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Research Article

Pilling Design in the Continental Shelf of Suakin, Red Sea, Sudan

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Abstract: The continental shelf of Suakin characterized by high accumulation of sediment due to the high ratio of sedimentation of these sediments are alluvial, sand, silt muddy silty stone were driven by drainage system pattern in surrounding areas. The coral reef limestone was highly weathered buried beneath the alluvial deposits. The overall objective of this study is to Pilling foundation design in the near shore zone through mixed marine deposits for gas/oil terminal construction. In this study Full-Scale Pile-Test is the best applicable method for taking site specific parameters into consideration. The adhesion value was neglected because it is very small in marine environment comparing with pile capacity and effective stress and surrounding soil condition. The settlement obtained to laboratory tests and the consolidation index was used for predication which is between 3.0 -11.5cm.

Keywords: Suakin, Pilling foundation, Karts formation, and Stander Penetration Test

INTRODUCTION

Areas between Red Sea bed and coastal plain in the Sudan are definitely less stable needed details and intensive investigation to avoid damage of heavy constructions such as harbors, oil and gas production terminals and pipeline. Very few geotechnical publications had been done in contrast, hazard map for engineering purposes planning and\or development never take any researcher interest. However Forth *et al*. [1] discussed the degree of influence of ten important factors of the hazard forming processes in Karts formation. Al-lmam [2] investigated the geotechnical properties of mixed of marine sediments on continental shelf and onshore pilling designation.

The fringing reef at Suakin is isolated on the north side of the harbor and characterized by gentle slope reef terrace and the sharp undercut cliff-face. The sea floor within the reef areas in the continental shelf consist of sloping face of 2-3m depth, punctuated by roughly circular and elongated depressions creating coastal lagoon, some of them reach 50-70m depth. The alluvial deposits reach the sea bottom hydrologically and mixed with marine reefal sediments. The distribution of these sediments controlled by surface bottom morphology.

LOCATION AND SAMPLING

Suakin is and old harbor developed to be an important port in the Sudan. Is located between 19.097301°, 19.122539°N,37.354663°,37.326367°E and about 60km south Port-Sudan (Fig. 1).

Rotary x-y rig on platform was used for drilling. The thick wall sample of 89mm, length is 200mm and weight of auto-hummer is 63.5kg with length of 810 mm. Drop distance is 760mm, tube 51m and the penetration per 300mm. The site was divided to three profiles each one consist three boreholes. One borehole for sampling and the other for identification (Table 1).

Objective

Pilling foundation design in the near shore zone through mixed marine deposits for gas/oil terminal construction.

Stratigraphy

There are not significant variations in the stratigraphy between boreholes. Profile I (Fig. 2) shows three types of facies: alluvial, muddy silty stone and coral reef limestone. The alluvial Layer increasing in thickness from 6.3 m to 24 m towards the east and the coral reef limestone appears as intrusive cutting short layer through muddy silty stone layer but not reach S_1BH-3.

Profile II (Fig. 3) characterized by appearance of medium sand, silt and thick alluvial layer of 24m on average. Intercalation of sand and silt in S_2BH-1 located between two layers of coral reef limestone. The Intercalation of sand and silt in S_2BH-2 between 22m of alluvial layer at the top and 2.0 m of muddy silty stone at the bottom. The average thickness of all lenses is 2.0 m in S_2BH-3 a muddy silty stone Layer of 6.0m thick overlain by 5.0m of coral reef limestone.

Profile III (Fig. 4) is very simple consist of one type, which is alluvial facies characterized by thickness from 10 m in west and 17.0 m in east. Only 2.0m silty lens in S_3BH-1 at 14.0m depth.

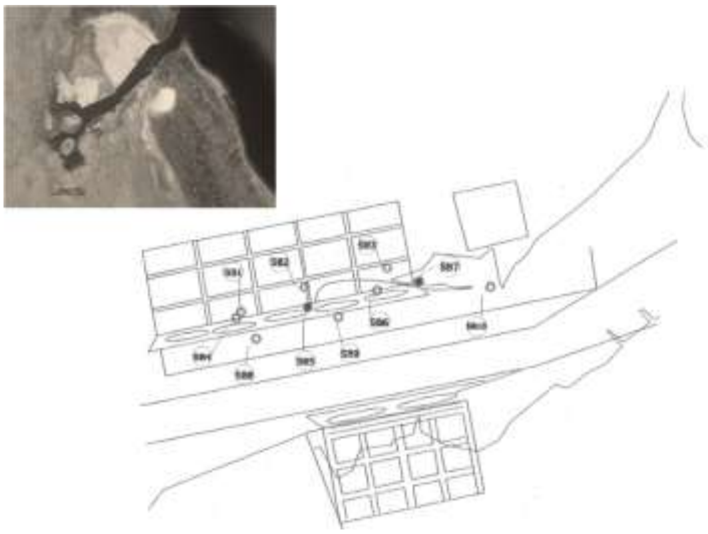

Fig.1: Location map of Suakin boreholes

Table1: Profiles and boreholes locations

Profile No.	BH No.	BH type	Depth(m)	Elevation (m)	Location coordinates	
					D(m)	C(m)
Profile (S_1)	S_1 BH-1	Sampling STP	12.40	-9.10	10310.80	9890.70
	S_1BH-2	Sampling STP	31.90	-0.30	10280.60	9999.60
	S_1BH-3	Sampling STP	28.60	-0.50	10258.50	10110.80
Profile (S_2)	S_2BH-1	Sampling STP	22.90	-2.20	10315.80	9905.60
	S_2BH-2	Sampling STP	29.10	-1.20	10301.50	10007.00
	S_2BH-3	Sampling STP	24.30	-9.40	10283.40	10126.20
Profile (S_3)	S_3BH-1	STP	8.80	-9.40	102272.60	9904.60
	S_3BH-2	STP	13.80	-4.50	10247.20	10034.70
	S_3BH-3	STP	16.05	-2.00	10228.60	101179.80

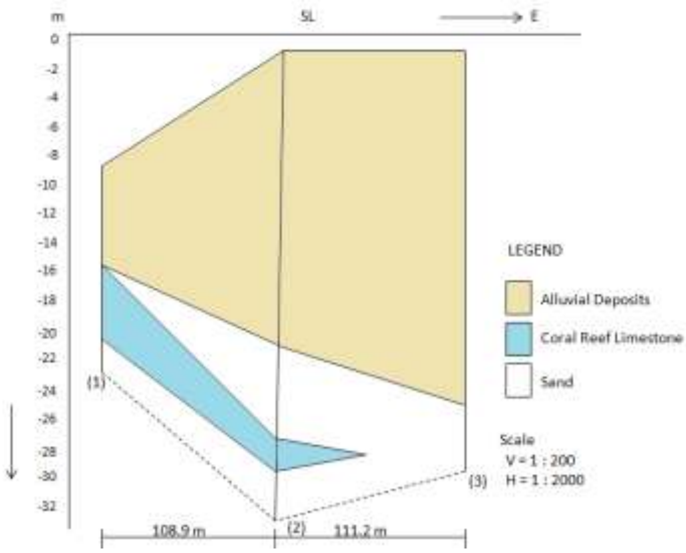

Fig. 2: Stratigraphy according to facies, profile I, borehole 1 to 3

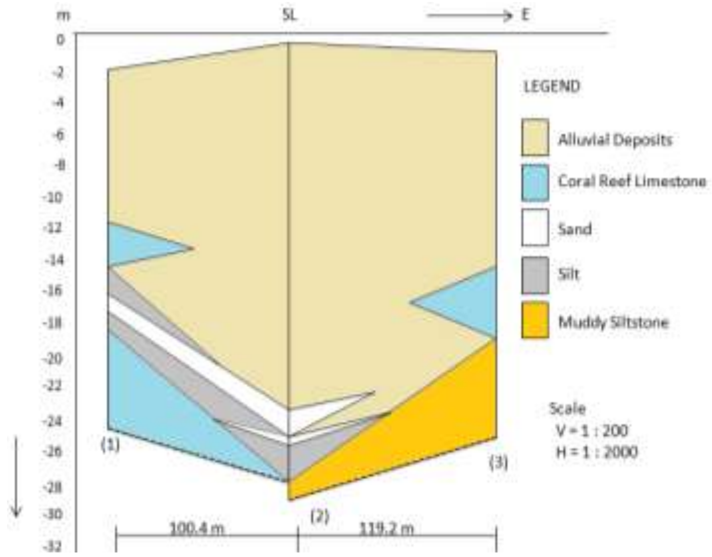

Fig. 3: Stratigraphy according to facies, profile II, borehole 4 to 6

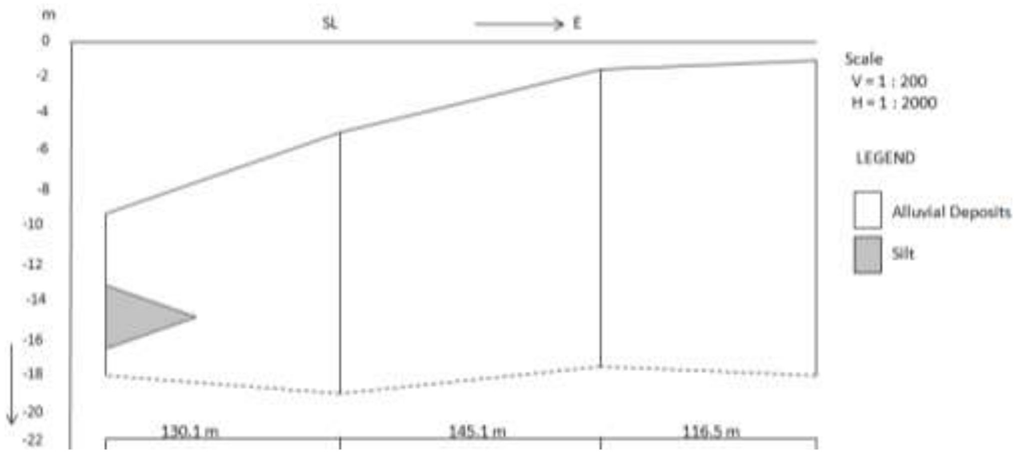

Fig. 4: Stratigraphy according to facies, profile III, borehole 7 to 10

METHODS

Piles used near shore and offshore zone are usually open and pipe pile can be easily applied, offer a good strength to weight ratio, minimize soil disturbance during installation and minimize driving resistance [3]. According to type of facies and stratigraphical formation the insert-pile technique can be used. Deferent methods possibly can be applied such as conversional theory which recommended by Mc Corel SC and Beard RM [3], Agarwal *et al*. [4] and Datta [5]. In this study Full-Scale Pile-Test is the best applicable method for taking site specific parameters into consideration.

Designation

Safety factor

Practically safety for an end-bearing and over load fallowed the equation:

$Q_{ult}/2$ for pile

And Q_{ult} for the shaft + $Q_{ult}/3$ for the base.

Tomlinson [7] decided a safety factor of 2.5 on the ultimate load as an average of base resistance and skin friction but in this case 3.0 had been taken as average.

Settlement

The consolidation settlement (P_c) should be predicted in the laboratory for (e-p) curve designed using equation:

$$P_{old} = {}^{H}\!/_{1 + e_1 (e_1 - e_2)}$$

Or by using the consolidation index (C_c) by using equation:

$$= {}^{H}\!/_{1 + e_1 \times log_{10} P_0 + {}^{\sigma_z}/_{P_0})}$$

Load Test

Consider that the total test load should be 20% of the proposed design load and 25% increasements applied to the pile [6]. Consideration of conditions of surrounding soil should be encouragement. However, Tomlinson [7] reported that, increasing the size of the base will not reduce the settlement.

Skin Friction

In marine environment, submerge calcareous soil act as slurry around the pile and reducing the frictional resistance while driving. By time, water and fine silt settles around the pile causing increasing of friction resistance. However, in such soil carry high load if time is allowed after driving.

The unit negative skin friction force at any depth can be calculated by Meyerhofe's equation:

$$f_{sneg} = \beta P_0$$

Where, β is reduction factor equal 0.2 for pile up to 40m long as same as in this study and Po is the effective overburden pressure.

The constant of proportionality is called (β) coefficient.

It is a function of the earth pressure coefficient in the soil (K_s).The ratio of the all friction: M=tanØ/tanØ [8]. Thus, the negative skin friction (q_n) follows the equation:

$F_{sneg}=q_n= BP_o=MK_s \tan Ø$ where: $M=P_o$

Load Capacity

Piles used to resist lateral load or uplift force. In such soil the skin friction increasing with depth down to critical depth, beyond which it remains almost constant. The load transfer mechanism between the pile and surround soil governs the behavior of the pile [9]. The adhesion value is generally very small possibly neglected in the calculation of load capacity of pile: $T_{ult} = C_A 2\pi$ RL

Where: C_A = adhesion value, R = diameter of pile and L = length of pile

Comparing with the pile capacity and effective stress and soil condition in marine environment, the value of (T_{ult}) is very small and can be neglected.

Application

Pile specifications: Diameter (D) = 0.9m, length (L) = 2.7.6m, material=concrete.

Soil profile: angle of internal friction (Ø), field density (Υ_{wet}) overburden pressure and critical depth (Z_c).

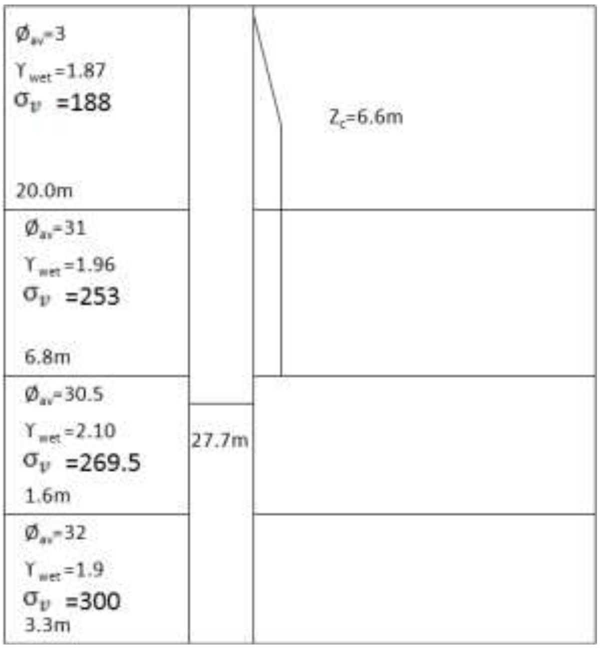

Fig. 5: Near shore soil profile, Suakin

Calculation

The general equation is: $Q = Q_s + Q_p = fA_s + qA_p$

Where: Q_s = Friction term; Q_p = Tip term; and $Q_s = fA_s$ = the load mobilized by the lateral friction between pile and soil, f = the lateral friction stress; As the lateral area of the inserted section of the pile; $Q_p = vqA_p$ =the load supported by the end of the pile; Q_p = the stress of the end of pile and A_p = the cross-section area.

In this case the pull out force of the pile is reduced to the friction term: $Q_s = f'A_s$.

Where (f') is invariable less than (f) and generally assumed f' =0.7f

Base bearing capacity

The unit bearing force of the end of the pile can theatrically be calculated by the following formula; $q = P_oN_q = \Upsilon' z N_q$

Where: P_o =vertical overburden pressure, N_q =bearing capacity factor determined from figure (6), Υ' =apparent density of soil (Υ' - 1), z = depth of insertion pile.

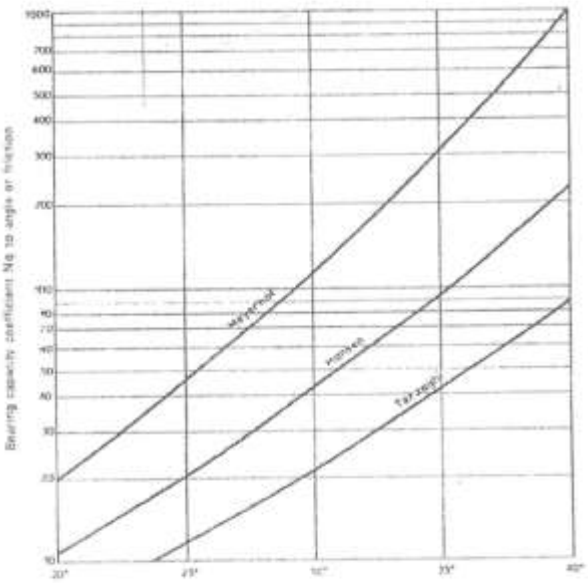

Fig. 6: Nq coefficient for deep foundation, after Pierre Le Tirant [10]

Skin Friction

The equation is: $f = KP_o \tan Ø$

Where: K = lateral pressure coefficient of the soil, P_o =over burden pressure

$Ø' = Ø$ -5 in marine

Then, the values of skin friction of each layer are:

a. 0.7× 8.7 × 20 =121.8 KN/m^2
b. 0.7 × 9.6 × 6.8 = 45.7 KN/m^2
c. 0.7 × 9.0 × 0.8 = 5.1 KN /m2

The sum of skin friction is = 172.6 KN/m^2

Then $Q_s = fA_s$ = 172.6 ×3.14 ×0.9 ×27.6 =13462 KN/m^2

Subtraction the pull out force from the total skin friction:

0.7 × 13462.4 = 9423.7 KN/m^2

Base Bearing Capacity

Q_p = 563.3 × 0.635 =3581.7 KN/m^2.

Then the total bearing capacity is : 358.17+9423.7 = 9781.87 KN/m^2

Divided by safety factor (3) =9781.87 /3 = 3260.6 KN/m^2

= 32.606 Ton / m^2

Load per ton $= \frac{32.606 \times 3.14 \times 0.81}{4}$ = 20.73 Ton

Settlement

The settlement estimated from (e – p) curve and consolidation index (C_c). Each sample has compression modulus (E_d) and laboratory settlement result by using (e – p) curve. The comparison between then in table (2) as fallow:

Sample No.	Lab test (e-p)eq.	Design (cm)	Lab. test (C_c)eq.	Design (cm)
S_1BH-1-1	0.39	0.81	4.14	8.57
S_1BH-2-1	0.42	0.87	1.79	3.70
S_1BH-2-3	0.58	1.20	5.55	11.48
S_1BH-3-1	0.21	0.44	1.54	3.19
S_2BH-6-1	0.31	0.642	3.79	7.85

The results show that the consolidation index equation should be used to calculate and predict the final settlement which is in between 3.0 and 11.5cm.

CONCLUSION

The continental shelf of Suakin characterized by high accumulation of sediment due to the high ratio of sedimentation of these sediments are alluvial, sand, silt muddy silty stone were driven by drainage system pattern in surrounding areas. The coral reef limestone was highly weathered buried beneath the alluvial deposits.

The adhesion value was neglected because it is very small in marine environment comparing with pile capacity and effective stress and surrounding soil condition. The settlement obtained to laboratory tests and the consolidation index was used for predication which is between 3.0 -11.5cm.

Care with high tension should be considered in such continental shelf to an ooid stability geological factor.

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