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Stability of River Branch (Creek) Banks in Khor Al-Zubair Area, NW Arabian Gulf

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ABSTRACT

The study area is located at the middle part of Khor Al-Zubair, NW the Arabian Gulf. Thirty-six samples were selected from six stations in the study area, six samples from each station, at the depth of 0.5m from ground surface. Distances, elevations and inclinations were measured in four traverses in the study area.

Mud corer and hand Auger tools, and level device were used for this purpose. The laboratory tests included direct shear test, moisture content, bulk & dry densities, consistency limits, grain size distribution and clay activity tests. Office calculation and computer programs were used to evaluate the bank stability.

The field measurements show low inclination angle of each bank about (18.50). Laboratory tests results indicate moderate value of cohesion 24-37 kN/m^2 with zero value of internal friction angle. The moisture content is between 38-68%, bulk density is 1100-1900 kg/m^3 and the value of dry density varies between 700-1200 kg/m^3. Consistency limits results show that the soils have high plasticity according to the USCS classification. Liquid limit values are between (55-64%); plastic limit and plasticity Index values are about (25-30%) and (26-40%) respectively. The soils classified as a Silty Clay, the sand content is less than (1%), Silt and Clay contents value varies between (41-56%) and (44-59%) respectively. Clay Activity is (0.47-0.73), which indicates that the soils are inactive clay. The sediments appear high cohesive, the high moisture content could be related to immersing all times and also to high content of clay fraction. The high content of fine-grained sediments conducts to rend the soil to be high plasticity, more moist, high cohesive and inorganic. The cohesive appearance of the soil in the area and the low inclination angle decrease the failure ability of the banks. The calculations proved that the factor of safety was more than one in each traverse, in spit of the tide phase.

KEYWORDS: Geotechnical Investigations; Engineering Geology; Geotechnical Properties; Khor Al Zubair; River Bank Stability; Basra, Iraq, Arabian Gulf.

INTRODUCTION

Study Area

Khor Al-Zubair channel is a semi-closed marine tongue from the Arabian Gulf water, which take the NNW-SSE direction for about 40 km distance and 18 m mid-cannel depth. The width of this channel vary due to tide phase, it may reach 1-2 km at the high tide. Khor Al-Zubair channel extends on a plane topographic area in which the land inclines NS-ward. It branches in the upper (North) end into two branches, which also branch into a lot of tidal branches, which called creeks. Today, this end of the channel was connected with the Almassab Ala'am River by Shatt Al-Basra cannel. The lower (South) end is connected with Khor Abdullah. The study area is located between

(40^o 51' – 47^o53') East and (30^o12' – 30^o-13') North (Fig. 1).

Geology of Study Area

The surrounded areas of NW part of the Arabian Gulf and Khor Al-Zubair waterway are coastal areas extend from the sea level shore line to an elevation line of

(3 m) above sea level. These areas are relatively low and planner with small lakes in few localities, which composed of Silty and clayey sediments (Kukal &Saadallah, 1973). Some of these clastic sediments are generally transported from surrounded areas, which forms the hard lands rocky cover in the Arabian Gulf (Aqrawi & Darmoian, 1986 and Aqrawi & Evans, 1994).

Khor Al-Zubair Area is one of the main tidal flats in the NW zone of the Arabian Gulf, in which the sedimentological processes are effected generally by the Tigris, Euphrates and Karun rivers (Khalaf et al., 1982 and Darmoian & Lindqvist, 1988). The eastern tidal flats in Khor Al-Zubair are mainly consisting of very fine sediments, which are considered as washed sediment from the flood plains (Albadran et al., 1991). The recent sediment of Khor Al-Zubair and Khor Abdullah are considered as results of the different transport factors with various energies (Albadran & Albadran, 1994).

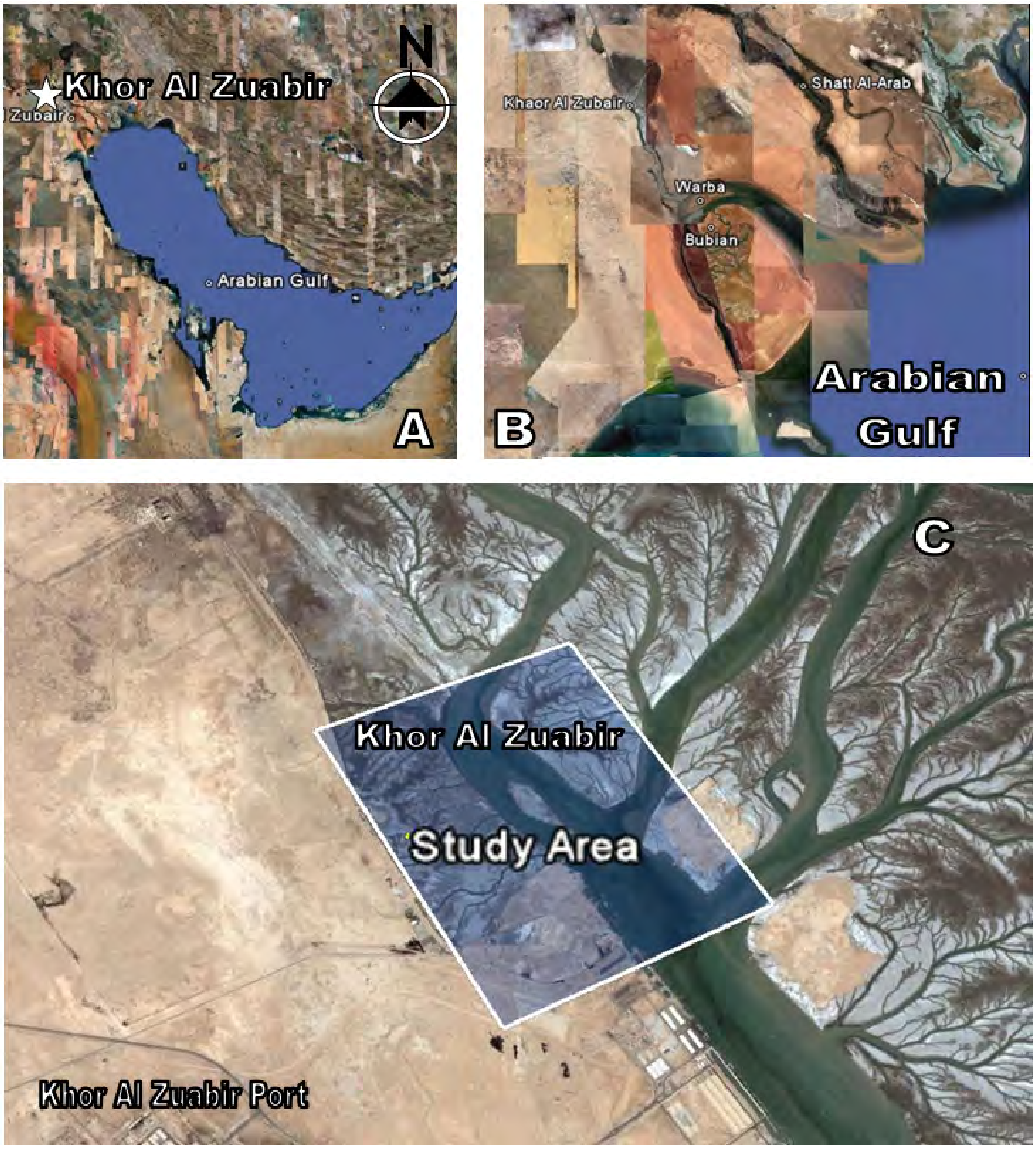

Figure 1: Study area: (A) Arabian Gulf (B) NW of Arabian Gulf (C) Khor Al Zuabir Port

The continental sediments increased during the Pleistocene period forming the Dibddiba Formation, which could be started to form during Upper Miocene. The thickness of this Formation varies from place to place, forming the southern Mesopotamian zone in the unstable platform through Abu-Jir zone in the stable platform, and it continue until it penetrates the big parts of the Kuwaiti lands (Buday, 1980). The coarse sand layers in the West of Khor Al-Zubair and Um-Qaser are the Dibddiba Formation outcrops which can be obtained near the ground surface (Saeedy & Mullah, 1990). The outcrops of Dibddiba Formation appear in the South and South West areas from the stable platform with 4m in thickness along Al-Batin valley, which considered as one of the main valleys of the West part surface in Basra. This valley poured its suspension sediments in this region, so it diffuse in the low lands with triangular silty fan shape which its origin go back to Pleistocene-Holocene Periods. The triangle base is in south of Al-Hammar marsh to the West of Khor Al-Zubair. Marine sediments cover most of Dibddiba Formation and Al-Batin fan especially in its lower lands and valleys, in the Southern Mesopotamia, these sediments form the recent Hammar Formation which its thickness is about 6-8 m, and contains micro mixed-marine shells dominated by Foraminifera and Ostracoda (Aqrawi, 1995). Hammar Formation overlaid by recent stream sediments in the unstable platform, it consist of silt and clay, which was brought by the Tigris, Euphrates, Shatt Al-Arab and Karun streams beside the windy sediments (Saeedy & Mullah, 1990).

Through the geological history, the Arabian plate has been treated with a lot of tectonic events, especially the continuous subsidence process, which occurred many times during the history of marine deluge. So, in the upper Miocene, despite the stable progress of the regional sea level, a lot of Formations were deposited, such as Upper Fars (Injanah) Formation and its equivalent such as Dibddiba and lower Bichtiary (Meqdadia) Formations (Sharland et al., 2001).

The coastal areas in the North of the Arabian Gulf were also treated with continuous subsidence process that results the non-progress of it above the sea level. The sediment load and the recent tectonic movements are the governing processes in the coastal area. The period from the Pleistocene beginning to date, about 1.5 M.Y, was characterized by relatively light land movements which were the continuous of the latest movement of Albians (Jones, 1986). The Formation of Khor Al-Zubair could be related to fault occurrence with tectonic subsidence extended from decline area extended from Al-Hammar marsh to the end of Khor Al-Subiia during Wurm glaciation period (70-17 T.Y) (Al-Mussawy, 1991 and Yaseen, 1998). According to classification, Khor Al-Zubair has been located in the Sagged basins of the Mesopotamian zone of the quasiplatform foreland (Numan, 2001).

Khor Al-Zubair area was affected from its Formation until today by many changes of its water quality and sediments etc. by the influence of many factors such as factors that related to erosion, sedimentation, recent tectonic activities and sea level change (Kassler, 1973 and Al-Mussawy, 1993). In the last stage (1000 year ago to1983), when the Shatt Al-Basra cannel was opened, and it is connected with Al-Massab Al-A'am project the Euphrates run changed its waterway, that made Khor Al-Zubair to be considered as longitudinal Beach Lake extend on marine tongue shape land ward
(Al-Mussawy, 1991). And now Shatt Al-Basra cannel was connected with Khor Al-Zubair, and the late came back as a channel in which the marine water mix with the river water.

METHODOLOGY

To evaluate the geotechnical properties and the banks stability of the study area, 36 undisturbed core samples were selected from 6 stations in the study area (6 samples from each station) at the depth of (0.5m) from ground surface (fig. 2). Mud corer and hand Auger tools were used for this purpose. Four traverses were chosen perpendicular on the two opposite banks to evaluate the bank stability. Distance, elevation and inclination of the banks in each traverse were measured by using Level device. (Alainachi, 2003).

Figure 2: Layout Showing the Gauging Station and Measurement Traverses

Laboratory tests program has been done which included direct shear test, moisture content, bulk & dry densities, consistency limits, grain size distribution and clay activity tests.

The shear strength test considers as a most important engineering test for soils. The method of quick undrained direct shear test (Head, 1982), have been used for this purpose by using the Shear box device. The Gravimetric moisture content method was used to determine the moisture content. The ratio between the sample volume and weight on the natural state and after the drying of the sample was the method, which have been used for determining the bulk density and dry density respectively. The consistency limits were determined by using the method which were described in Head (1980), such as cone penetration method for determining the liquid limit and the Cassagrande fibers for determining the plastic limit. The Plasticity chart was used to determine the plasticity index according to the Unified soil classification system (USCS) as shown in (ASTM D2487-83). The soil type was classified according to Shepard (1954) in Pettighon (1975) classification. The Clay Activity was calculated according to the equations that shown in Head (1980).

According to Rosenak (1963) and Bell (1980), Swedish method and Bishop simplified method, were used to analyze the bank stability.

RESULTS

The average of the results of the laboratory tests of each station can be obtained in (Table 1).
The fieldwork shows that the banks have relatively low inclination (not more than 18.50).
The results of the distance and elevation measurements for each traverse can be obtained in (Table 2).

After using the previous methods to analyze the stability in high tide and low tide phases, and the factor of safety was calculated to be in each traverse as can be obtained in (Table 3) by using the computer program which proposed by Milligan & Houlsby (1980).

Table 1: The result average of the laboratory tests of the stations

St. No.	τ kN/m^2	C kN/m^2	∅ Deg.	M.C %	γ_b g/cm^3	γ_d g/cm^3	L.L. %	P.L. %
1	34	34	0	56	1.5	1.0	60	27
2	27	27	0	46	1.8	1.2	62	26
3	29	29	0	46	1.8	1.2	57	27
4	31	31	0	64	1.3	0.8	57	29
5	26	26	0	41	1.6	1.1	62	27
6	26	26	0	40	1.6	1.1	62	27

St. No.	P.I. %	S.T	S %	M %	C %	C.A	Class.
1	33	CH	<1	47	53	0.61	Silty Clay
2	36	CH	<1	48	52	0.73	Silty Clay
3	30	CH	<1	55	45	0.67	Clayey Silt
4	28	CH	<1	41	59	0.47	Silty Clay
5	35	CH	<1	50	50	0.71	Silty Clay
6	35	CH	<1	50	50	0.70	Silty Clay

where

τ : Shear Strength (kN/m^2) **C :**Cohesion (kN/m^2)
∅ : Internal friction angle (Deg.) **M.C.:** Moisture Content (%)
γ_b : Bulk Density (g / cm^3) **γ_d**: Dry Density (g/cm^3)
L.L.: Liquid Limit (%) **P.L.:** Plastic Limit (%)
P.I.: Plastic Index (%) **S:** Sand Content (%)
M: Silt Content (%) **C:** Clay Content (%)
C.A.: Clay Activity
S.T.: Soil Type According to USCS
Class. : Soil Type according to Shepard 1954 classification

Table 2: The result of Distance and Elevation measurements of the traverses

Dis. (m)	Elev. (m)	Dis. (m)	Elev. (m)
Trav. 1		Trav. 2	
0	0	0	0
4	-0.075	6	-0.19
9	-0.04	12	-0.59
15	-0.025	16	-1.27
20	-0.655	18	-1.5
24	-1.27	25	-1.72
Trav. 3		Trav. 4	
0	0	0	0
9	-0.7	10	-0.9
16	-0.86	17	-1.0
18	-1.03	20	-1.12
23	-1.37	25	-1.4
26	-1.66	28	-1.8
32	-2.2	34	-2.8
34	-2.91	36	-3.3

Table 3: The values of Factor of safety by using Swedish and Bishop methods in the high and low tide phases in each traverse

Tide Type	$F_{S.M}$	$F_{B.M}$
	Trav. 1	
High Tide	1.63	1.63
Low Tide	1.63	1.63
	Trav. 2	
High Tide	1.78	1.78
Low Tide	1.78	1.78
	Trav. 3	
High Tide	1.53	1.53
Low Tide	1.53	1.53
	Trav. 4	
High Tide	1.65	1.65
Low Tide	1.65	1.65

DISCUSSION

To predict the bank stability, it is necessary to evaluate the effects of disturbing forces and resisting forces. The instability of riverbanks, is not only related to the effects of runoff water and the waves activities, it depends mainly on the geotechnical properties of the bank materials. The bank height and the materials engineering characteristics can be considered as a control key for the bank retreat (Sowers, 1979). From these characteristics, balanced analyze methods can be used to determine the dimensionless factor of safety, which define the stability for expecting failure surface in a bank slope (Albadran, 1987).

From previous results, it may be obtained that the values of the engineering properties of stations were close, which means that the area is generally with similar characters. The influence of the engineering properties over each other is clear so we can not segregate between their influences

The sediment of the study area consists mainly from fine-grained sediments. It was obtained that the sand contents were less than (1%) in each station. The silt and clay contents vary between (41-55%) and (45-59%) respectively, and could obtain the sovereignty of the clay content on the sediments of most stations (Fig. 3). These materials can be considered as washed sediments from the flood plains (Albadran et al., 1991).

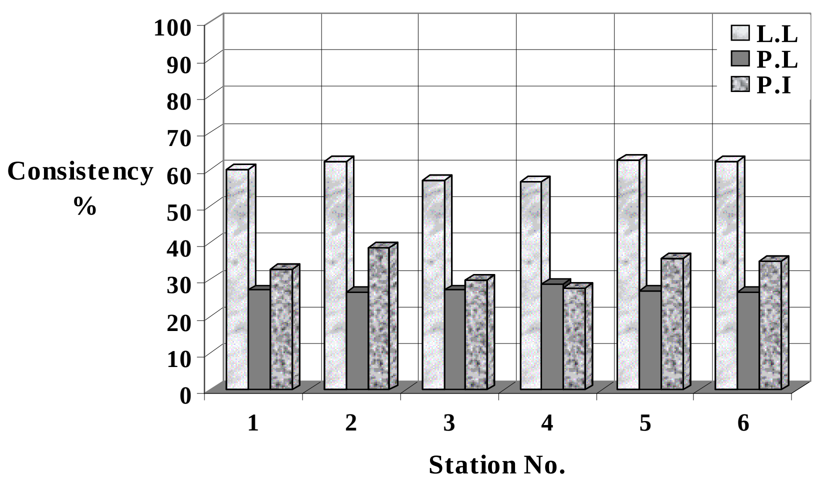

Figure 3: The relationship between the consistency limits

The direct influence for these clays on the geotechnical properties of the study area can be obtained from its ability of possessing large quantities of water, which was shown by the high moisture content of the sediments (40-64%). This feature decreases the sediment strength against any stress, and conducts at the end to softness on sediment layers (Powers, 1981).

The shear strength values were moderate (26-34 kN/m^2). The internal friction angel was zero in all stations, which correspond with the results that were shown in (Saeedy & Mullah, 1990 and Albadran & Albadran, 1994). The reason of that may relate to the high clay content on the area. Generally the cohesion values which were determined in the study area can be consider as moderate values. The soils of high moisture contents are mostly cohesive soils with low internal friction angle (Bell, 1980), thus the moderate values of the cohesion and zero values of the internal friction angle of the study area may be related to the high clay and moisture contents.

The high contents of clay execute preservation of high quantities of water, which increase the liquid limit. The plastic limit indicates the soil ability of changing size because of the moisture content (Mahmood & Albadran, 2002). The silt content is (48%) as average, it is more effective on the decreasing of the liquid limit (Albadran, 1986). Although the liquid limit values let the soil a high plasticity with plastic limit values of (26-29%). No remarkable differences in the consistency limits between the stations (Fig. 3). The high silt content in the sediment may also result to increasing the permeability and decreasing liquid limit and capillary property (Hunt, 1984). According to USCS classification, the study area's soil was of the inorganic clay with high plasticity type (CH), the liquid limit was between (57-62%). This classification is similar to the results that were obtained by Wassel (2003), in which the organic matter ratio on the study area sediment was between (0.09-0.48%) with (0.35%) average, and according to Mahmood (1997) the study area sediments are of ineffective organic content.

The soil densities moderate (1300-1800 kg/m^3) with (1550 kg/m^3) as average, and it is in the typical values for such soils (Al-Khateeb, 2002). This value is an indicator of the increasing of clay content. The soil of high clay or silt content have usually less bulk density than the soils of low content of fine grains (Jones, 1983), and that which was seen in the study area. The dry density values were obtained in the study area between (800-1200 kg/m^3), this could be related to the increase of the clay content (Al-Shayea, 2001).

The clay activity is between (0.5-0.72) which indicates, according to Head (1980), that most of the soils in the study area are inactive clayey. The clay activity values on the east bank of the study area were less than that in the west bank. This could correspond to the decreasing of the soil plasticity index on the east bank comparatively with the west bank according to the relationship between the plasticity index and the quantity of clay colloids which was point out by Skempton (1953).

The study area soil, as shown previously, is cohesive. Thus the stability analysis was evaluated by using slices methods, which are used mainly for cohesive soils, with rotational failure surfaces. The factor of safety values are in each traverse more than one, which means that the banks are stable, due to the resisting forces (cohesion and internal friction angle) dominated on the driving (disturbing) forces. The low inclination angle (18.5O) may be related to the fact that the study area is a tidal flat, so it may be a target for wash and drift with continuos movements of high tide and low tide during previous periods, until it became to this geomorphological feature.

The most important factors in bank stability evaluation are the cohesion, internal friction angle and density for bank materials. The zero value of the internal friction angle had a great effect in the calculation of the factor of safety, so that the factor of safety value didn't effect with the change in pore water pressure even in high tide or low tide. The moderate values of cohesion increased the bank stability in the study area, because it is the main factor in the stability equation in this study case, therefore it acts the only resisting factor with the absence of the internal friction angle, which can help in decreasing the stability. In addition to the low value of bulk densities, this also helped in increasing stability, by decreasing the weight effect of each slice.

Actually, the low banks in the study area was relatively stable under the conditions of moderate cohesion, in spite of the effect of the runoff and waves that generated by winds and the boats motion. It is possible to say that the present status for the banks is finally collector of stability after a period of high inclination angle according to a lot of references, which indicated that Khor Al-Zubair was a continuous fault for the Euphrates fault (Al-Mussawy, 1993).

CONCLUSIONS

The high water content in the study area could be related to the immersing of the sediments by the Gulf salt water. The main constituent is the fine-grained material of silty clay. This high content of fine-grained sediments conducts to rend the soil to be high plasticity, more moist, high cohesive and inorganic.

The cohesive appearance of the soil in the area and the low inclination angle decrease the failure ability of the banks. Bank stability evaluation indicates that the banks are stable.

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