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Properties of Soil Sediment in Wadi Arar, Kingdom of Saudi Arabia

Alnos Hegazy[1+] and Mohammed Alghamdi[2]

[1]Associate Prof. of Civil Engineering, Faculty of Engineering, Northern Border University, KSA
[2]Assistant Prof. of Engineering Geology, Earth Science Faculty, King Abdulaziz University, KSA

Abstract. According to the urban extension of Arar's city, the soil properties are strongly required. The surface deposits of Wadi Arar, that extend for 22 km at north-east direction is a mature river deposits. The deposits are silty sand with low plasticity as unified soil classification system (USCS). The average contents of sand, silt and gravel are 54%, 30% and 16% respectively. Due to the convergence of the Sha'ibs with Wadi Arar, the average content of sand, silt and gravel are changed. The results indicated that the soil in Wadi Arar is suitable as a structure soil and it is not suitable as a cementing material product

Keywords: Wadi Arar, sediment, soil grains, soil properties, grain size distribution.

1. Introduction

Arar's city is the main city of Northern Border Region at the north part of Saudi Arabia(KSA), Fig. 1. Where, this region is located between Latitudes 32° 30' 0'' N and 28° 15' 0'' N and Longitudes 38° 20' 0'' E and 46° 15' 0'' E. Wadi Arar is located at central part of NBR. Where, it penetrates Arar's city from the south west to the north east. Wadi Arar starts by small Sha'ibs from about 125 km towards Arar's city and meets many Wadis and Sha'ibs. Then, it continues in the direction to the Iraqi border [1&2]. Additionally, this area is located between Latitudes 31° 00' N and 30° 45' N and Longitudes 40° 30' E and 41° 05' E. Where, these regions are characterized by a rocky layer of limestone and sandstone with a few of dolomites and silt. Also, this area is belonging to configure Aruma of the Cretaceous era. There is also widespread rises, small Wadis and Sha'ibs in many areas [2&3].

The properties of sedimentary soils relate to the source of rock and to the transporting agent, whether it is gravity, water, wind, glacial ice, or activities of scrapers, bulldozers, and pocket gophers. Soils that have recently been moved from their place of origin are re-deposited as fill [4&5]. Generally, soil grains size plays a main role for engineering strength quality and behavior of underlying soil. Conesus, aggregates and grained soils are primarily used to improve the engineering properties of structure soil, construction soil and pavement materials [4-7].

Soliman and Alsubhi [8] stated that a few studies are dealt with most Wadis and Sha'ibs in KSA, mainly concerned with geological mapping at various scales and stratigraphic classification in addition to description of the component rock varieties. Also, there are no enough studies available to show the soil type and soil properties of Wadi Arar. Accordingly, the present work is mainly focused on the properties of sediment soil at Wadi Arar. Therefore, the study area is carefully chosen to represent a key sector of soil properties due to urban expansion in Arar's city. Also, the present study is concentrated on the part of Wadi Arar for probably used in future constructions according to the urbanization of Arar's city, Fig. 1.

2. Field Work Description

Geological maps and topographical maps were used to adapt the study area of Wadi Arar. Network stations were selected to cover the studied area. An experimental program was prepared to investigate physical properties of the natural surface soil. The study area of Wadi Arar was chosen as shown in Fig. 1.

[+] Corresponding author. Tel.: +966533438100; fax: +966146610631. *On leave: Faculty of Engineering, Benha University, Egypt.*
E-mail address: hegazyalnos@yahoo.com.

The studied area of Wadi Arar is located between Latitudes 30^{o} $50^{'}$ $30^{''}$ N and 30^{o} $56^{'}$ $30^{''}$ N and Longitudes: 40^{o} $50^{'}$ $30^{''}$ E and 41^{o} $02^{'}$ $30^{''}$ E. For the purpose of this study, seven cross-sections (A, B, C, D, E, F, G) perpendicular on the path direction of the Wadi were chosen, as shown in Fig. 1, depending upon the drainage pattern of soil grains. It was taken into consideration that: (a) the soil sediment property is the reflection of the sedimentation process and its environment deposits, and (b) the probably changes of soil properties may be occurring at soil sediment locations. Therefore,

1- Cross-sections were adopted according to the presence of catchment area or the presence of meandering of Wadi path or the meeting area with other Wadis or quite straight path of Wadi Arar.

2- The measured length of cross-sections A, B, C, D, E, F, G are about 1500, 1050, 1400,1900, 3000, 1500 and 3000 m respectively. The distance between cross-sections is around 2000-4500 m.

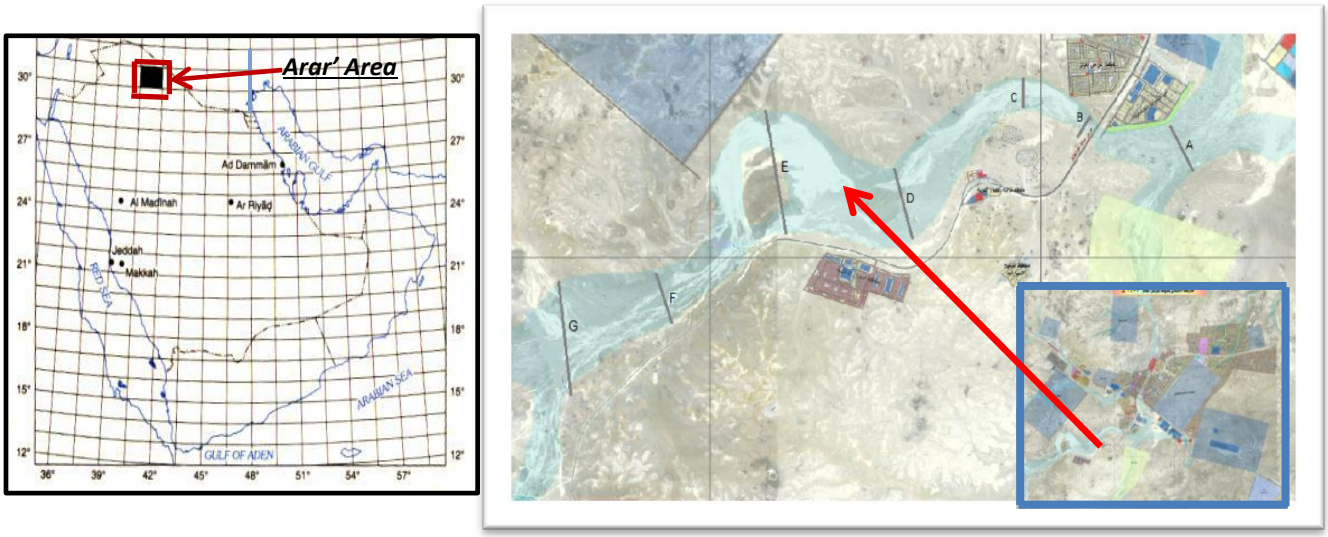

Fig. 1: KSA index map and topographical plan of Arar's city and the studied area of Wadi Arar

3. Soil Sampling and Testing

Soil sampling points are 3, 3, 3, 3, 5, 3 and 4 at cross-sections A, B, C, D, E, F and G respectively. For instant, Fig. 2 shows soil sampling points for cross-section G. Two natural soil samples were obtained from each point. The first soil sample was obtained from the surface of natural sediment of soil layer, i.e. from the top 10 cm of surface soil layer. The second was obtained from the depth of 60-80 cm below the first one. Accordingly, 48 soil samples were obtained. Coding reference for each soil sample includes cross-sections letters, soil sampling point's numbers and soil sample number. For instant, soil sample code G3-2 means that the second soil sample at sampling point 3 and cross-section G. Laboratory tests were carried out on soil samples based on the manner of testing and measuring in text books, such as Bowels [9]. Also, international standard specifications for testing and measuring were taken into considerations, such as ASTM [10].

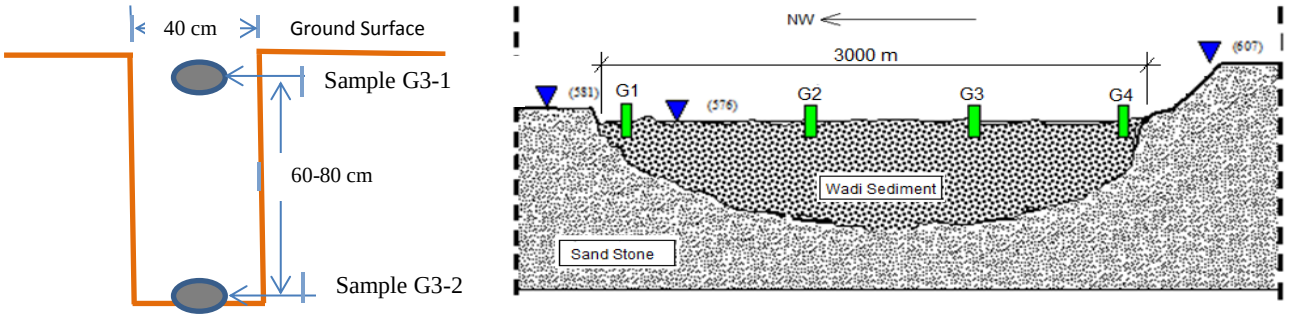

Fig. 2: A schematic sectional elevation of cross-section G and soil samples

4. Results and Analysis

Grain size distribution curves of the obtained soil samples are summarized in Fig. 3. Also, the measured properties of soil are recorded in Tables 1 and 2. Based on these results, it is noticed that:

- The soil grains distribution trends are approximately similar. Where, sand grains are extremely the main content of sediment soil in Wadi Arar. The average contents of sand, fine grains and gravel are about 54%, 30% and 16% respectively.
- Specific gravity (G_s) values are approximately closed. The highest value of G_s is 2.71, the lowest is 2.54 and the average value of G_s is 2.67.
- The average value of natural moisture content (w_n) is about 4.5%, the lowest is 2.6% and the highest is 6.4%. In other side, the average value of liquid limit (LL) is 28%, the lowest is 23% and the highest is 36%. Additionally, the average measured plastic limit (PL) is 25%, the lowest is 23% and the highest is 28%. Accordingly, the values of plasticity index (PI) are small. Then, the plasticity of soil sediment at Wadi Arar is small and can be neglected. Cconsequently, shrinkage limit (SL) cannot be measured as well as plastic limit for some soil samples because the soil specimen was broken and lost water quickly.
- According to unified soil classification system (USCS), the sediment soil at the studied area of Wadi Arar is classified into silty sand (SM). Where, fine grains are silt with low plasticity (ML).

Table 1: Soil grains content at the studied area of Wadi Arar

Cross-section	Gravel grain content (%)			Sand grain content (%)			Fine grain content (%)		
	Max.	Min.	Average	Max.	Min.	Average	Max.	Min.	Average
A	25	10	19	62	43	54	40	13	28
B	16	6	10	68	52	61	34	23	28
C	24	8	18	60	48	56	31	22	26
D	23	11	13	59	46	53	42	18	34
E	17	5	10	56	43	50	48	27	40
F	44	18	31	58	42	47	35	8	22
G	26	4	11	62	53	57	41	20	32
Average	16			54			30		

Table 2: Basic physical properties at the studied area of Wadi Arar

Cross-sections	Specific gravity, G_s			Moisture content, w_n, (%)			Liquid limit, LL, (%)			Plastic limit, PL, (%)		
	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min	Av.	Max.	Min.	Av.
A	2.71	2.65	2.67	6.4	3.5	4.75	34	24	28	27	-	27
B	2.7	2.65	2.67	5.8	4.8	5.2	31	25	27	24	-	24
C	2.7	2.66	2.69	4.4	3.6	4	28	24	26	-	-	-
D	2.7	2.54	2.64	5	4.4	4.7	32	26	29	27	24	25
E	2.7	2.65	2.67	5.6	3.8	4.75	36	24	31	28	24	26
F	2.7	2.68	2.69	3.5	2.6	3.2	26	23	24	-	-	-
G	2.7	2.63	2.66	5.6	3.8	4.8	35	24	31	26	23	24
Average	2.67			4.5			28			25		

5. Discussion

In Wadi Arar, the soil grains are approximately uniform through most cross-sections except cross-sections E and F. These results are attributed to: (a) sedimentation state of soil grains, (b) the speed of flowing soil in Wadi, (c) Wadi cross-section length, (d) the presence of the meandering system and (e) the existing of Sha'ibs which meets with Wadi. Accordingly, the increase of gravel grains content through cross-sections F of Wadi Arar attributes to the presence of Sha'ib Al-Awshazi and other small Sha'ibs.

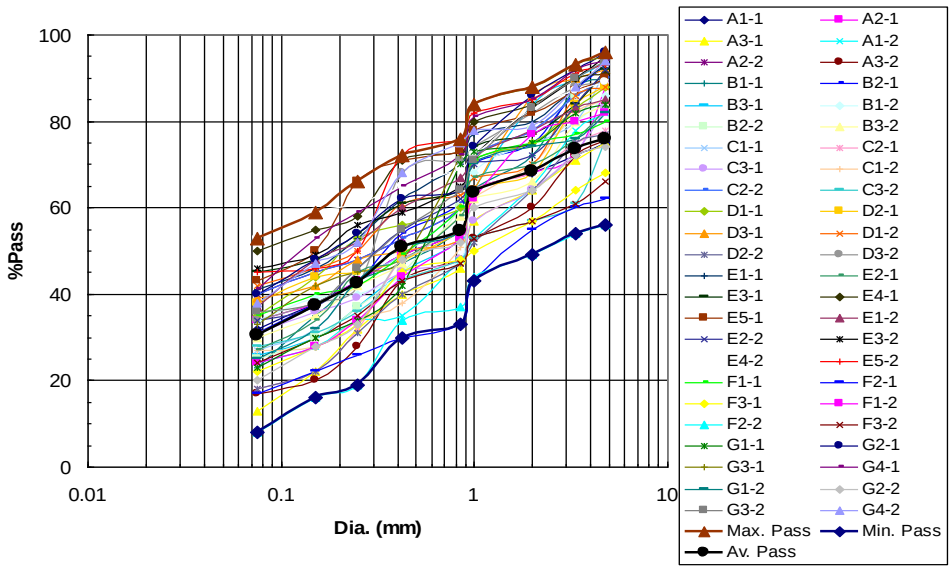

Fig. 3: Grain size distribution curves of studied soil samples in Wadi Arar

Depending on environmental deposit, sand grains contents are mostly common grains in the studied soil of Wadi Arar. The grading of sand grains is expressed in empirical formula according to William et al [11] by using Microsoft Excel program. The following function formula can be expressed as:

$$Y=A.X^{B} \qquad (1)$$

Where, Y represents %Pass of soil grains, X is the grains passing diameter (by mm), while, A and B are constant variations depending upon soil grains content. It can be noted that: (a) the highest value of A is 75, the lowest is 35.5 and the average value of A is 58.8, (b) the highest value of B is 0.44, the lowest is 0.13 and the average is 0.26, and (c) the highest matching difference between grain size distribution curve and the fitting curve is about 10%, the lowest is 1% and the average matching difference is about 4%.

An overview about specific gravity (G_s) values, it is noticed that values of G_s are approximately closed around 2.70 to 2.65. Where, G_s is commonly used in industry and manufactures as a simple means of obtaining information about the origin of materials and the concentration of other various materials. Accordingly, G_s results indicate that the sediment of soil grains in Wadi Arar is formed and deposited from the same source of rocks by physical weathering.

Otherwise, it was observed that the natural moisture content (w_n) is correlated with fine grains content in the oboist relation. It is clear that w_n in the ranged from 2.6% to 6.4% as well as the content of fine grains is ranged from 8% to 48% respectively. Mostly, w_n of soil in the arid and desert areas is considered hold adsorbed water. Similar to that, the values of liquid limit (LL) and plastic limit (PL) are correlated also with fine grains content. Where, LL is ranged from 23% to 36% as well as the fine grains content is ranged from 8% to 48% respectively. For instant, the highest value of LL is 36% for soil at cross-section E which has 48% fine grains content, while, the lowest LL is 23% for soil at cross-section F which has 8% fine grains content.

Additionally, plastic limit cannot be measured for some soil samples which have low liquid limit values (less than 30%) and shrinkage limit (SL) cannot be measured for all soil samples. That is because the soil was cracked, broken and lost water quickly.

Referring to international specifications such as ASTM [10] and in the point view of construction and quality control engineers, the soil in Wadi Arar is not suitable as a cementing material product. But, it is suitable soil as filling materials and bearing soil.

6. Conclusions

1- The soil in Wadi Arar is transported soil and classified as silty sand (SM). The value of specific gravity is approximately closed around 2.67

2- Sand grains are the common grains in the soil sediment of Wadi Arar. The average content of sand, fine and gravel grains is 54%, 30% and 16% respectively. Fine grains is classified into silt soil type with low plasticity.

3- Empirical formula is expressed as a relation between grains size and grains content in the sediment soil.

4- Soil grains content plays main role about the values of natural moisture content (w_n). Where, w_n value increases with the increase of fine grains content and vice versa.

5- The average value of liquid limit is about 28%. Cconsequently, plastic limit cannot be measured for soils which have liquid limit less than 30%. The measured plastic limits is approximately closed around 25%.

6- With the increase of fine grains content from 8% to 48% the natural moisture content (w_n) increases from 2.6% to 6.4% as well as the increase of liquid limit from 23% to 36%.

7- Wadi Arar soil is not suitable to use as a cementing mortar product because its grading is not agreed with the international specification grading limits. Regarding to low values of Atterberg's limits (LL, PL and SL), the soil in Wadi Arar can be used safely as structure materials. Also, the soil is suitable for using as filling, base and subase material.

8- Continuing in-situ and laboratory studies on engineering properties of soil in Arar's city are stongly required for future developments.

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