International Journal of Civil
Engineering (IJCE)
ISSN(P): 2278-9987; ISSN(E): 2278-9995
Vol. 2, Issue 5, Nov 2013, 1-8

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations
IASET

PHYSICAL PROPERTIES OF SOIL SEDIMENT IN WADIARAR, KINGDOM OF SAUDI ARABIA

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ABSTRACT

The top half meter of the surface deposits of wadiArar, that extend for 22 km at north-east direction and located between latitudes 30^o 45′ and 31^o 00′ N and longitude 40^o 30′ and 41^o 05′ E is a mature river deposits. The deposits of studied area are silty sand as unified soil classification system (USCS). The average contents of sand, silt and gravel are 54%, 30% and 16% respectively. The $Y = A.X^B$ equation and equation of $Y = A.\ \ln X+B$ represent the best two mathematical forms to represent the grains size distribution. Where Y represents the percentage of passing (%Pass), while X represent the sieve diameter by mm. Otherwise, the sudden change in the proportion passing 1 mm means no feeding from the source with this size which may reflect the change of the mineral composition.

Comparing between the start and the end of the study area, it was found that the average content of sand and silt decrease from 57% to 54% and from 32% to 28% respectively, while, the average content of gravel increase from 11% to 19%. This is a result of the convergence of the Sha'ibs with WadiArar. Otherwise, at the meandering point bars, it was found that for the whole three meanders the average contents of sand content was the highest, then, silt and gravel with 53%, 33%, 13% respectively. Either the sand content was the highest or the gravel was the lowest for each meander.

KEYWORDS: Grain Size Distribution, Physical Properties, Sediment, Soil Grains, WadiArar

INTRODUCTION

Residual soils are readily removed and re-deposited through actions of wind, moving water, or glacial ice, to become sedimentary soils or sediments. The properties of sedimentary soils relate to the source 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 [1, 2 and 3]

The Unified Soil Classification System (USCS) is a soil classification system used in engineering and geology to describe the texture and grain size of a soil. The classification system can be applied to most unconsolidated materials, and is represented by a two-letter symbol [1and 4]. Generally, soil grains size plays a main role for engineering strength quality and behavior of underlying soil [1, 5 and 6]. Conesus, aggregates and grained soils are primarily used to improve the engineering properties of structure soil, construction soil and pavement materials. Arar's city is the main city of Northern Border Region (NBR) at the north part of the Kingdom of Saudi Arabia (KSA) [7], Figure 1. Where, NBR is located between Latitudes 32^o 30' 0'' N and 28^o 15' 0'' N and Longitudes 38^o 20' 0'' E and 46^o 15' 0'' E.

WadiArar is located at central part of Northern Border Region. Where, it penetrates Arar's city from the south west to the northeast. WadiArar 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 Iraqiborder [8], Figure 2. Where, this area is located between Latitudes 31^o 00' N and 30^o 45' N and Longitudes 40^o 30' E and 41^o 05' E. 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 Cretaceousera. There is also widespread rises, small Wadis and Sha'ibsin many areas [9]. There are no enough studies available to show the soil type, soil classification and soil properties of WadiArar. Soliman, M.A.M and Alsubhi, M.B. [10] and Ahmed, A.H., et al. [11] 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. Accordingly, the present work is mainly focused on the grains of sediment soil. It is attempted to portray grain size distribution of the sediment soil at WadiArar. Therefore, the study area is carefully chosen to represent a key sector of soil grains content due to urban expansion in Arar's city. Also, the present study is concentrated on the part of WadiArar for probably used in future constructions, Figure 2.

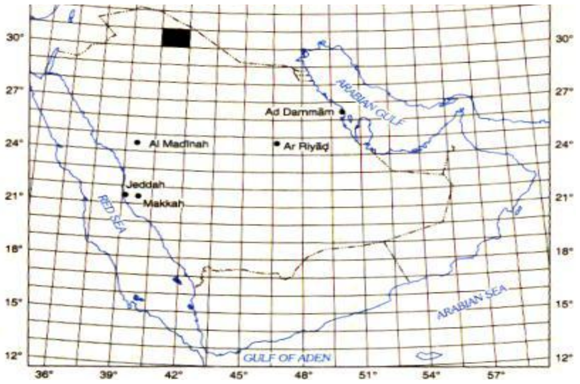

Figure 1: Index Map of Saudi Arabia

Figure 2: Topographical Plan of Arar's City and WadiArar

FIELD DESCRIPTION

Landsat images, geological maps, geo-graphical and topographical maps of northern border region were used to adapt the study area of WadiArar. According to that, a network stations were selected to cover the studied area. An experimental program was designed to investigate grains size and physical properties of the natural surface soil layer. According to the urbanization of Arar's city, the study area of WadiArar was chosen as shown in Figure 2.Where, the study area 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 Figure 3, depending upon the drainage pattern and the possible changes of soil grains. Where, the grain size distribution is the reflection of the sedimentation process and its environment deposits. The probably changes of grains contents may be occurring at soil sediment locations of the adapted cross-sections. Therefore, the chosen cross-sections were adopted. Where:

- Cross-section A was adopted according to the presence of catchment area of Sha'ib Mu'ayyilahand WadiArar. The measured length of cross-section A is about 1500 m.
- Cross-section B was chosen due to the change of Wadipath direction. The distance between cross-section A and cross-section B is about 3500 m and the length of cross-section B is about 1050 m.
- At distance about 1900 m from cross-section B, cross-section C was adopted due to the meandering of Wadi path direction. The measured length of cross-section C is about 1400 m.
- Cross-section D was chosen due to the change of meandering of Wadi path in the vice of meandering path at cross-section C. The distance between cross-section C and cross-section D is about 3750 m and length of cross-section D is about 1900 m.

- At 4700 m from cross-section D, cross-section E was adopted due to the presence of meandering at Wadi path and another path of Wadi around the mound. Cross-section E length is about 3000 m.
- Cross-section F has a straight path. Also, grains move from Al-Awshari Sha'ib to sediment in WadiArar. The distance from section E to F is about 4500 m and the length of cross-section F is about 1500 m.
- Due to the meeting area of WadiArar with Wadi Ghurabah, cross-section G was adopted. The length of cross-section G is about 3000 m and the distance to cross-section F is about 4000 m.

Figure 3: Topographical Plan of the Studied Area of WadiArar

SOIL SAMPLING AND TESTING

Soil sampling points were chosen to obtain soil samples, as indicated in Figure 4 for cross-section G. Where, soil sampling points are 3, 3, 3, 3, 5, 3 and 4 at cross-sections A, B, C, D, E, F and G respectively. Two natural soil samples were obtained from each soil sampling point. First one was obtained from the surface of natural sediment of soil layer, i.e. from the top 10 cm of surface soil layer. The second sample was obtained from the depth of 60-80 cm below the first one. Accordingly, 48 soil samples were obtained. The considerations were attended for soil sampling such as: (a) coordinates of soil sampling point were recorded using GPS, (b) manual excavation to obtain the natural soil samples, and(c) field report contains visual inspection, color and odor of soil samples were recorded.

Coding reference for each soil sample includes cross-sections letters, soil sampling point's numbers and soil sample number. For instant, soil sample number G3-2 means that soil sample at cross-section G and at soil sampling point 3, then, the soil sample number is 2. By the end of soil sampling, soil samples were transported to soil mechanics and foundation engineering laboratory, faculty of engineering, Northern Border University.

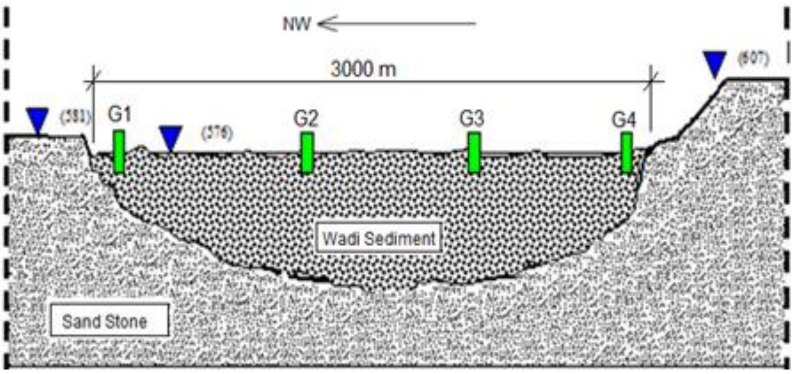

Figure 4: A Schematic Sectional Elevation of Cross-Section G Contains Levels and Soil Sampling Points

Sieve analysis test, Pycnometer test, Atterberg's limits were carried out on soil samples based on the manner of testing and measuring in text books, such as Bowels [12]. Also, international standard specifications for testing and measuring were taken into considerations, such as AASHTO [13] and ASTM [14].

RESULTS ANALYSIS

Grain size distribution curves of studied soil samples at the adopted cross-sections of WadiArar are plotted and summarized in Figure 5. Also, maximum, minimum and average grain size distributions are represented in Figure 6. In addition to that, the measured physical properties of the studied soil samples are recorded in table 1 and table 2. Based on grain size distribution curves and the measured physical properties of soil samples at the studied area of WadiArar, it is noticed that:

- The maximum passing percent (% Pass) are concentrated at cross-sections E and G, while, the minimum passing percent are appeared at cross-sections F. It means that the highest contents of fine grains are sediment at the area around cross-section E and G, but, the highest contents of coarse grains are sediment at the area around cross-section F. Also, the soil grains distribution trends are approximately similar.
- Sand grains are extremely the main content of sediment soil in wadiArar. Where, the highest content of sand grains is 68%, the lowest is 42% and the average is about 54%. While, fine grains are the second by average content 30%, but, the highest content is 48% and the lowest 8%. Accordingly, gravel grains content is the last by average content 16%, while, the highest content is 44% and the lowest is 4%.

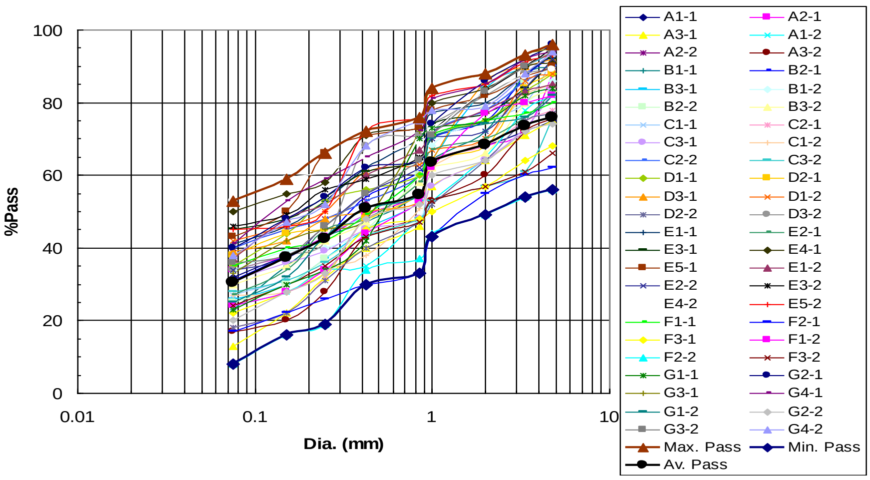

Figure 5: Grain Size Distribution Curves of Studied Soil Samples in WadiArar

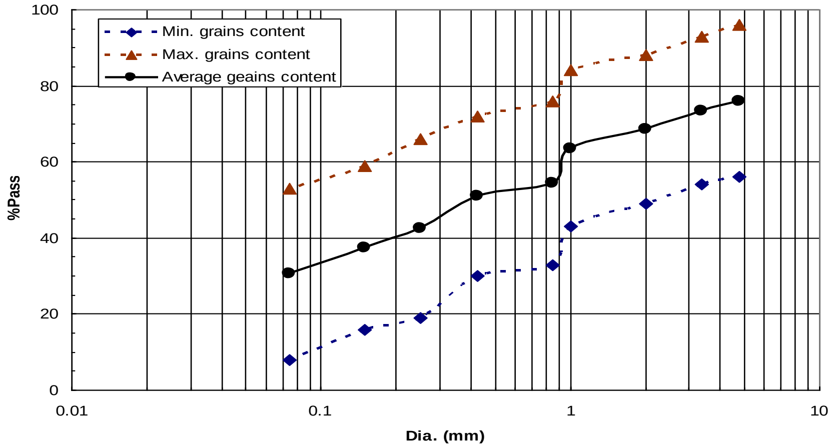

Figure 6: Maximum, Minimum and Average Grain Size Distribution Curves of Soil in WadiArar

Table 1: Soil Grains Content at the Studied Area of WadiArar

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 WadiArar

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**		

- 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 specific gravity is 2.67.
- The highest value of natural moisture content (w_n) is 6.4%, the lowest w_n is 2.6% and the average w_n is about 4.5%. On the other hand, the average value of liquid limit (LL) is 28%, while the highest LL is 36% and the lowest is 23%. Additionally, the average measured plastic limit (PL) is 25%, but, the highest value of measured PL is 28% and lowest PL is 23%. Accordingly, the values of plasticity index (PI) are small depending upon the values of LL and PL. Then, the plasticity of soil sediment at WadiAraris small and can be neglected. Consequently, 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 classification of soil at the studied area of WadiAraris silty sand and the soil symbol is SM. In addition to that the classification of fine grains is silt with low plasticity (ML) according to the results of LL, PL and PI.

DISCUSSIONS

Unquestionably, the environmental deposit plays a significant effects on grain size distribution, grains content and physical properties of the soil. In WadiArar, the soil grains are approximately uniform through most cross-sections except cross-sections E and F which have difference of soil physical properties. 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 WadiArar attributes to the presence of Sha'ib Al-Awshazi. It is known that the sedimentation of gravel grains is faster than other soil grains. Therefore, the gravel grains are less than that of soil at cross-section F. Sand grains contents are mostly common grains in the studied of WadiArar. The grading of sand grains is expressed in empirical formula according to William et al [15] and by using Microsoft Excel program. The functions were used to find the best formula to express grading of sand grains in WadiArar. By using powerful of the exponential form, the first function formula can be expressed as the following:

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

Where, Y represents %Pass of soil grains, X is the grains passing diameter (measured by mm), while, A and B are constants depending upon soil grains content of the tested soil sample. A and B variations are recorded. By counting A and B as a result of fitting forty-eight (48) grain size distribution curves, 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 about 58.8, (b) the highest value of B is 0.44, the lowest is 0.13 and the average value of B 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 less than 4%.

The second function using logarithmic of the exponential form can be expressed as the following:

$$Y=A.\ln(X) + B \quad (2)$$

Where, Y represents the passing percent (%Pass) of soil grains, X is the grains passing diameter (measured by mm). While, A and B are constants depend on soil grains content. According to the variations of grain size distribution curves, Figures 5 and 6, the values of A and B were obtained. It is obvious that: (a) the highest value of A is 18, the lowest A is 9, while, the average value of A is 13.5, (b) the highest value of B is 76, the lowest 40 and the average value of B is 62.8, (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 3.65%.

Fine grains are considered the second content of grains, after sand grains, for soil sediment in the studied area of WadiArar. Where, the highest value of silt grains is 48% at cross-section E and the lowest value is 8% cross-section F depending upon the surrounding environment soil of grains sedimentation. That is the confirmation to the aforementioned discussion, where, the fine grains contents are attributed to flowing speed of deposit and types of soil grains coming from other Sha'ibs. 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, specific gravity 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, specific gravity (G_s) results indicate that the sediment of soil grains in WadiArar is deposited from the same source of rocks.

Otherwise, it was observed that the natural moisture content (w_n) is correlated with fine grains content in the oboist relation. Where, if fine grains content decreases water content (w_n) increases. It is clear that w_n in the ranged from 2.6% to 6.4% as well as the value of fine grains is ranged from 8% to 48% respectively. It is generally known that w_n values are depending upon: (a) the adsorbed water by soil grains from atmosphere, (b) the humidity in the region and (c) type, size and surface area of soil grains and soil particles. Mostly, w_n of soil in the desert areas is considered hold adsorbed water, i.e. soil grains surface water. Moreover, the values of w_n of soil studied area are in normal values and agree with that mentioned by Lee [16] and Bowels [12].

Similar to that mentioned about w_n, it is noticed that the values of liquid limit (LL) are correlated with fine grains content. Where, liquid limit in the ranged from 23% to 36% as well as the value of fine grains content is ranged from 8% to 48% respectively. It is noticed also that 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. On the other hand, it is clear that the values of measured plastic limit (PL) are correlated with fine grains content and LL value. Where, the measured PL are in the ranged from 23% to 28% as well as the value of LL values more than 30%. It is clear also that the highest PLis 28% for soil at cross-section E4-2 which have 48% fine grains content and LL is 36%. While, the lowest measured PL is 23% for soil at cross-section G which have 35% fine grains content and 32%LL. It is clear that the measured PL values are approximately near LL value. Therefore, plasticity index (PI=LL-PL) value is low.

Additionally, plastic limit cannot be measured for some soil samples which have low liquid limit values (less than 30%).Also, shrinkage limit (SL) cannot be measured for all soil samples because the soil specimen was broken into many weak pieces. Where, the soil specimen was cracked, broken and lost water quickly is attributed to the low values of LL and plasticity. In the point view of construction engineers and quality control engineer, the soil in WadiArar is not suitable as a cementing material product. Regardless to chemical properties of soil, the soil grain size distribution is not agreed with that mentioned and approved by international standards and specifications such as AASHTO [13] ASTM [14].

CONCLUSIONS

The studied are of WadiArar is about 22 km length. Landsat image, topographic maps and geological maps were used to recognize the studied area. Soil samples were taken through 7 cross-sections, then, laboratory tests were performed. The obtained results were recorded, analyzed and discussed. According to that the following conclusions were obtained:

- WadiArar is classified as a middle course of river, nature age with U-shape valley, lateral erosion, flood plain and meanders OX-bow Lake. It is considered as the main Wadi in Arar's city. Many sides Sha'ibs meet with WadiArar.
- The soil in WadiArar is considered transported soil. The sediment soil in WadiArar is classified as silty sand (SM) as unified soil classification system (USCS) and fine grains with low plasticity.
- Sand grains are extremely common grains in the soil studied area of WadiArar and average sand grains content is about 54%. Empirical formulas are expressed as a relation between grains size and grains content in the sediment soil.
- Fine grains which classified into silt soil type are the second grains content of sediment soil and the average content of silt grains is about 30%. Fine grains are classified as low plasticity silt.
- Gravel grains contents are almost less than other soil grains at WadiArar and the average content of gravel grains is about 16%.
- The values of specific gravity (G_s) are approximately closed and the average value of G_s is 2.67. But, some of soil samples have a little increase or little decrease of G_s about ± 0.04.
- 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. Where, the average $w_n$is about 4.5%.
- The highest value of LL is 36%, the lowest is 23% and the average is about 28%. Consequently, plastic limit (PL) cannot be measured for soil which have liquid limit less than 30%. While, the measured plastic limits (PL) is approximately closed values and the average PL is about 25%. Also, shrinkage limit (SL) cannot be measured.
- No plasticity for soil which have liquid limit less than 30%, but, others has low plasticity according to close values of LL and PL. Where, the highest measured value of plasticity index (PI) is 11% and the lowest is 7%.
- 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%.
- WadiArar 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 WadiArar can be used safely to support many constructions. Also, the soil is suitable for using as filling, base

and subase material.Continuing this study on the present grain size distribution and physical properties of soil in WadiArar that has shown, more in-situ and laboratory studies are required.

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