Effect of Chemical Composition Variations on Geotechnical Parameters, (Cohesion (c), and Internal friction angle (Ø)) in Abu-Shaybah and Kikla Formations, Gharyan Area, Libya"

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Abstract— the variation of chemical composition has a great deal of influence on the geotechnical parameters namely: The cohesive strength and the internal friction angle. This influence could be due to the variation of cementation materials and their strength. This study is about the effect of variation in chemical composition on the geotechnical parameters in the study area. Thirteen cutting samples of Abu-shaybah formation and ten cutting samples of Kikla formation were tested in the lab using the direct shear test, the atomic absorption test, and the flame photometry test.

Based on the laboratory testing, the most common elements in all samples are Aluminum (Al), iron (Fe) and calcium (Ca), the values of cohesive strength and the internal friction angle are ranged from (0 to 0.55) kg/cm2 and from (21° to 37.56°) respectively. The cohesive strength increases with increasing of carbonate (Mg & Ca) and clay (Al & K) contents in the cementation materials, but the cohesive strength and the internal friction angle are increase by increasing of the element combination ratios (Ca & Mg/Al & K) and (Fe/Al & K). The multiple regression analysis displays a good agreement between expected and observed values of shear strength parameters.

Index Terms: Geotechnical properties; the cohesive strength and the internal friction angle. Laboratory tests; atomic absorption, flame photometry, and direct shear test. Linear Multiple and regression analysis.

I. INTRODUCTION

The location of the study area is 12.5km to the north of Gharyan City, at the south side of the main road which connects Al-aziziyah and Gharyan Cities.

The studied area is located at latitude, (32°, 30 - 32°, 15) and longitudes (13°, 15 - 13°, 00) as shown in "Figure. 1," this study aims to conclude the effect of variation in the chemical composition of the rock mass on geotechnical parameters (cohesion and internal friction angle), field and lab works have done in this study. Thirteen cutting samples of Abu-shaybah formation and ten cutting samples of Kikla formation were collected in the fieldwork. Those samples have been tested in the lab using the direct shear test, the atomic absorption test, and the flame photometry test.
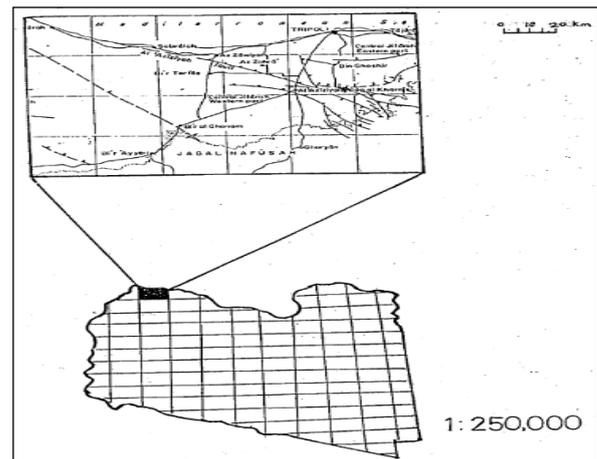

Figure1. Study Site Location

II. GEOLOGY AND STRATIGRAPHY

The rock units at the area belong to the Mesozoic Era, the rocks are divided into the following formations:

A. Abu-shaybah Formation

The Abu-shaybah Formation is laying between two erosive surfaces, making this formation unconformable, overlaying by the Abu-Ghaylan Formation and underlying by Al-Aziziya Formation.(El-Hinnawy, 1975) [1]. The Abu-shaybah Formation represents the slopes of

the scarp east of wadi-Ghan where it lies unconformably below Sidi- Assid Formation. This Formation is mainly formed by, red, yellow, and greenish sandstone alternating with red and green clays especially in the upper part. The thickness of the formation is about 125m measured at Ghryan dome where the top and base are exposed. The age of Abu-shaybah Formation is Carnian(Upper Triassic)(Desio et al. , 1963)[2]. This conclusion is based on the fact that the main part of the Formation is sandwiched between two carnelian beds, Alaziziya Formation below and the coquina limestone with carnelian fossils above (recorded by Desio et al., 1963 sited in Assereto & Benelli, 1971)[3] at Tarhuna Scarp. "Figure. 2," According to Desio et al., 1963, the Abu-shaybah Formation composed of three members: upper member consists of continental sandstone, middle member consists of fossiliferous limestone, and lower member consists mainly of red sandstone.

B. Kikla Formation.

The Kikla formation was first described in the Gharyan area by (Christie, 1955)[4]. It crops out along the escarpment of Jabal Nafusah for about 300km from Ghayan in the east to the Tunisian border. Unconformably, it overlies all earlier sequences and itself is overlain through-out the entire Jabal Nafusah by conspicuous limestone unit known as Ain Tobi formation. The Kikla Formation is represented by the stratigraphical sections located between Wadi Ghan and Wadi Zaqqut in the vicinity of Gharyan. The western region includes all the sections in the west of Arayayinah to the Tunisian border. It is mainly comprised of super mature quartz, arenite, sandstone, and conglomeratic units which were deposited under alluvial conditions. (El-Zouki, 1976)[5]. In the eastern region of the Gharyan area, the Kikla Formation was laid down by turbulent current activity in the braided channel, but in the western region (Jadu-Wazin area), The Kikla formation is Mesozoic continental classics lower cretaceous exposed extensively along the escarpment of Jabel Nafusah, northwestern Libya.
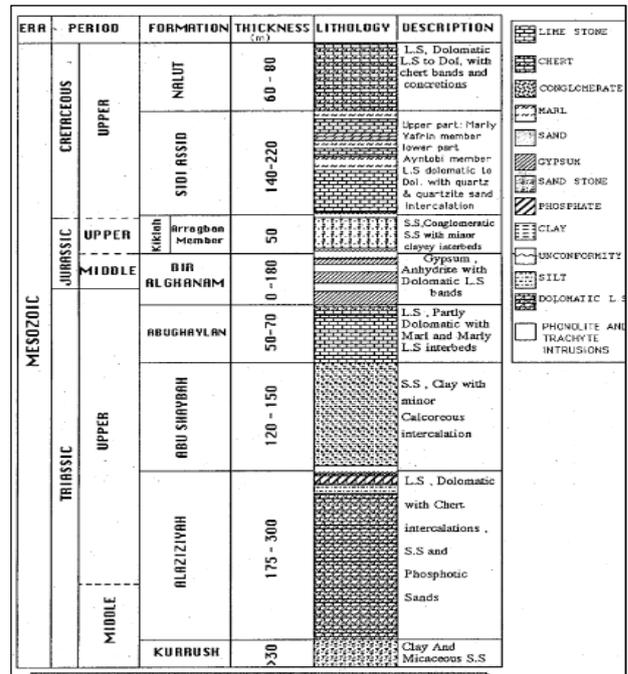

Figure 2. Columnar Section of Gharyan.

III.   METHODOLOGY AND RESULTS

Many field trips were conducted to observe the general geological condition and to organize the sample collection program in the study area. The sampling method is based on Variation in color and the grain size, where the laboratory work was divided into the following tests:

A.   Moisture content determination (w %), "Eq. (1)"

$$W= [(W1-W2)/W1]*100\% \qquad (1)$$

Where:

W is the moisture content,
W1 is the weight of wet sample, and
W2 is the weight of dry sample.

The moisture content results for Abu-shaybah Formation and Kikla Formation Samples are shown in "Table 1,"

Table 1. Moisture Content Results for Abu-shaybah Formation and Kikla Formation Samples

Abu-shaybah Formation Samples (*. Clay Samples)	Moisture Content (%)	Kikla Formation Samples	Moisture Content (%)
B1	0.21	K1	6.17
B2	1.71	K2	6.94
B3	0.28	K3	0.28
B4	0.49	K4	0.54
B5	0.19	K5	0.36
B6	0.09	K6	4.10
B7*	2.17	K7	2.16
B8*	0.92	K8	0.14
B9*	3.78	K9	0.28
B10	0.12	K10	0.88
B11	0.14	-	-
B12	0.1	-	-
B13	0.11	-	-

B. Direct shear test

The shear strength of a sample is its maximum resistance to shearing stresses. When this resistance is exceeded, failure occurs; shear strength is a function of angle of internal friction (Ø) (the resistance due to interlocking of particles) and Cohesion (C) (The resistance due to the forces tending to hold the particles together in a solid mass). In this test, the sample is placed in a square box which is split into two halves horizontally, the box is 60mm, a dial weight is applied to the top of the sample and shear stress is applied by forcing the two halves of the box in opposite directions until failure occurs on the horizontal plane between them, the test is repeated with different stress. The linear relationship is obtained by plotting the shear strength against normal stress on the horizontal failure surface (Smith, 1980)[6]. The direct shear test is constructed principally to measure the friction angle (Ø) and cohesion (c). Their relationship is presented by Coulomb's shear strength equation "Eq. (2)", :

$$\tau = c + \sigma \tan (\emptyset) \qquad (2)$$

Where:

τ is the shear strength,
C is the cohesion,
σ is the normal stress, and
Ø is the friction angle.

By plotting shear stress against normal stress, the intersection of the curve with a vertical axis is the value of cohesive strength (c) and the slope of the curve is the internal friction angle (Ø). The direct shear test results for Abu-shaybah Formation and Kikla Formation Samples are shown in "Table 2," & "Table 3,"

Table 2. Direct Shear Test Results for Abu-shaybah Formation Samples .

Abu-shaybah Formation Samples	Cohesion (c)(kg/cm²)	friction angle (Ø°)
B1	0.00	26.56
B2	0.15	26.56
B3	0.10	29.10
B4	0.15	25.50
B5	0.20	27.65
B6	0.05	31.00
B7*	0.35	30.50
B8*	0.45	21.00
B9*	0.35	21.37
B10	0.11	27.40
B11	0.15	27.60
B12	0.08	26.50
B13	0.10	29.40

Table 3. Direct Shear Test results for Kikla Formation Samples.

Kikla Formation Samples	Cohesion (c)(kg/cm²)	friction angle (Ø°)
K1	0.35	21.80
K2	0.35	22.60
K3	0.55	33.70
K4	0.10	29.00
K5	0.15	27.76
K6	0.25	37.56
K7	0.20	26.60
K8	0.20	30.96
K9	0.10	22.00
K10	0.23	25.00

C. Specific Gravity test

Specific gravity is defined as the ratio of a unit weight of material to the unit weight of water. The test aims to determine the specific gravity of the samples. The specific gravity is calculated by using the following equation "Eq. (3)" (Bowles, 1984) [7]:

$$G = W2 / (W2 - W3 + W1) \qquad (3)$$

Where:

G is the specific gravity,
W1 is the weight of dry sample,
W2 is the weight of pycnometer filled with water, and
W3 is the weight of pycnometer filled with water and sample.

The Specific Gravity test results for Abu-shaybah Formation and Kikla Formation Samples are shown in "Table 4,"

Table 4. Specific Gravity Results for Abu-Shaybah Formation and Kikla Formation Samples

Abu-shaybah Formation Samples (*. Clay Samples)	Specific Gravity	Kikla Formation Samples	Specific Gravity
B1	2.64	K1	2.52
B2	2.64	K2	2.62
B3	2.62	K3	2.59
B4	2.60	K4	2.57
B5	2.61	K5	2.60
B6	2.57	K6	2.90
B7*	2.55	K7	2.60
B8*	2.50	K8	2.61
B9*	2.62	K9	2.56
B10	2.64	K10	2.66
B11	2.73	-	-
B12	2.70	-	-
B13	2.65	-	-

D. Atomic absorption test

The basic principles of atomic absorption spectroscopy can be expressed by three simple statements:

All atoms can absorb light, the wavelength, at which light is absorbed in specific for a particular chemical element and the amount of light. The atomic absorption test results for Abu-shaybah Formation and Kikla Formation Samples are shown in "Table 5,", "Table 6,", "Table 7," & "Table 8,"

Table 5. Atomic Absorption Test Results for Abu-Shaybah Formation Samples.

Abu-shaybah Formation Samples	Fe (g/l)	Mg (g/l)	Mn (g/l)
B1	0.7123	0.333	0.000
B2	1.232	0.0030	0.0045
B3	0.157	0.0023	0.0150
B4	1.996	0.0232	0.000
B5	2.035	0.0403	0.0003
B6	1.222	0.0210	0.000
B7*	31.58	0.0163	0.0489
B8*	24.04	0.0232	0.0459
B9*	18.79	0.0676	0.1600
B10	0.8916	0.0066	0.000
B11	0.5433	0.0254	0.000
B12	0.3299	0.0174	0.000
B13	0.4484	0.0044	0.000

Table 6. Atomic Absorption Test Results for Abu-Shaybah Formation Samples.

Abu-shaybah Formation Samples	Ca (g/l)	Al (g/l)	Zn (g/l)
B1	1.830	12.97	0.000
B2	1.210	14.28	0.0045
B3	0.8290	16.78	0.0150
B4	0.5090	15.88	0.000
B5	1.846	13.70	0.0003
B6	0.4000	4.770	0.000
B7*	2.025	72.38	0.0489
B8*	3.114	30.69	0.0459
B9*	2.110	70.21	0.1600
B10	0.0960	14.95	0.000
B11	0.1390	9.417	0.000
B12	0.1260	8.890	0.000
B13	0.1580	9.620	0.000

Table 7. Atomic Absorption Test Results for kikla Formation Samples.

Kikla Formation Samples	Fe (g/l)	Mg (g/l)	Mn (g/l)
K1	2.172	0.0739	0.2712
K2	3.319	0.0746	0.2286
K3	15.20	0.0333	0.0514
K4	3.706	0.0732	0.0461
K5	0.9320	0.0614	0.000
K6	9.998	0.0378	0.1745
K7	1.603	0.0876	0.0699
K8	1.700	0.0741	0.0502
K9	1.378	0.0864	0.0410
K10	2.212	0.0450	0.0463

Table 8. Atomic Absorption Test Results for kikla Formation Samples.

Kikla Formation Samples	Ca (g/l)	Al (g/l)	Zn (g/l)
K1	50.96	42.11	0.371
K2	60.99	16.23	0.0241
K3	4.100	4.570	0.1195
K4	22.67	3.480	0.0071
K5	1.120	1.750	0.0105
K6	53.80	7.580	0.0179
K7	55.57	1.560	0.0034
K8	28.97	4.490	0.000
K9	27.66	0.1500	0.000
K10	26.73	2.527	0.000

E. Flame photometry test

The alkali metals, under a sufficient temperature, will absorb energy from the source of heat and by raised to an excited state in their atomic form. As these individuals unexcited state and re-emit their absorbed energy by way of radiation of aspecific wavelengths, some of which are in the visible region. Therefore, if an alkali metal in solution is aspirated into low temperature flame in an aerosol form it will, after excitation by the flame, emit a discrete frequency which can be isolated by an optical filter. The emission is propotional to the number of atoms excited (i.e the concentration of the sample). The flame photometry test is used to determine K&Na concentration by flame emission spectroscope in the samples. Flame photometry test results for Abu-shaybah Formation and Kikla Formation Samples are shown in "Table 9,", "Table 10,"

Table 9. Flame Photometry Test Results for Abu-Shaybah Formation Samples.

Abu-shaybah Formation Samples	Na (g/l)	K (g/l)
B1	0.0121	0.0013
B2	0.0113	0.0016
B3	0.0121	0.0012
B4	0.0156	0.0009
B5	0.0130	0.0013
B6	0.0173	0.0012
B7*	0.0139	0.0052
B8*	0.0113	0.0030
B9*	0.0104	0.0064
B10	0.0130	0.0008
B11	0.0113	0.0007
B12	0.0304	0.0025
B13	0.0069	0.0007

Table 10. Flame Photometry Test Results for for kikla Formation Samples.

Kikla Formation Samples	Na (g/l)	K (g/l)
K1	0.0060	0.0065
K2	0.0095	0.0045
K3	0.0086	0.0009
K4	0.0165	0.0020
K5	0.0043	0.0005
K6	0.0095	0.0048
K7	0.0130	0.0009
K8	0.0121	0.0012
K9	0.0226	0.0012
K10	0.0181	0.0013

Table 11. Correlation Coefficient (r) Results Between the Variables for All the Samples

Variable 1	Variable 2	Correlation Coefficient (R)
Cohesion (C)	Iron (Fe)	0.710
Cohesion (C)	Magnesium (Mg)	0.186
Cohesion (C)	Manganese (Mn)	0.548
Cohesion(C)	Sodium (Na)	- 0.387
Cohesion (C)	Potassium (K)	0.518
Cohesion (C)	Calcium (Ca)	0.243
Cohesion (C)	Aluminum (Al)	0.454
Cohesion (C)	Zink (Z)	0.789
Cohesion (C)	Specific gravity	- 0.230
Cohesion (C)	Moisture content	0.489
Friction angle (Ø°)	Iron (Fe)	0.020
Friction angle (Ø°)	Magnesium (Mg)	- 0.311
Friction angle (Ø°)	Manganese (Mn)	- 0.226
Friction angle (Ø°)	Sodium (Na)	- 0.120
Friction angle (Ø°)	Potassium (K)	- 0.233
Friction angle (Ø°)	Calcium (Ca)	- 0.055
Friction angle (Ø°)	Aluminum (Al)	- 0.301
Friction angle (Ø°)	Zink (Z)	0.198
Friction angle (Ø°)	Specific gravity	0.523
Friction angle (Ø°)	Moisture content	- 0.268

IV. DISCUSSION

In the linear regression analysis, one variable is singled out as being dependent upon the others (Stanley, 1973) [8]. The regression analysis is concerned with estimating one variable from another. Table x shows the values of correlation coefficients between the variables for the studied samples which are obtained by the Statistical programming package (Stanly, 1973). The cementation materials of sandstones usually control the shear strength parameters such as the internal friction angle and cohesive strength. Abu-shaybah formation consists of alternating sandstone and shale layers and its cementation materials are clay materials and/or iron oxides as indicated by the description of samples. The amount of these materials is varied and sometimes becomes a minimum in clean sandstone. Similarly, the kiklah formation is characterized by the presence of clay materials and iron oxides, the relationships between shear strength parameters and (Fe, Al & K), the average contents of Ca and Mg in these formations are low and its effect on shear strength parameters noticed only in clay samples of kiklah formation indicated previously, and they are insignificantly if other factors are controlling the shear behavior. Generally, the chemical composition relationships with shear strength parameters are significant. In the multiple correlations and regression analysis is to help to know which terms are significantly and which are not. Relationships between one dependent and several independent variables can be described both by the regression coefficient and by the correlation coefficient "Table 11,"

As a result of data deficiency, especially the chemical analysis on the form of oxides, the mineral content was not estimated. However, the element content combinations have been used instead to fulfill the purpose of this study. The element combination is as follows Mg & Ca assigned for carbonate content in the cementing materials, Al & K assigned for clay minerals content, and Fe for iron oxides. In Abu-shaybah formation, the cohesive strength increases with increasing contents of Mg & Ca. "Figure. 3,", while the internal friction angle increases as the contents of Mg & Ca decreases, "Figure. 4,".
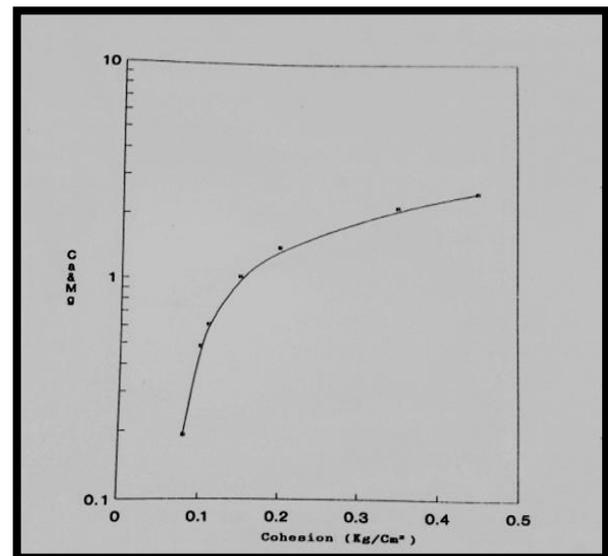

Figure 3. Relationship between (Ca&Mg) Concentrations and Cohesion for Abu-shaybah formation.
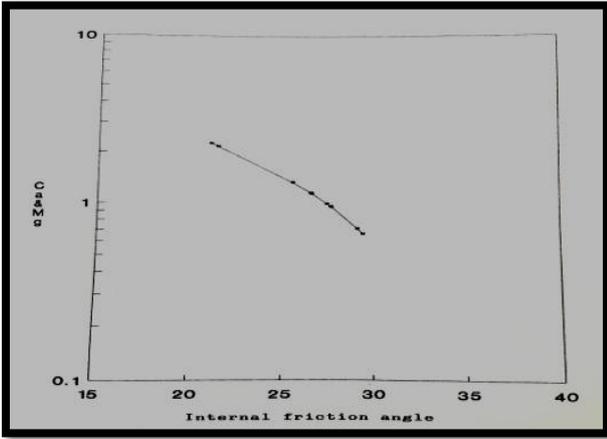
Figure 4.   Relationship between (Ca&Mg) Concentrations and the Internal Friction Angle for Abu-Shaybah Formation.

The clay contents in Abu-shaybah sandstone show similar behavior of the clay contents in Kikla formation. Figures.5, 6, 7, and 8, this may be explained by the weak cementation forces as a result of the purity of sandstone in Abu-shaybah formation.
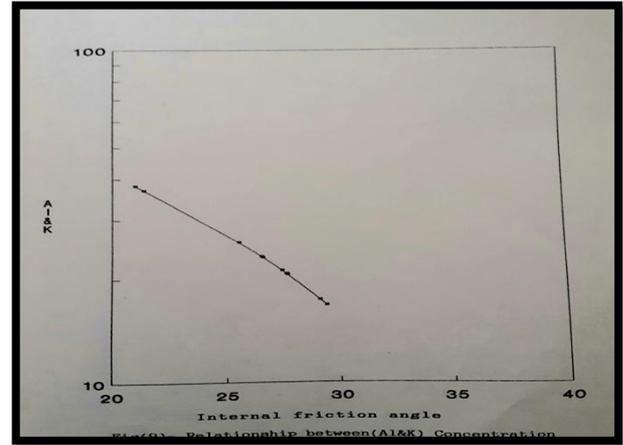

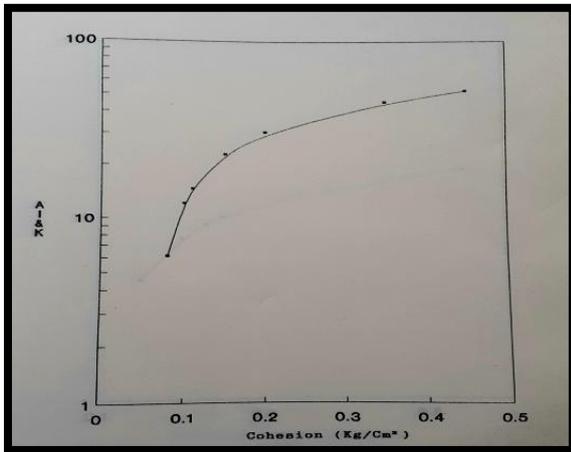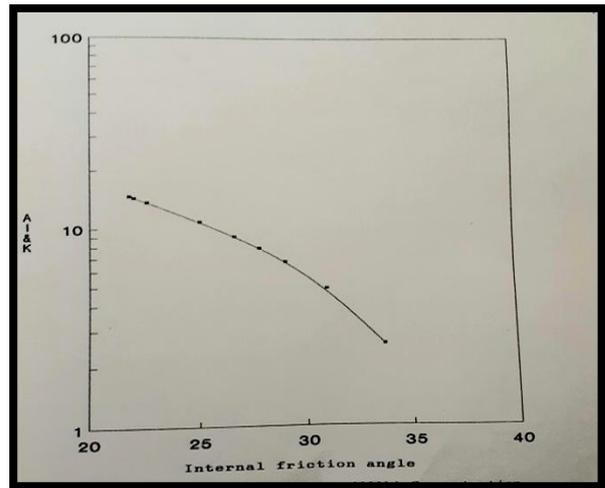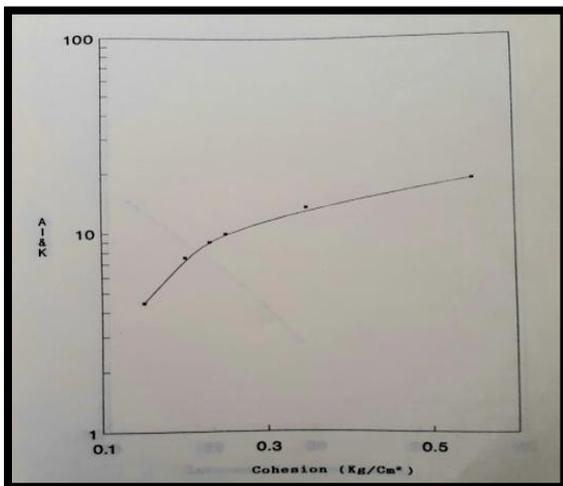Figure 5.   Relationship between (Al & K) Concentrations and Cohesion for Abu-Shaybah Formation.

Figure 6.   Relationship between (Al & K) Concentrations and Cohesion for Kikla Formation.

Figure 7.   Relationship between (Al & K) Concentrations and Cohesion for Abu-Shaybah Formation.

Figure 8.   Relationship between (Al & K) Concentrations and Internal Friction Angle for the Kikla Formation.

The clay samples, however, exhibit expectable results where the friction angle is decreased as the increase of clay content. Kiklah formation samples indicated similar behavior even though the amount of clay content in Abu-shaybah formation is higher than in Kiklah. The internal friction angle is decreased with the increasing of carbonate content in cementation materials "Figure. 9,", and
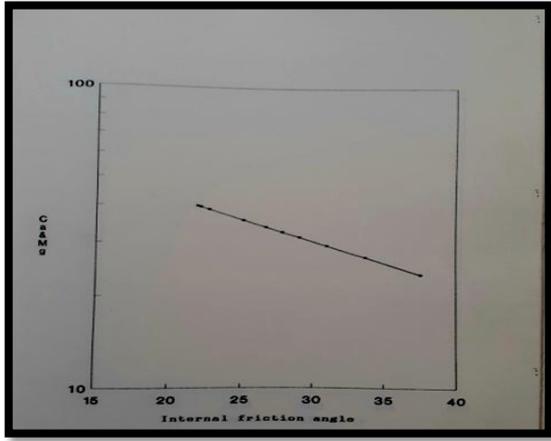
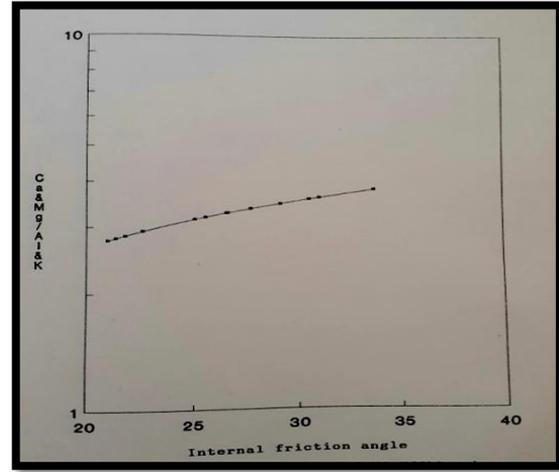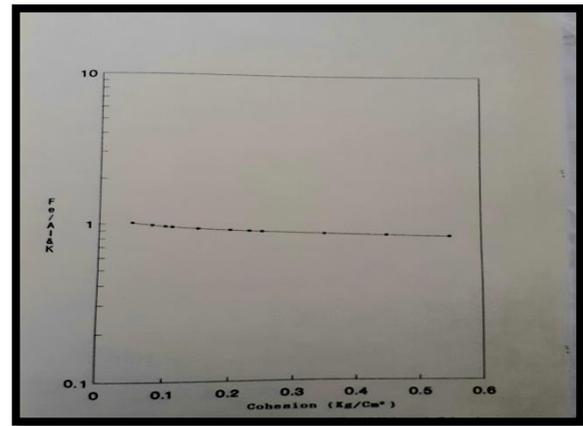Figure 9.   Relationship between (Ca & Mg) Concentrations and the Internal Friction Angle for the Kikla Formation.

It also decreased as the clay content increased "Figure. 8,". Also, the cohesive strength is increased by the increasing content of carbonate and clay content "Figures. 3, 5,". Also, the cohesive strength is increased by the increasing content of carbonate and clay content; also, the cohesive strength and the internal friction angle are increased by increasing the ratios of (Ca & Mg/Al & K) and Fe/Al & K. "Figures. 10, 11, 12, 13".
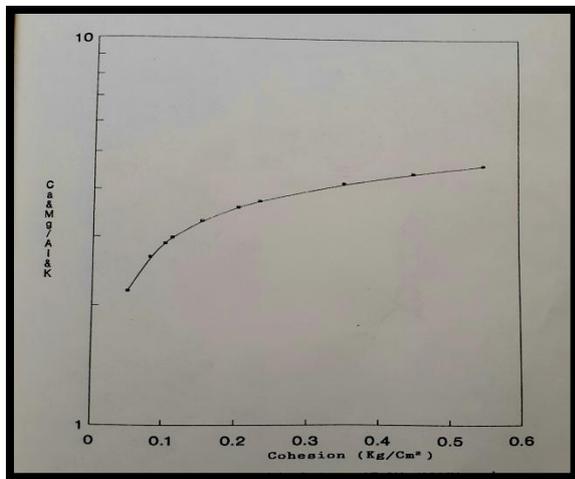

Figure 10.   Relationship between (Ca & Mg/Al & K) Concentrations and Cohesion for Abu-Shaybah and Kikla Formation.

Figure 11.   Relationship between (Ca & Mg/Al & K) Concentrations and the Internal Friction Angle for Abu-Shaybah and Kikla Formation.

Figure 12.   Relationship between (Fe/Al & K) Concentrations and the Cohesion for Abu-shaybah and Kikla formation.
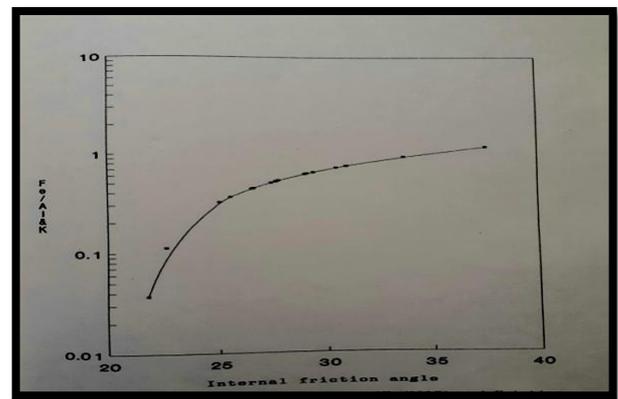

Figure 13.   Relationship between (Fe/Al & K) Concentrations and the internal friction angle for Abu-shaybah and Kikla formation.

The multiple regression analysis plots "Figs. 14, 15" indicated fair dependency of strength parameters on the composition of cementation materials. This can be interpreted as the strength parameters are dependent on composition only at lower stresses because these rock types are naturally weak.
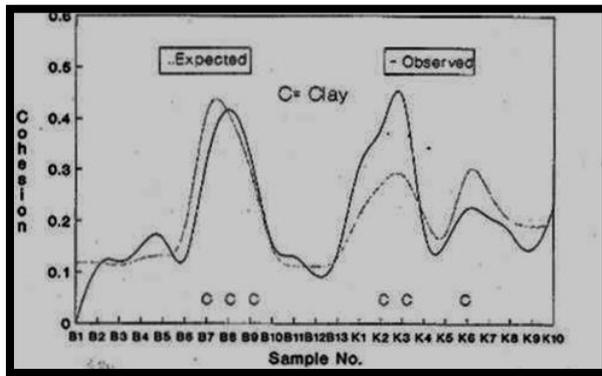
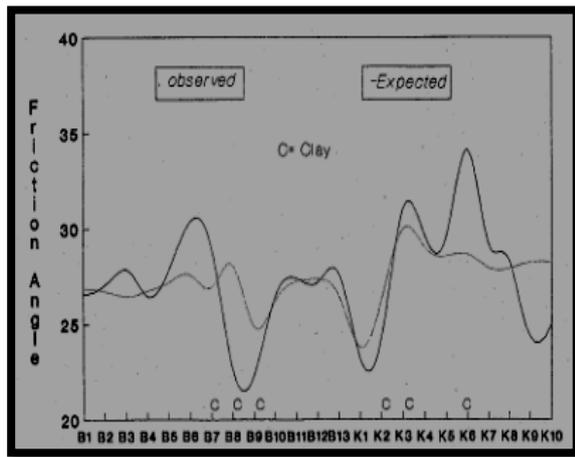Figure 14. Graphical Plotting of Observed and Expected Values of Cohesion

Figure 15. Graphical Plotting of Observed and Expected Values of Friction Angle

V.   CONCLUSIONS

Based on the obtained results by direct shear, atomic absorption, flame photometry analyses, and multiple regression analysis, the following remarks can be concluded:

1- The most common elements in all samples are Aluminum (Al), iron (Fe) and calcium (Ca).
2- The element content combinations have been used instead of the mineral content to fulfill the purpose of this study.
3- The element combination is as follows; Mg & Ca assigned for carbonate content in the cementing materials, Al & K assigned for clay minerals content, and Fe assigned for iron oxides.
4- The cohesive strength increases with increasing contents of carbonate (Mg & Ca) in the cementation materials in both of the Abu-shaybah and Kikla formations, while the internal friction angle is decreased.

5- The cohesive strength increases with increasing contents of clay (Al & K) in the cementation materials in both of the Abu-shaybah and Kikla formations, sandstone show similar behavior of the clay contents in Kikla formation; this is may be explained by the weak cementation forces as a result of the purity of sandstone in Abu-shaybah formation, while the internal friction angle is decreased, but the cohesive strength and the internal friction angle are increased by increasing of the element combination ratios (Ca & Mg/Al & K) and (Fe/Al & K).
6- The multiple regression analysis shows good agreement between expected and observed values of shear strength parameters just for clay samples. The previous analyses generally indicated that there is no clear cut dependency of either cohesive strength or the internal friction angle on the chemical composition of cementing materials. This is obvious because these rock types are considered weak and couldn't stand stresses.

ACKNOWLEDGMENT

REFERENCES

[1] M El-Hinnawy, "*Geological map of Libya; 1 : 250,000. Sheet: Tarabulas NI 33-13. Explanatory Booklet. Ind. Res. Cent.* , Tripoli, 110pp,1975.
[2] Desio et al. ,. "*Stratigraphic Lexicon of Libya, 1963.*
[3] R. Assereto and F. Benelli, "*Sedimentology of precenomanian of Jabal Gharyan, Libya*" In:Symb. Of Geol. Of Libya., Ed. by M. Salem & M. Busrewil, Tripoli, Libya, pp. 39-83, 1971.
[4] A. M. Christie, "*Geology of the Gharin area*". Tripolitania, Libya. U. N. Tech. Assistance program, Rept. TAA/Lib/2, 60P, 1955.
[5] A. Y. El-Zouki, "*Sedimentological & Stratigraphical Aspects of the Kikla, Cabao and Chameau Mort Formation (U. Jurassic-L.Cretaceaus) of Jabal Nefusa, N. W. Libya. Ph.D.thesis*, Univ. Bristol, 249pp.
[6] G. N. Smith, "*Elements of Soil Mechanics for Civil & Mining Engineers.*", Pub: Granada, 513pp.
[7] J. E. Bowles, "*Physical and geotechnical properties of soils,*" Pub: Mc Graw-HILL, pp .:44-45, 1984.
[8] Stanly, "*Practical Statistics for Petroleum Engineers*" Pub: Tulsa Oklahoma, USA, pp.:88-116, 1992.