Geotechnical Evaluation of Quaternary Gravels Quarries Exposed along New Upper Egypt-Red Sea Road, Eastern Desert, Egypt

Hesham A.H. Ismaiel, Mohamed M. Askalany and Mohamed M. Badry

Abstract- A new Upper Egypt-Red Sea road was constructed to develop Upper Egypt in different fields including an urban expansion, commerce, agriculture and different economic activities. This road connects Upper Egypt cities in the Nile valley (Qena, Sohag and Assiut) with Red Sea cities along the Red Sea coast. In this work, geotechnical properties of Quaternary gravels exposed along the studied road were investigated to evaluate their geotechnical behavior and their suitability for using as quarries. To achieve these aims, several specimens of the studied Quaternary gravels were collected from different six sites represented six proposed gravels quarries distributed along the studied road. Chemical and mineralogical analyses of the studied gravels were carried out. A percent of dissolved sulfates and chlorides of the studied gravels were determined. Petrographical examination of the gravels grains was conducted to determine their lithology. Physical and geotechnical parameters including specific gravity, water absorption, degradation in water, particle size analysis, adhering clay lumps percent, elongate/flatness percent, Les Angeles percent and California bearing ratio of the studied Quaternary gravels were measured. The results showed that the studied gravels distributed at the studied area along the road were belonging to Quaternary alluvial fans and stream sediments and the main source rocks were Maaza plateau including both Serai and Drunka Formations (Lower Eocene) which composed of different carbonate facieses and flints at the base. The results showed also that the studied gravels were suitable for quarrying. They could be used in road constructions, asphalt mixtures and cement concretes except the gravels at Wadi Qena which were not suitable for using in cement concretes. Because the studied gravels at Wadi Qena contained a high percent of dissolved chlorides and sulfates.

Index Terms- Quaternary, Les Angeles percent, Gravels Quarries, Water Absorption and Degradation, Dissolved Sulfates and Chlorides.

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1 INTRODUCTION

A new Upper Egypt-Red Sea road was constructed to develop Upper Egypt in different fields including an urban expansion, commerce, agriculture and different economic activities. This road connects Upper Egypt cities in the Nile valley (Qena, Sohag and Assiut) with Red Sea cities along the Red Sea coast. A roadway section consists of a complete pavement system shown in Figure 1. The sub-grade refers to the *in situ* soils on which the stresses from the overlying roadway will be distributed. The sub-base or sub-base course and the base or base course materials are stress distributing layer overlying sub-grade layer and underlying of the pavement layer.

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The pavement structure consists of a relatively thin wearing surface constructed over a base course and a sub-base course, which rests upon an *in situ* sub-grade. The wearing surface is primarily asphalt layer [1]. The quality of the sub-grade soils used in pavement application is classified into 5-types (very poor, poor to fair, fair, good and excellent) depending on California bearing ratio [2]. In Egypt, especially in eastern desert, there is a huge amount of natural aggregates which consider an economic deposit. They can be used in different engineering applications such as road constructions, cement concretes and asphalts mixtures. These natural aggregates need to evaluate their geotechnical behavior to determine their suitability for quarrying and for using in different engineering applications.

1.1 Location of Study Area

The study area lies in the central eastern desert. It extends from the Nile valley at the west to the Red sea at the east. It lies between latitudes 26° 00¯ and 27° 30¯ N and longitudes 31° 30¯ and 34° 00¯E. In the present work, six sections at different locations are selected along the Upper Egypt-Red Sea road to evaluate the studied aggregates (gravels) as six proposed quarries (Figure 2).

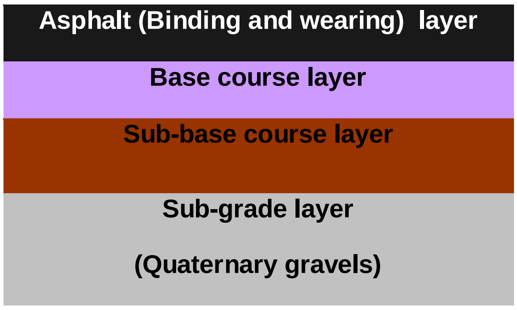

Fig. 1. A typical flexible pavement structure.

1.2 Previous Studies

Many geological investigations were carried out on the study area like [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13] and others. Few geotechnical investigations in the studied area were achieved like [14], [15], [16], [17] and [18].

1.3 Scope of Present Study

This work dealt with an investigation of the geotechnical properties of the Quaternary gravels exposed along the studied road to evaluate their geotechnical behavior and their suitability for using as quarries (Figure 3). The main goal of this study was a determination of the suitability of the studied gravels for using in different engineering applications especially road constructions, cement concretes and asphalt mixtures.

2 GEOLOGICAL SETTING OF STUDY AREA

Landforms of the investigated area are represented by a large carbonate plateau (Eocene) and several terraces of variable levels intercalated occasionally by marly and carbonate sediments and covered with Quaternary (Pleistocene and Recent) sediments. The major wadis dissecting the limestone plateau (east Sohag) are summarized as Wadi Abu Nafukh, Wadi Kiman and Wadi Dir El-Hadied which connected with the Nile river. Also, the plateau is dissecting by Wadi Shiton and Wadi Girdi which connected with Wadi Qena [19]. The studied sediments belong to Quaternary age. They are alluvial and Wadi deposits derived from the adjacent high lands. The distribution of the sediments is mapped in some details in a geological map as shown in Figure 4.

3 MATERIALS AND METHODS

3.1 Materials

Forty two specimens of the studied gravels were collected from six sections distributed along the Upper Egypt-Red sea road. The studied gravels represented the sub-grade of the road (Figure 1). The weight of each studied sample was ranging from 30.00 to 50.00 kg. The proposed volumetric quantity of the studied aggregate was calculated using the geological maps and the field observations and measurements. Very huge amount of the aggregates occurred at the studied area (Table 1).

3.2 Methods

Chemical and mineralogical analysis (X-ray fluorescence, XRF and X-ray diffraction, XRD) of the studied gravels was carried out. Percent of dissolved sulfates [20] and chlorides [21] were determined. Physical and geotechnical parameters including specific gravity, water absorption and degradation [22], particle size analysis [23], adhering clay lumps percent [24], elongate/flatness percent [25], Les Angeles percent [26] and California bearing ratio [27] of the studied Quaternary gravels were measured. Pertrographical examination of the studied gravel grains using polarized microscope with digital camera was conducted.

4 RESULTS

4.1 Chemical and Mineralogical Results

The chemical analysis results showed that the studied samples were mainly composed of calcium (87.17 to 98.93 %), silica (1.00 to 8.36 %) and iron (1.00 to 2.50 %). The sample of Wadi Qena was contained sulfur (3.07 %) and chlorine (2.50 %). The results showed also that the soluble salts including sulfates and chlorides of the studied samples were ranging from 7.30 to 36.00 ppm and from 52.00 to 130.00 ppm respectively. Except, the soluble sulfates and chlorides of the sample at Wadi Qena were 408.00 and 1603.00 ppm respectively. The mineralogical analysis results showed that the studied samples were mainly composed of calcite (80.95 to 98.93 %), quartz (00.00 to 13.10 %) and hematite (00.70 to 3.40 %). The studied sample of Wadi Qena was also contained halite (2.84 %) and gypsum (2.00 %), see Table 2 and 3.

4.2 Physical and Geotechnical Results

4.2.1 Specific Gravity, Water Absorption and Degradation in Water

The results showed that the specific gravity values of the studied samples were ranging from 2.59 to 2.67 g/cm^3. The water absorption values were ranging from 0.90 to 2.00 %. The results showed also that the degradation in water values of the studied aggregates were ranging from 0.03 to 0.90 % (Table 4).

4.2.2 Adhering Clay Lumps and Friable Particles

Table 4 illustrated the percent of the adhering clay lumps and the friable particles of the studied aggregates. These values were ranging from 0.50 to 1.00 %.

4.2.3 Sieve Grain Size Analysis

The results showed that the studied samples were composed of gravel size (60 to 70 %) and sand size (30 to 40 %), as shown in Figure 5. The studied samples were classified according to unified soil classification system (USCS) as well graded gravel (GW) and as A1-a to A1-b according to American association of state highway and transportation official (AASHTO).

4.2.4 Shape of Aggregates

Table 4 illustrated the percent of the different grain shapes of the studied samples including spherical, elongated and flatted shapes. The percent of the spherical shape was ranging from 85.60 to 88.90 %. The percent of elongated shape was ranging from 4.10 to 6.50 %. The flatted shape percent was ranging from 5.00 to 8.80 %.

4.2.5 Les Angeles Percent and California Bearing Ratio

Table 4 showed the les Angeles percent and the California bearing ratio values of the studied aggregates. The percent of Les Angeles of the studied samples was ranging from 24.30 to 31.20 %. The result showed that the California bearing ratio of the studied samples was ranging from 64.60 to 95.30 %. Table 5 illustrated specification limits of the aggregates used in different engineering applications according to AASHTO.

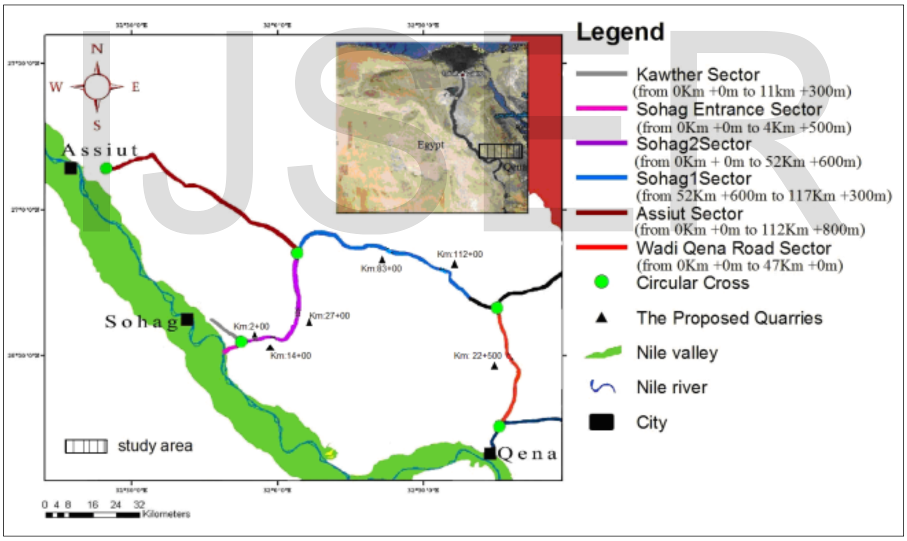

Fig. 2. Location map of the studied area and the six proposed quarries.

Fig. 3. Gravels at Sohag1 sector, Wadi Girdi, Km: 112+00m.

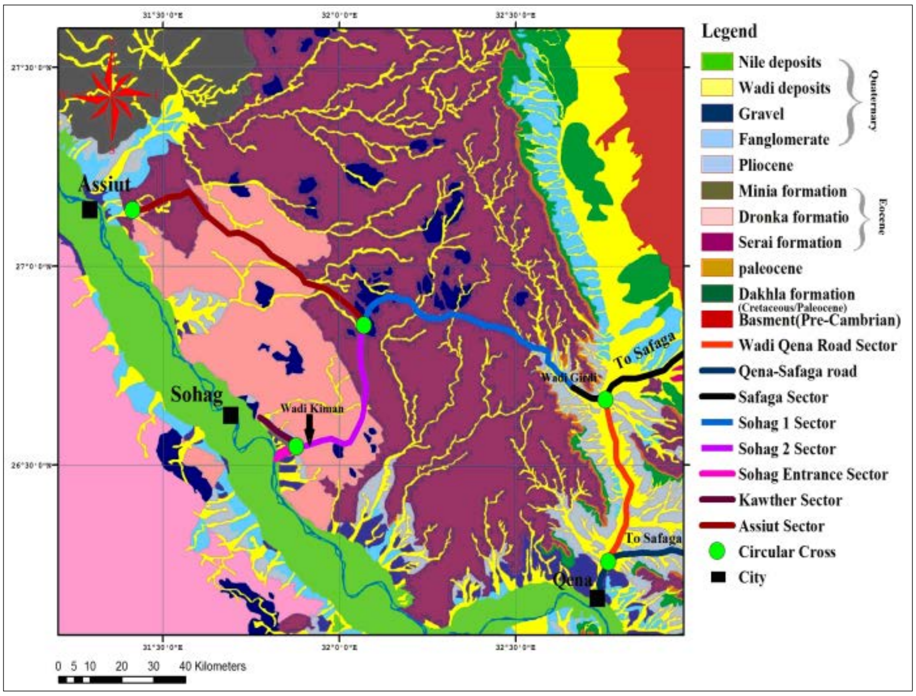

Fig. 4. Geological map of the studied area modified after [28].

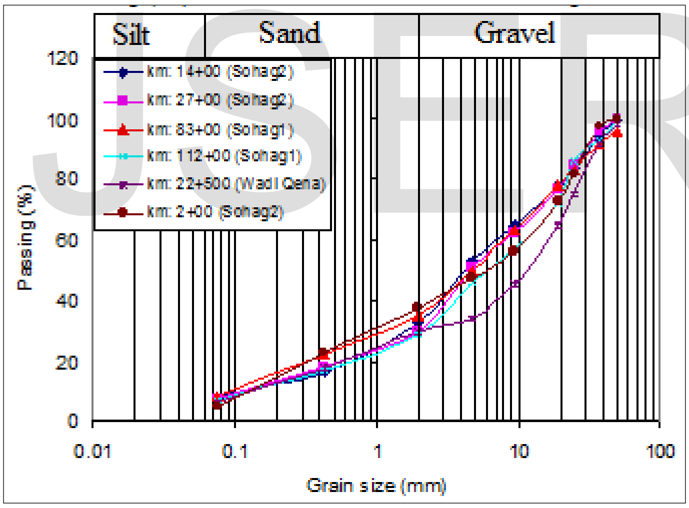

Fig. 5. Grain size distribution curves of the studied samples.

TABLE 1
PROPOSED VOLUMETRIC QUANTITY OF THE STUDIED AGREGGATE

Location		Volumetric Quantity (m^3)
Sector	Kilometer	
Sohag2	0+00	From 8.00 to 12.00 X10^6
	14+00	From 10.00 to 15.00 X10^6
	27+00	From 5.00 to 7.00 X10^6
Sohag1	83+00	From 4.00 to 5.00 X10^6
Sohag1 (Wadi Girdi)	112+00	From 70.00 to 105.00 X10^6
Wadi Qena	22+500	From 90.00 to 135.00 X10^6

TABLE 2

CHMECAL COMPOSITION OF THE STUDIED SAMPLES

Location of samples		Soluble salts (ppm)		Chemical Oxides (%)													
Sector	Km	Sulfates	Chlorides	Mg	Al	Si	Cl	K	Ca	Ti	Mn	Fe	S	Sr	P	Na	Sum
Sohag 1	83km +00m	7.30	52.00	-	-	-	-	-	98.93	-	-	1.07	-	-	-	-	100
	112km +00 m	24.40	65.00	-	-	8.36	-	-	88.17	-	-	2.45	-	1.02	-	-	100
Sohag 2	2km +00m	36.00	130.00	-	-	1.00	-	-	96.50	-	-	2.50	-	-	-	-	100
	14km +00m	31.40	57.00	-	-	1.30	-	-	97.70	-	-	1.00	-	-	-	-	100
	27km +00m	12.90	75.40	-	-	1.96	-	-	97.50	-	-	0.54	-	-	-	-	100
Wadi Qena	22km +500m	408.00	1603.00	-	-	5.36	2.50	-	87.17	0.55	-	1.35	3.07	-	-	-	100

TABLE 3

MINERALOGICAL COMPOSITION OF THE STUSIED SAMPLES

Location		Mineralogical composition (%)							
Sector	Kilometer	Quartz	Halit	Calcite	Dolomite.	Clay	Gyps.um	Hematite	Sum
Sohag1	83km+00m	0	0	98.93	0	0	0	1.07	100
	112km+00m	8.40	0	88.20	0	0	0	3.40	100
Sohag2	2km+00m	4.50	0	94.80	0	0	0	0.70	100
	14km+00m	1.30	0	96.90	0	0	0	1.80	100
	27km+00m	1.93	0	97.00	0	0	0	1.07	100
Wadi Qena	22km+500m	13.14	2.84	80.95	0	0	2.00	1.07	100

TABLE 4

PHYSICAL AND GEOTECHNICAL PROPERTIES OF THE STUDIED SAMPLES

Location / Properties		2km+00m	14km+00m	27km+00m	83km+00m	112km+00m	22km+500m
		Sohag2			Sohag1	Sohag1 (Wadi Girdi)	Wadi Qena
Saturated specific gravity (g/cm^3)		02.59	02.67	02.60	02.64	02.62	02.60
Bulk specific gravity (g/cm^3)		02.56	02.62	02.56	02.61	02.59	02.59
Apparent specific gravity (g/cm^3)		02.61	02.70	02.66	02.68	02.63	02.61
Water absorption (%)		02.00	01.00	01.20	01.00	00.90	01.30
Degradation in water (%)		00.03	00.03	00.08	00.10	00.05	00.90
Adhering clay lumps and foreign materials (%)		00.50	00.70	00.65	00.87	00.82	01.00
Shape of aggregate (%)	spherical	88.50	87.00	85.60	86.90	87.60	87.80
	elongated	06.50	04.80	05.60	05.70	04.10	05.70
	flatted	05.00	08.20	08.80	07.40	08.30	06.50
Les Angeles (%)		24.30	30.50	27.50	30.40	25.20	31.20
CBR (%)		92.30	94.50	95.30	75.40	86.50	64.60

TABLE 5

SPECIFICATION LIMITS OF AGREGGATES USED IN DIFFERENT APLICATIONS (AASHTO)

Parameter / Application	Les Angeles (%) AASHTO, T 96	Adhering clay lumps (%) AASHTO, T 112	Water absorption (%) AASHTO, T 85	Degradation in water (%) AASHTO, T 85	Dissolved sulfates and chlorides (ppm)	Elongate and flatness (%) AASHTO, TP 081
Cement concretes	Lower than 40	Lower than 1	Not more than 5	Not more than 1	Not more than 600 for sulfates AASHTO, T 290 Not more than 400 for chlorides AASHTO, T 291	Not more than 20
Asphalt mixtures	Lower than 40	-	Not more than 5	Not more than 1	-	Not more than 20
Road constructions (Base and sub-base)	Lower than 50	-	Not more than 5	Not more than 1	-	Not more than 20

4.3 Petrographyical examination

The petrographical examination of several representative gravel grains of the studied samples under the polarized light microscope illustrated that the studied gravel grains were mainly composed of very hard crystalline limestone, hard marly limestone and partially recrystallized chalky limestone. Some gravels grains were composed of very hard partially silicified limestone. The limestone grains were characterized by crystalline texture and some grains were characterized by micritic matrix with partially recrystallization to sparite. The major component of the gravel grains was calcite and the minor component was hematite (Figure 6). Some examined grains were very hard flint and composed of quartz.

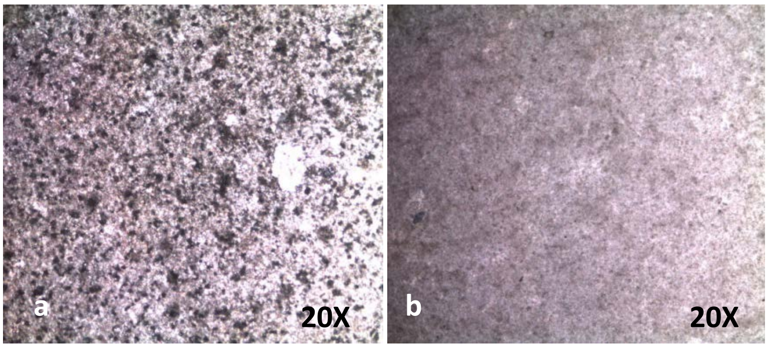

Fig. 6. Photomicrographs of the studied gravel grains using light polarized microscope,

a) chalky limestone and b) crystalline limestone.

5 DISCUSSIONS AND CONCLUSIONS

The studied aggregates were mainly composed of calcium (87.17 to 98.93 %), silica (1.00 to 8.36 %) and iron (1.00 to 2.50 %). The sample of Wadi Qena was contained sulfur (3.07 %) and chlorine (2.50 %). The dissolved salts including sulfates and chlorides of the studied aggregates were ranging from 7.30 to 36.00 ppm and from 52.00 to 130.00 ppm respectively. The dissolved sulfates and chlorides of the studied samples at Wadi Qena were 408.00 and 1603.00 ppm respectively. The percent of dissolved chlorides and sulfates occurred in Wadi Qena was high compared to the other studied locations. Accordingly, the aggregates at Wadi Qena were not suitable for using in cement concretes [20] and [21]. The studied aggregates were mainly composed of calcite (80.95 to 98.93 %), quartz (00.00 to 13.10 %) and hematite (00.70 to 3.40 %). The studied samples of Wadi Qena were also contained halite (2.84 %) and gypsum (2.00 %). The specific gravity values of the studied samples were ranging from 2.59 to 2.67 g/cm^3. The specific gravity of the aggregates is considered to be a strong indicator of the strength or the quality of an aggregate type [29]. The results indicated that the studied gravels were dense and hard. The water absorption values were ranging from 0.90 to 2.00 % (Not more than 5 %). The degradation in water values were ranging from 0.03 to 0.90 % (Not more than 1 %). These values indicated that the aggregates were suitable for cement concretes, asphalt mixtures and road constructions (as base and sub-base), according to [22]. One of the main factors for cement concrete to achieve a good strength is the bond between gravel and both sand and cement. This bond is greatly affected by the presence of dust on the aggregates particles or any other materials adhering to them such as clay and friable particles [30]. The percent of the adhering lumps and the friable particles of the studied samples were ranging from 0.50 to 1.00 %. These foreign materials should be less than 1% by weight according to [24]. That meant the foreign materials of the studied gravels were suitable for the cement concretes. The studied aggregates were contained about 60 to 70 % gravel size and about 30 to 40 % sand size. They were classified according to unified soil classification system (USCS) as well graded gravel (GW) and as A1-a to A1-b according to AAHSTO. Well graded gravels had a good quality for the cement concretes especially with optimum amount of cement. The recommended sizes of the gravels are 38.1-4.75 mm, 19.5-4.75 mm and 12.6-4.75 mm [23]. The grain size of the studied gravels at the six studied proposed quarries had the standard grain size range. The aggregate grains should be generally spherical or cubic in shape. The percentage of flatted and elongated grains in any size group should not exceed 20 % [23]. The percent of the spherical shape of the studied aggregate was ranging from 85.60 to 88.90 %. The percent of the elongated shape was ranging from 4.10 to 6.50 %. The flatted shape percent was ranging from 5.00 to 8.80 %. The elongate and flatness of the studied aggregates at the study area were suitable for quarrying and for using in road constructions, cement concretes and asphalt mixtures [25]. The percent of Les Angeles of the studied aggregates was ranging from 24.30 to 31.20 %. The les Angeles percent should not exceed 50 % for the base and sub-base aggregates in road construction and not exceed 40 % for the aggregates of cement concretes and asphalt mixtures. That meant the studied aggregates were suitable for road construction as base and sub-base and for cement concretes and asphalt mixtures [26]. The California bearing ratio of the studied aggregates was ranging from 64.60 to 95.30 %. The lowest values of the studied samples were at Wadi Qena. The typical CBR-values of the well graded gravels are ranging from 60 to 80 % according to [72]. The studied aggregates had CBR-values more than 50 %. That meant the studied samples were excellent as sub-grade in the road constructions [2]. The studied gravel grains were manly composed of very hard crystalline limestone, hard marly limestone and chalky limestone which were composed mainly of calcite. Some grains were very hard flint and composed of quartz. The studied aggregates occurred along the new Upper Egypt–Red sea road were suitable for the road constructions where they were hard enough to withstand abrasion from tires, strong enough to support the load of vehicles and sound enough to withstand wetting and drying conditions. The chemical and mineralogical composition of the studied aggregates as well as the petrographical examination indicated that they were belonging to Quaternary alluvial fans and stream sediments. The main source rocks might be the Maaza plateau including both Serai and Drunka Formations (Lower Eocene) which composed of different carbonate facieses (crystalline, partially recrystallized chalky limestone and partially silicified limestone) and flints at the base, as well as Issawia limestone Formation which composed of very hard limestone (Pliocene).

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References

[1] Tensar Technical Note, "Chemical and Mechanical Stabilization of Sub-grades and Flexible Pavement Sections," *TTN, BR 10*, 1998.

[2] J. Bowles, "Engineering Properties of Soil and their Measurements, " 4th Edition , McGraw-Hill, Boston, 1992.

[3] T. Barron and W.F. Hume, "Topography and geology of the eastern desert of Egypt (central portion)," Survey Dept., Cairo, Egypt, 331p, 1902.

[4] K.S. Sandford and W.J. Arkel, "Paleolithic Man and the Nile-Faiyum Divide, " Chicago University, Oriental Inst. Publ., 1, pp. 1-77, 1929.

[5] J. Ball, "Constructions to the geography of Egypt," Survey and Mines Dept., Cairo, Egypt, 308p, 1939.

[6] M.E. Mustafa, "Computerized analysis of geologic structures in central eastern desert, Egypt, and their role in distribution of radioactive mineralization," PhD disseration, Cairo University, Egypt, 1979.

[7] A.A. Omran, E.R. Philobbos, S. Riad and A.B. Othman, "Sedimentary basins and crustal thickness in Wadi Qena and the surrounding areas as interpretated from Bouguer anomalies," *Egypt journal of Geology*, vol. 39, no. 1, pp. 377-398, 1995.

[8] S.R. El-kholy, "Geophysical studies on some parts of the eastern desert of Egypt," PhD dissertation, Faculty of science, South valley university, Egypt, 1996.

[9] Y.A. El-Kazzaz, "Active faulting along Qena-Safaga road, Eastern desert, Egypt," *The first international conference on the geology of Africa*, Assiut University, Egypt, vol. Z, pp. 385-404, 1999.

[10] A.M. El-Akraby, "A contribution to the delineation of the geologic setting of the fracture area (km 19-31) along Qena-Safaga road, using geoelectrical studies," *Ain Shams University bulletin*, vol. 38, pp. 95-112, 2000.

[11] A. Badawy, S.M. Abdel-Monem, K. Sakr and Sh.M. Ali, "Seismicity and kinematic evolution of middle Egypt," *Journal of Geodynamics*, vol. 42, pp. 28–37, 2006.

[12] M.A. Azab, "Assessment management of natural hazards and disasters along Qena-Safaga road, central eastern desert, Egypt," *Remote sensing & space Sci.*, vol. 12, pp. 55-70, 2009.

[13] M.M.I. Zayan, "Sedimentological, mineralogical and geochemical studies of the Neogene-Quaternary sediments around Qena, Egypt," PhD dissertation, Assiut University, Egypt, 2009.

[14] A.M. Youssef, "Mapping the Pliocene clay deposits using remote sensing and its impact on the urbanization developments in Egypt, case study, East Sohag area," *Geotech. Geol. Eng.*, vol. 26, pp. 579-591, 2008.

[15] A.M. Mahrous, M. Tantawi and H. El-Sageer, "Evaluation of the engineering properties of some Egyptian limestones as construction materials for highway pavements," *Construction and Building Materials journal*, vol. 24, pp. 2598-2603, 2010.

[16] H.A.H. Ismaiel, M.M. Askalany and M.M. Badry, "Geotechnical Propertied and Classification of both Non-Expansive and Expansive Soils Exposed along the New Upper Egypt-Red Sea Road, Eastern Desert, Egypt," *Scientific Journal of Banha University*, no. 6, pp. 1-18, 2011.

[17] H.A.H. Ismaiel and M.M. Badry, "Geotechnical Evaluation of Sedimentary Rocks and Karstification Phenomena of Carbonates Exposed along New Upper Egypt-Red Sea Road, Eastern Desert, Egypt," *Journal of Earth Science and Engineering*, vol. 2, 636-647, 2012.

[18] H.A.H. Ismaiel and M.M. Badry, "Lime Chmical Stabilization of Expansive Deposits Exposed At El-Kawther Quarter, Sohag Region, Egypt," *Geoscience*s, vol. 3, no. 3, pp. 89-98, 2013.

[19] A.A. Abdelmoneim, "Hydrogeology of the Nile basin in Sohag province," Msc. dissertation, Assiut University, Egypt, 1988.

[20] AASHTO, T 290, "Standard Method of Test for Determining Water-Soluble Sulfate Ion Content in Soil," Single User Digital Publication. American Association of State Highway and Transportation Officials, Washington, DC., 2010.

[21] AASHTO, T 291, "Standard Method of Test for Determining Water-Soluble Chloride Ion Content in Soil," Single User Digital Publication. American Association of State Highway and Transportation Officials, Washington, DC., 2010.

[22] AASHTO, T 85, "Standard Method of Test for Specific Gravity and Absorption of Coarse Aggregate," Single User Digital Publication. American Association of State Highway and Transportation Officials, Washington, DC., 2010.

[23] AASHTO, T 27, "Standard Method of Test for Sieve Analysis of Fine and Coarse Aggregates," Single User Digital Publication. American Association of State Highway and Transportation Officials, Washington, DC., 2010.

[24] AASHTO, T 112, "Standard Method of Test for Clay Lumps and Friable Particles in Aggregate," Single User Digital Publication. American Association of State Highway and Transportation Officials, Washington, DC., 2010.

[25] AASHTO, TP 081, "Standard Method of Test for Determining Aggregate Shape Properties by Means of Digital Image Analysis," Single User Digital Publication. American Association of State Highway and Transportation Officials, Washington, DC., 2010.

[26] AASHTO, T 96, "Standard Method of Test for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Les Angeles Machine," Single User Digital Publication. American Association of State Highway and Transportation Officials, Washington, DC., 2010.

[27] AASHTO, T 193, "Standard Method of Test for The California Bearing Ratio," Single User Digital Publication. American Association of State Highway and Transportation Officials, Washington, DC., 2010.

[28] Conoco, "Geological Map of Egypt, 1: 500000-NG36NW-(ASYUT)," The Egyptian Petroleum Co-operation, Cairo, Egypt, 1987.

[29] M.A. Kamal, A.M. Sulehri and D.A.B. Hughes, "Engineering characteristics of road aggregates from northern Pakistan and the development of a toughness index," *Geotechnical and geological engineering*, vol. 24, pp. 819-831, 2006.

[30] A.M. Mansour, M.M. Askalany, Z.A. El-Alfy and A.N. Ahmed, "Drainage basins between Marsa Alam and Ras banas and their flood hazard and ground water potentials, Red sea," *3th International Conference, geology of Africa*, *Egypt*, vol. 1, pp. 77-97, 2003.