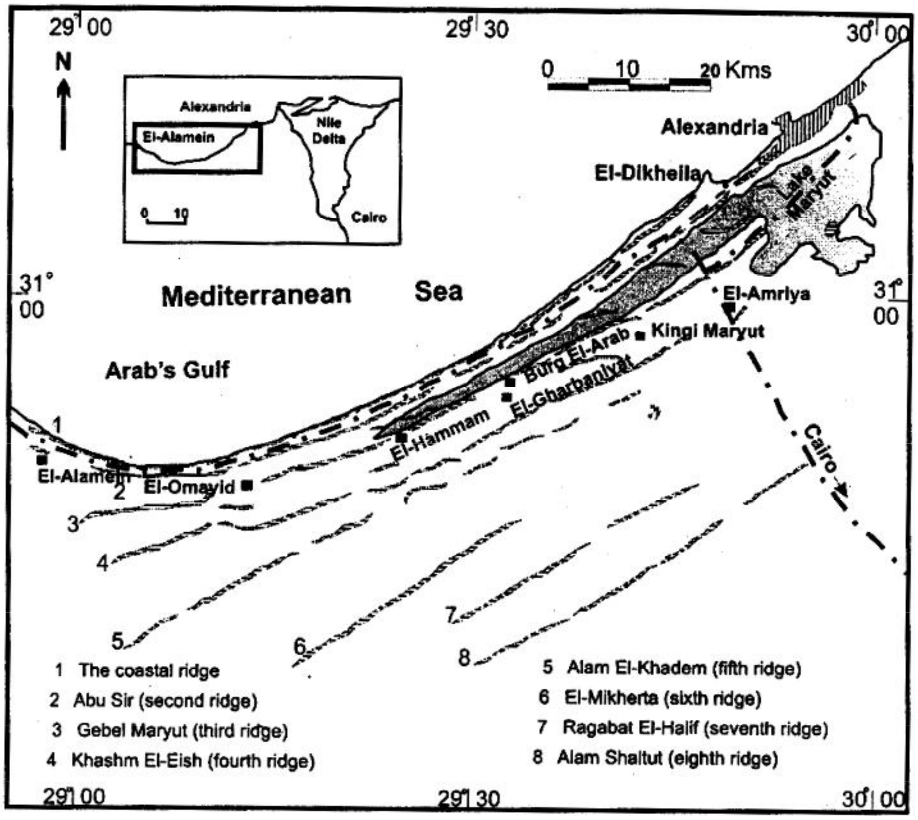


Fig. (1) : Location map of the study area (modified after Hassouba, 1995)

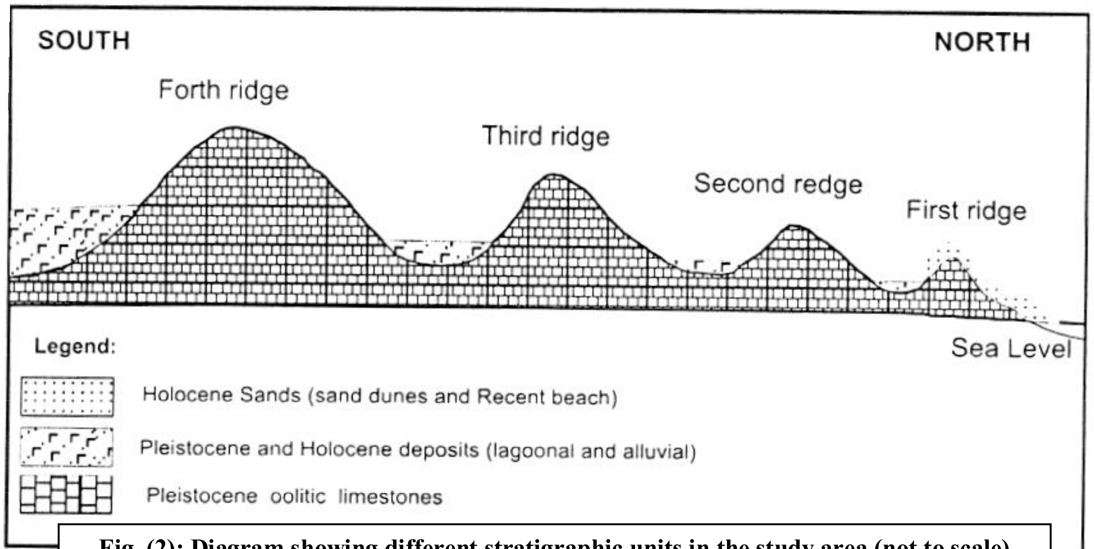


Fig. (2): Diagram showing different stratigraphic units in the study area (not to scale)

3-Geotechnical Measurement:

The mechanical behaviour of rocks is very important for practical purposes related to foundation stability, subsurface excavation, tunneling, and construction materials. The mechanical properties of a rock are influenced by several factors. The most important of them are mineralogical composition, grain-size, textcures, porosity, bulk density, moisture content, anisotropy, temperature and rate of deformation (Bell 1983). The physical and mechanical properties of the carbonate rocks of the first four ridges were determined in terms of bulk density porosity, void ratio, compressive strength tensile strength and shear parameters.

4-Expermintal work:

Sample preparation:

One of the important factors for measuring and evaluating the geotechnical properties of rocks is the shape of tested specimen. A block samples were collected from the carbonate rocks of the first four ridges the sample were chosen from different rock units present. Most studies make use of cubic shape or cylindrical specimens with length/diameter ratio ranging 2:1 for compressive and tensile strength test.

Laboratory work:

The experimental testing programme can be classified into two main testing groups the first group includes test related to the physical properties, while second group comprises test related to the mechanical properties.

RESULTS AND DISCUSSION:

The results of the physical and mechanical properties are summarized in tables (2, 3).

Table (1): $CaCO_3$ and $MgCO_3$ contents of the studied carbonate ridges

Location	Sample No.	$CaCO_3$ %	$MgCO_3$
First ridge	1	93.45	2.48
	2	92.83	2.46
	3	94.35	1.75
	4	93.65	1.65
	5	93.75	1.55
	Average	93.61	1.95
Second ridge	1	91.35	2.35
	2	90.85	2.43
	3	90.45	3.35
	4	91.55	3.69
	5	92.25	3.98
	Average	91.29	3.16
Third ridge	1	85.72	5.78
	2	84.67	5.63
	3	85.20	5.78
	4	84.55	4.87
	5	85.86	5.49
	Average	85.20	5.51
Fourth ridge	1	83.41	6.65
	2	82.89	6.86
	3	83.25	7.34
	4	82.62	6.69
	5	82.35	7.27
	Average	82.90	6.97

Table (2): Physical properties of the studied rock samples

Location	Sample No.	γ_d (kN/m^3)	γ_s (kN/m^3)	W_c%	G_s	N%	e_o	A%	D%	CC%
First ridge	1-1	19.6	22.7	0.26	1.88	28.51	0.40	15.87	0	85.80
	1-2	19.4	22.1	0.28	1.81	26.51	0.36	16.35	0.54	90.00
	Average	19.5	22.4	0.27	1.8	27.51	0.38	16.11	0.27	87.9
	STDEV	0.1	0.4	0.01	0.05	1.41	0.03	0.34	0.38	2.96
Second ridge	2-1	18.4	2.16	0.55	1.60	32.59	0.48	17.73	0.55	66.40
	2-2	18.8	21.9	0.54	1.42	31.06	0.45	16.49	0.54	67.20
	2-3	18.6	22	0.27	1.49	35.11	0.52	18.31	0.27	70.80
	2-4	19.1	22.3	0.53	1.43	31.57	0.46	16.53	0.53	73.00
	2-5	18.8	21.8	2.71	1.52	30.04	0.43	15.99	2.6	75.20
	2-6	18.8	21.7	0.81	1.54	29.02	0.41	15.41	0.8	79.00
	2-7	19.9	23	1.04	1.55	30.13	0.43	15.10	0.78	85.40
	2-8	18.8	21.9	0.55	1.66	31.17	0.45	17.22	1.1	82.20
	2-9	20.3	23.4	0.26	1.69	31.69	0.46	15.68	0.26	85.60
	2-10	20.0	23.3	0.55	1.47	32.50	0.48	16.5	0.74	84.60
	2-11	19.9	22.8	0.26	1.58	29.02	0.41	14.58	0.26	85.80
	2-12	19.1	22.4	0.53	1.71	32.59	0.48	47.38	0.8	85.40
	2-13	18.7	21.7	0.55	2.41	30.54	0.44	16.35	0.54	87.40
	2-14	19.2	22.3	0.27	2.31	31.05	0.45	15.87	0	90.60
	2-15	19.2	22.2	0.53	1.55	30.04	0.43	15.65	0.53	90.60
	2-16	18.5	21.6	0.82	1.52	30.55	0.44	16.48	0.82	91.20
	2-17	18.8	2.16	0.81	1.54	28.00	0.39	14.86	0.8	91.80
	2-18	18.7	21.7	0.81	1.59	30.04	0.43	16.03	0.81	92.00
	2-19	18.2	21.2	0.27	1.61	29.53	0.42	16.2	0.28	92.00
	2-20	18.7	21.5	2.45	1.69	28.00	0.39	14.95	0.39	93.60
	2-21	18.4	2.14	2.21	1.53	30.04	0.43	16.3	2.16	92.80
	2-22	18	21.4	3.95	1.38	35.11	0.52	18.93	3.8	93.80
	2-23	18.6	21.6	2.74	1.75	30.55	0.44	16.44	2.67	73.00
	Average	18.9	22.0	1.04	1.63	30.78	0.32	16.30	1.04	83.84
	STDEV	0.6	0.6	1.02	0.25	1.64	0.21	1.08	0.98	8.91
Third ridge	3-1	17.1	20.7	0.59	1.60	35.13	0.54	20.47	0.59	75.20
	3-2	16.1	19.3	5.11	1.55	32.07	0.47	19.94	3.95	86.20
	3-3	17.7	21.3	2.53	1.54	35.63	0.55	20.13	2.3	89.20
	3-4	16	19.2	4.76	1.56	31.56	0.49	19.68	4.55	85.40
	3-5	18.8	21.3	2.16	1.82	25.44	0.32	12.97	2.12	90.60
	3-6	17	20.2	2.10	1.70	32.07	0.47	18.86	2.05	89.20
	3-7	25.4	26.9	0.57	1.94	25.44	0.32	10.00	0.57	85.20
	3-8	19.4	21.4	0.26	1.96	19.35	0.24	9.95	0.26	87.00
	3-9	22.1	23.8	0.92	2.04	16.80	0.20	7.59	0.91	88.00
	Average	18.7	21.6	1.98	1.75	27.94	0.28	15.51	1.92	86.11
	STDEV	2.9	2.4	1.60	0.20	6.90	0.22	5.30	1.53	4.56
Fourth ridge	4-1	20.1	21.6	0.25	1.93	15.27	0.18	7.59	0.25	80.00
	4-2	22.6	23	0.23	1.84	3.56	0.04	1.58	0.22	78.00
	4-3	20.9	23.2	0.73	1.78	22.91	0.30	10.95	0.72	86.20
	4-4	21.6	23.5	0.47	1.92	18.84	0.23	8.73	0.47	87.60
	4-5	22.1	23.9	0.23	2.42	17.82	0.22	8.05	0.23	81.20
	4-6	22	24	0.32	1.76	20.25	0.25	9.21	0.32	73.40
	4-7	21.4	23.2	0.71	1.99	18.33	0.22	8.57	0.71	90.20
	Average	21.5	23.2	0.42	1.95	16.71	0.18	7.81	0.42	82.37
	STDEV	0.8	0.8	0.22	0.22	6.25	0.11	2.95	0.22	5.91

γ_d=Dry unit weight (kN/m^3), γ_s=Saturated unit weight (kN/m^3), W_c%=Water content, G_s=Specific gravity, n%=Porosity, e_o=Void ratio, A%=Water absorption, D%=Disintegration percentage, CC%=Carbonate content, STDEV= Standard deviation.

Table (3): Mechanical properties of the studied rock samples

Location	Sample No.	C_s (MPa)	T_s (MPa)	C (MPa)	τ (MPa)	Br. No.	$\phi°$	$\mu = \tan \phi$
First ridge	1-1	1.27	0.42	0.42	1.1	0.50	29.00	0.55
	1-2	2.2	0.69	0.62	1.8	0.52	28.00	0.53
	Average	**1.7**	**0.56**	**0.52**	**1.5**	**0.51**	**28.50**	**0.54**
	STDEV	**0.7**	**0.19**	**0.15**	**0.47**	**0.01**	**0.71**	**0.01**
Second ridge	2-1	5.3	1.5	1.5	3.8	0.49	28.00	0.53
	2-2	1.1	0.37	0.35	0.83	0.49	25.00	0.46
	2-3	6.2	2.2	1.8	5.2	0.47	29.00	0.55
	2-4	10.2	3.1	2.7	9.4	0.53	33.00	0.65
	2-5	6.7	2.1	1.9	5.3	0.52	27.00	0.50
	2-6	6.4	1.9	1.8	5.3	0.53	29.00	0.55
	2-7	3.6	1.1	1	3.1	0.55	30.00	0.57
	2-8	1.4	0.43	0.42	1.3	0.54	31.00	0.60
	2-9	4.6	1.3	1.2	3.7	0.55	28.00	0.53
	2-10	7.7	2.4	2.2	6.1	0.53	27.00	0.50
	2-11	5.1	1.5	1.4	4.5	0.56	31.00	0.60
	2-12	5.3	1.3	1.17	3.5	0.53	28.00	0.53
	2-13	5	1.5	1.3	5.2	0.54	30.00	0.57
	2-14	0.2	0.08	0.07	0.17	0.45	29.00	0.55
	2-15	6	1.6	1.5	4.6	0.57	26.00	0.49
	2-16	5.9	1.6	1. 6	4.9	0.56	30.00	0.57
	2-17	7.6	1.7	1.6	5.6	0.64	28.00	0.53
	2-18	8.3	2.4	2.2	7.1	0.56	31.00	0.60
	2-19	6.4	2.1	2	5.5	0.51	29.00	0.55
	2-20	9.1	2.5	2.4	7.8	0.56	31.00	0.60
	2-21	8.4	2.7	2.6	7.1	0.51	28.00	0.53
	2-22	6.4	1.9	1.8	5.5	0.54	30.00	0.57
	2-23	2.7	0.78	0.69	2.2	0.54	29.00	0.55
	Average	**5.5**	**1.7**	**1.5**	**3.3**	**0.53**	**29.00**	**0.55**
	STDEV	**2.6**	**0.77**	**0.70**	**2.8**	**0.04**	**1.83**	**0.04**
Third ridge	3-1	2.8	0.76	0.68	2.4	0.57	32.00	0.62
	3-2	1.2	0.31	0.40	1	0.60	27.00	0.50
	3-3	2.1	0.54	0.53	2	0.60	34.00	0.67
	3-4	3.1	0.78	0.75	2.9	0.60	35.00	0.70
	3-5	7.1	1.8	1.8	6.8	0.60	35.00	0.70
	3-6	2	0.56	0.58	1.9	0.56	34.00	0.67
	3-7	4.6	1.3	1.3	4.5	0.55	35.00	0.70
	3-8	5.1	1.1	0.98	3.5	0.66	26.00	0.48
	3-9	10	2.1	2	9	0.66	35.00	0.70
	Average	**5.2**	**1.2**	**1**	**3.1**	**0.60**	**32.56**	**0.64**
	STDEV	**2.8**	**0.6**	**0.57**	**2.7**	**0.04**	**3.57**	**0.09**
Fourth ridge	4-1	13.2	2.8	2.6	10.77	0.66	32.00	0.62
	4-2	27.7	7.7	7.2	26.6	0.57	35.00	0.70
	4-3	10.2	3.1	3.1	9.9	0.54	34.00	0.67
	4-4	19.4	5.5	5.5	19.1	0.56	35.00	0.70
	4-5	15.6	4.6	4.6	15.5	0.55	35.00	0.70
	4-6	16.5	5.3	5.2	15.8	0.58	35.00	0.70
	4-7	25.4	6.8	6.6	22.9	0.57	34.00	0.67
	Average	**18.1**	**5**	**4.8**	**15.1**	**0.57**	**35.29**	**0.68**
	STDEV	**6.2**	**1.8**	**1.74**	**8.3**	**0.04**	**1.11**	**0.03**

C_s=Compressive strength, T_s=Tensile strength, τ=Shear strength, C=Cohesion, Br. No.=Brittleness number, $\phi°$=Angle of internal friction, μ = Coefficient of internal friction, STDEV = Standard deviation.

Physical properties:

The physical properties of the tested samples, their standard methods of testing and their procedures. The conducted test are the void ratio, porosity, density, moisture content as well as water absorption and carbonate content.

Void ratio: **The void ratio can be calculated from the following equation:**

Void ratio = $\frac{n}{n-1}$ **where n=porosity**

The void ratio values for the tested samples range from 0.04 to 0.54 the average value is found equal to 0.29.

Water absorption and disintegration percentages: **The water absorption percentage, A% given by the following equation:**

$$A\ \% = \frac{m_s - m_1}{m_1} \times 100$$

Where:
m_s=mass of saturated sample.
m_1=mass of the dried sample after immersion.

The disintegration (D%) is given by the following equation:

$$(D\%) = \frac{m_d - m_1}{m_d}\ x\,100$$

Where m_d=mass of the dried sample before immersion while the percentage of carbonate content is calculated from the following equation:

Carbonate content % = $\frac{m_c}{m_s}\ x\ 100$

Where: m_c is weight of carbonte and m_s is the sample weight or saturated sample.

Table (4) given Chemical analysis of some selected water samples from Bahig canal, gypsum quarries and Mallahet Maryut at both El-Gharbaniyat and El-Hammam areas.

Mechanical properties:

The mechanical properties normally give information about the performance of rock material when subjected to a particular loading system. Such as compressive strength, tensile strength and shear parameters.

The uniaxial compressive strength is given by equation:

$$S_c = F/A$$

Where:
F = applied force.
A = cross-sectional area.

While the tensile strength was obtained according to the following formula:

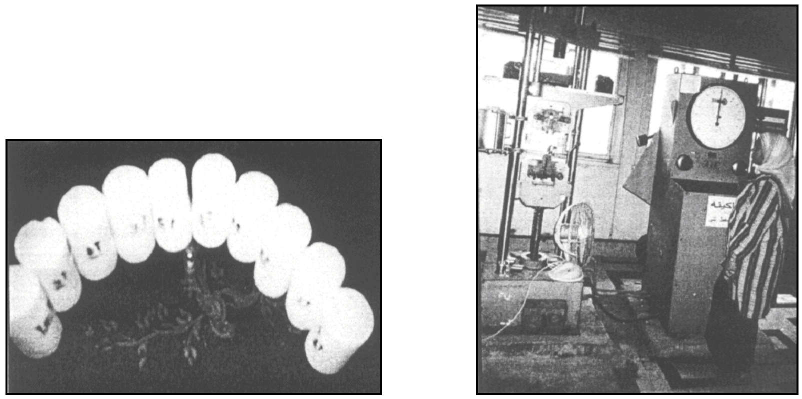
$$S_t = 2F/2\,\Pi\,DL$$

Where:
S_t = tensile strength.
F = failure load applied force.
D = diameter of specimen.
L = length of specimen.

The shear strength was obtained graphically parameters such as cohesive force and-angle of internal friction using Mohr's Circles through compressive strength and tensile strength values. The cohesion and the angle of internal friction can be calculated by using the Mohr's envelope equation which is expressed by the following formula:

$$\tau = C + \sigma_n \tan\phi$$

Where: τ, σ_n shear and normal stress acting across the failure plane. C is the cohesive force and ϕ is the angle of internal friction Fig. (4).



(A) Prepared Specimens **(B) Uniaxial Testing Machine**

Fig. (3): Prepared specimens and uniaxial testing machine.

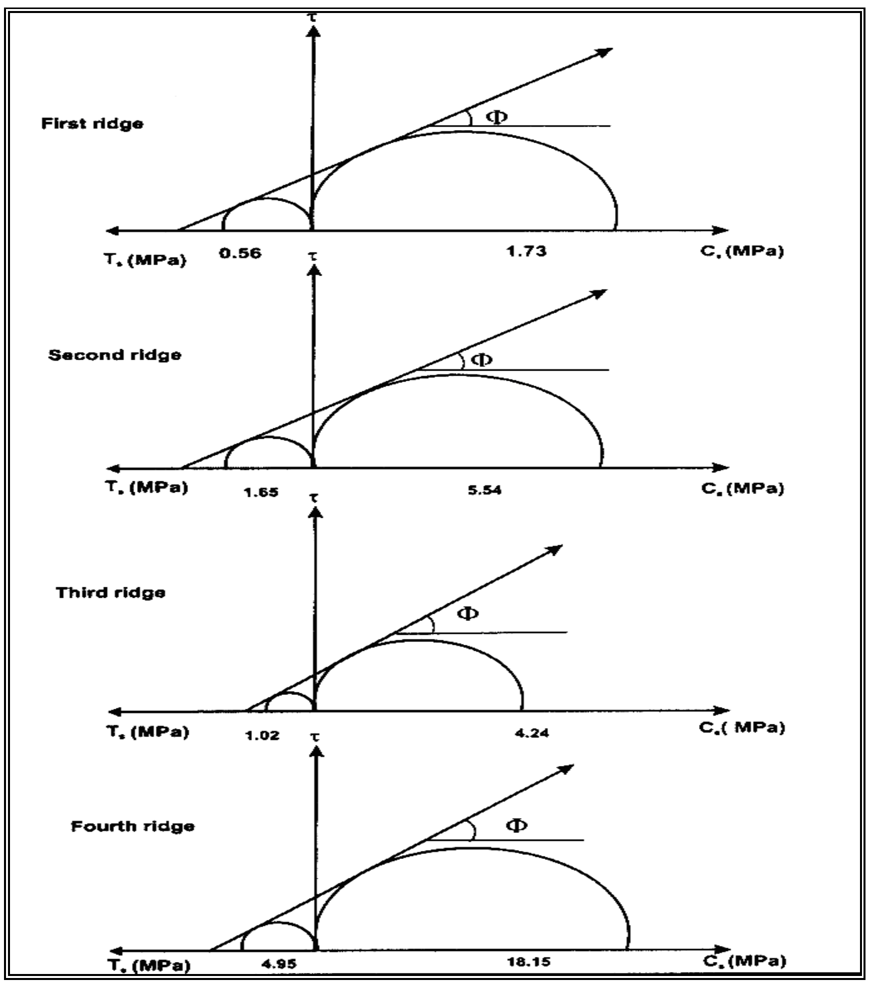


Fig. (4): Mohr's circle using the average values of the compressive and tensile strengths for the rocks of the four ridges

According to tested rock samples the porosity values ranged from 3.56% to 35.63% and most of these samples have porosities-up to 15%. According IAEG classification (Anon, 1981), the tested rock samples can classified into four classes; low porosity (less than 5%), medium porosity (5-15%), high porosity (15-30%) and very high porosity (over 30%). Based on the compressive strength values (0.2-7) Mpa, the collected samples can be classified to coat (1964) classification as very weak rocks. Nevertheless, according to ISRM classification (1979), Deere and Miller (1966) and Bieniawski-(1973), the samples can be classified as low or/and very low strength.

CONCLUSIONS:

1-The main purpose is to evaluate this important area for future development, solving some of the geotechnical problems and minimizing potential damage of buildings.

2-The study area is located west of Alexandria and extends further west to El-Alamain city for distance of about 100 kms; to the south, it extends inland for a distance ranging between 10-20 kms.

3-The carbonate ridges are composed of oolitic and biogenic calcareous sands.

4-The carbonate rocks in the present study were subjected to several diagenetic processes, in both meteoric and marine environments.

5-The chemical analysis of carbonate rocks of the studied ridges has indicated that calcium carbonate is the main component of these rocks. However, a slight decrease is noted towards the oldest ridge due to increase of the insoluble residue content in that direction and to leaching processes that took place after the deposition of these rocks. In contrast to calcium carbonate, magnesium carbonate showed a marked increase towards the oldest ridge, which is attributed to dolomitization of calcite by aging. The processes may be enhanced by groundwater movement and attributed to leaching process by rain water.

6-The geotechnical investigation of carbonate rocks have indicated that the studied rocks are oolitic limestone that have a wide range of density. They are of low to very low strength and high failure strain due to low cementation-borce and low coherence of carbonate grains.

7-The geological hazards in the present area included ground subsidence, landslides, and cavernous the subsidence problems was under taken from the engineering point of view. The suggested solution are represented by soil replacement in case of sarfaical sinkholes and cement mortar and grout injection the case of deep sinkholes.

8-The rock sliding problems can be stabilized by making retaining walls of reinforced concrete, crib walls or supportive walls. Fixation may be made by using wire anchors and benching in cut slopes.

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دراسة جيوتقنية للحجر الجيري على المنطقة الواقعة بين الإسكندرية و العلمين على امتداد البحر الأبيض المتوسط لمصر

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معهد التبين للدراسات المعدنية – حلوان – القاهرة

تتناول الدراسة مقدمة عن المنطقة والتتابع الطبقي والتحليل الكيميائي للحجر الجيري الموجود بالمنطقة محل الدراسة، وكذلك الخواص الميكانيكية والطبيعية مثل: مقاومة الضغط ومقاومة الشد ومقاومة القص. وباستخدام دوائر موهر تم استنتاج قوة التماسك بين الحبيبات وزاوية الاحتكاك الداخلي.

أما بالنسبة للخواص الطبيعية فقد تم تعيين النفاذية والكثافة، وأهم المشاكل الموجودة بالمنطقة مثل: الانزلاقات الأرضية والهبوط الناتج عن تأثير المياه الجوفية بالمنطقة. وقد توصلت الدراسة الجيوتقنية إلى أن الصخور الجيرية تراوحت بين ضعيفة الإجهاد إلي ضعيفة جداً وذات مدى واسع من الكثافة والمسامية، وذلك لضعف قوى التماسك بين الحبيبات.