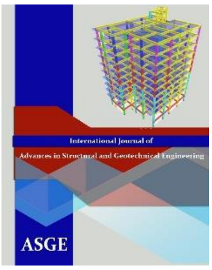


International Journal of Advances in Structural and Geotechnical Engineering

https://asge.journals.ekb.eg/

Print ISSN 2785-9509 Online ISSN 2812-5142

Special Issue for ICASGE'19

GEOTECHNICAL ASPECTS OF WEAK SOIL DEPOSITS AT THE NEW COMMUNITY OF NORTH EAST REGION OF EGYPT

Gamal El-Dean M.R, Bahr M.A and Tarek M.F

ASGE Vol. 03 (04), pp. 16-32, 2019

Geotechnical Aspects of Weak Soil Deposits at the New Community of North East Region of Egypt

Gamal El-Dean M.R.[1] , Bahr M.A.[2] and Tarek M.F.[3]

[1]*Assistant Lecturer, AL Azhar University, Cairo, Egypt*
E-mail: m_gamal_eldean@yahoo.com
[2]*Professor of Geotechnical and Foundation Engineering, Al-Azhar University, Cairo,*
E-mail: mbahr_eg@yahoo.com
[3]*Professor of Geotechnical and Foundation Engineering, Al-Azhar University, Cairo,*
E-mail: ecob.tad@gmail.com

ABSTRACT

The present study addresses the weak soil problems in terms of loose sand and soft clay at the north east region of Egypt. Historical, geological and geotechnical background of the soil layers as a Nile Delta deposit have been evaluated and studied. Both loose sand and soft clay soil parameters and characteristics have been evaluated being based on some site characterization from executed numerous boreholes. A treatment method for foundation on these types of soil deposits, where mega projects such as wind turbines, power stations, oil tanks and nuclear plants exist, has to be established. To suggest the suitable foundation system considering this approach numerically, 2D and 3D PLAXIS models available in literature have firstly been examined. As a result, a new Skirted foundation as a model adopted for the compressible soils in the scope of this study has been suggested. Skirted foundations type has been analyzed and discussed, taken into consideration both skirt configuration and length. The output of non-skirted foundation were taken as a reference for comparison. The outcomes of the verified numerical models showed well agreement to the attested references, and the proposed model is able to simulate the cases for the current study purposes.

Keywords: *3D Plaxis, 2D Plaxis, Loose Sand, Soft Clay, Treatment Methods, Numerical Model*

1. INTRODUCTION

The contemporary industrial development aroused the need for mega power structures such as wind turbines, power stations and nuclear plants. It is challenging to support such structures on very weak soils. Weak and loose soils extend to cover a considerable area of the world. They exhibit low shear resistance and high deformations upon loading. In Japan, most of construction projects are constructed on weak/liquefiable or organic soils, large deformations are likely to occur for such constructions [1]. Many coastal areas of Australia suffer from the very weak clays those possess undesirable properties such as high compressibility [2]. High speed railway in Sweden had been constructed on deep layers of weak soils deposited in marine conditions 5000 years ago [3]. Full scale tests have been adopted to evaluate the settlement off embankments founded on floating columns (Lime-Cement columns). Also, weak soils are widely distributed in Canada and they represent a difficulty for embankment construction. [4].

Due to the recently economic development orientation in Egypt, the construction of new ports becomes essentially especially in the north east part of Egypt. Literature review on the geotechnical properties of these new regions; as weak soil deposit which becomes one of the problematic soil from the geotechnical practice point of view. Ismail and Ryden (2012) [5] studied the mineralogy and engineering characteristics of soil materials derived from eastern part of Nile Delta. The soil mainly consists of 0.3% gravel, 5% sand, 51.5 % silt and 42.4 % clay which makes these soils poses problems under light constructions. They concluded that, the buildings constructed on such soils suffer from differential settlements and the application of soil improvement is recommended. Azzam et. al. (2010) [6] studied the improvement of bearing capacity of footing on soft clay with and without skirts, they found that the bearing capacity has been improved through confinement by skirts.

In the present study, the geotechnical aspects of an industrial extension regions lie in the north east of Egypt will be discussed and analyzed, for the purposes of constructing foundations of light weight structures like wind turbines, administration buildings and underground lifeline utilities. The current adopted and proposed improvement techniques are compared to each other. Plaxis 2D and 3D have been used to validate the proposed models those will be adopted in the whole study. Using 2D Plaxis, reference study model has been modelled in which the behavior of raft foundation with vertical skirts has been evaluated. Plaxis 3D has also been used to evaluate the model size effect on the settlement of skirted foundations.

2. NORTH EAST GEOLOGICAL BACKGROUND

Nile Delta is considered as one of the most important and largest depositional basin in the world. The Nile river was classified into five deposits named; Eonile, paleonile, protonile, prenile and neonile [7]. The Nile Delta is divided into three zones, southern, middle and northern Delta. The northern part is known for its finest neonile sediments. It has several lagoons like Maryut, Idku, Burullus and Manzala. As indicated in literature, the thickness of weak soil increases toward the north of Egypt [5]. Elsohby et. al., (1988) [8] studied the geological evolution of the Nile Delta and they concluded that, the Nile river has undergone considerable changes. Figure 1 illustrates the stages through which the Nile River has passed.

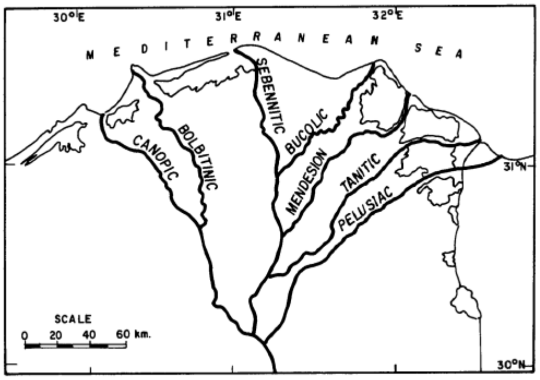
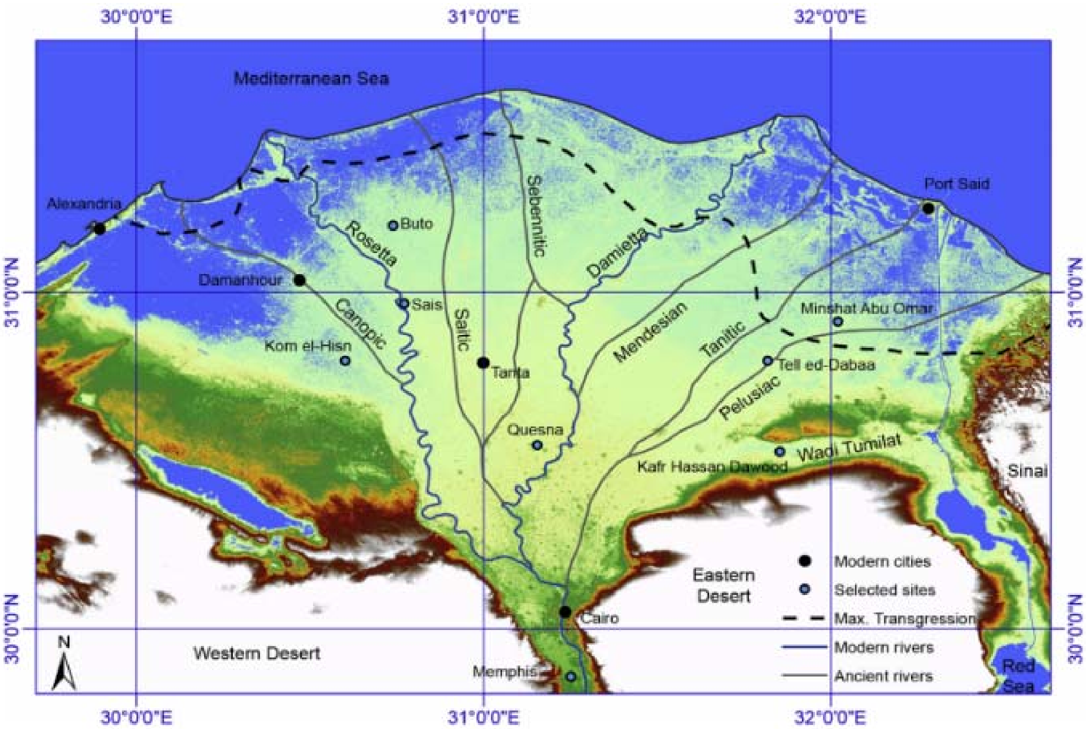
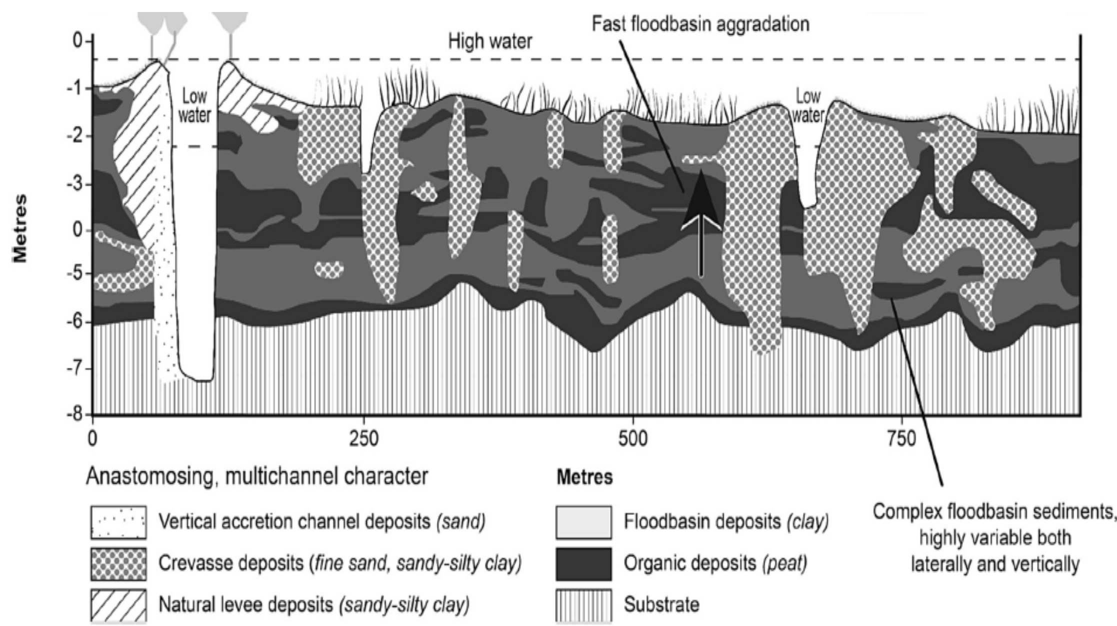


Figure (1) Old and Recent Branches of the Nile

It is observed that the parent Nile River consists of seven branches as shown in figure 1a. Figure 1b illustrates more detailed distribution for the old Nile River branches with some changes through Pelusiac branch, and the branch of Saitic has been added. Figure 2a shows another pattern for the old branches as the Delta apex was further south, and that was attributed to the Nile development during the decreasing rates of sea-level rise and high sediments of Holocene age. Initially, the sea level raised and caused high rates of flood basin aggradation followed by the creation of swampy and wetland landscape, and the resulting environment was known as "Large Scale Crevassing" or "LSC", figure 2-b illustrates the landscape during this period [9].



(a) Old Branches and Delta Apex



(b) "LSC Landscape"

Figure (2) Ancient River Branches and Followed deposition (After Benjamin, 2017) [9]

The high bed level decreased the Nile energy to move sediments and the super elevation increased. Then, the Nile started to maintain its volumetric flow over the surrounding flood basin causing high rates of floodplain. After the mid-Holocene age, lower sea-level rise had recorded and the river migrated through lateral channels causing a reduction in the channels network. Flood plain decreased and soils developed and the resulting landscape was known as "meandering" deltaic environment. The mobility Number "M" is a dimensionless number through which it can be determined whether a river aggrades vertically or migrates horizontally. The current Nile River and accompanying deposits have been born from the old branches to the current both Rosetta and Damietta branches. The construction of high dam caused a kind of retreat to delta and the flow was reduced. The Nile River evolution has a great effect on the deposits of the north east region of Egypt. There is a great deposit of weak soils that extend down to about 60 meters. The existence of weak soil is considered a barrier for the industrial progress in the region. Weak soils exhibit high deformations under light loads which represent a problem for over ground structures.

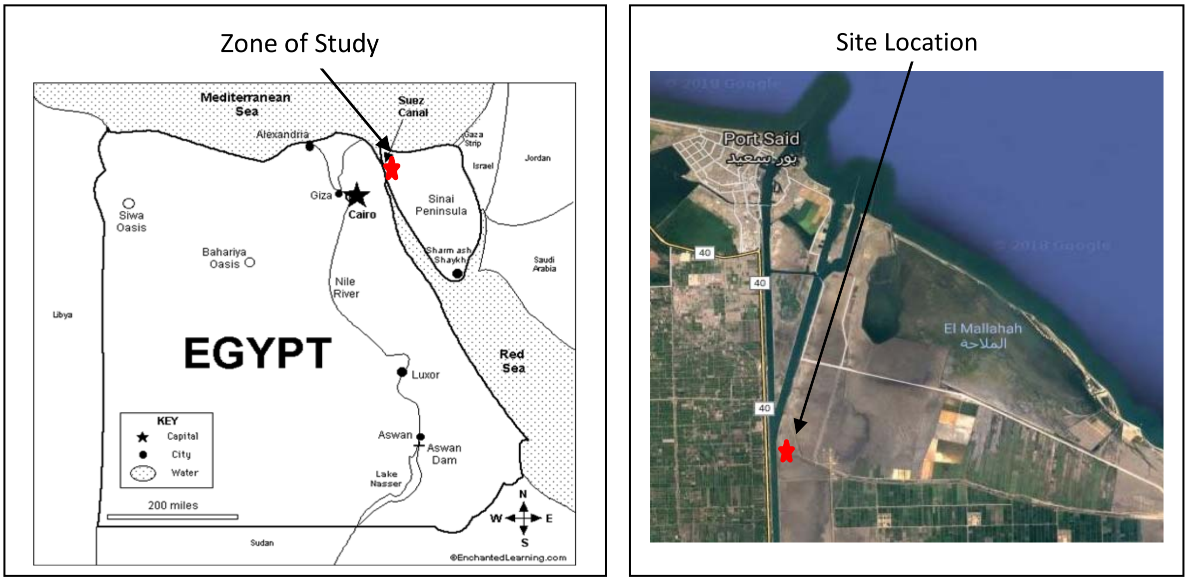
$$M = \frac{hv_c}{BV_a}$$ (After, Benjamin; 2017) [9]

Where: h: River depth B: River width Vc: bank erosion rate Va: vertical aggrade rate

The Large Scale Crevassing "LSC" was first existed near shores and extended later to cover a considerable part of delta then, it was replaced by drained environment with the decrease of sea-level rise, and the delta front had ended with barrier beaches and lagoons. The pre-explained development for deposits composition and the Nile River evolution provides a general picture about the landscape changes and it will be used for site predictions.

3. WEAK SOIL STRATIFICATION AT THE AREA OF STUDY

The physical and engineering properties of weak clay soil that exist north east of Egypt have been collected and characterized. Figure 3a shows the zone of study at the north east of Egypt and figure 3b shows a close view for the area. It is considered as an extension area for Port Said seaport. It is covered by a great depth of soft soil unlike its boundaries of agricultural areas as shown in figure 3b. Summary of the boreholes showed that there is an upper fill layer having a thickness ranges from 0.5 m to 1.50 m followed by very weak clay that extend down to about 50 m which becomes medium stiff at a nearly depth of 35 m, then becomes stiff at its final depth at 50 m. Some laminations and small thickness layers of clayey silt or sandy silt have been encountered through the weak clay layer. The pocket penetrometer showed that the unconfined compressive strength is less than 10 kN/m^2 for the upper 20 m then becomes 20 to 30 kN/m^2 for the second 20 m. The last 20 m revealed medium stiff clay that has unconfined compressive strength ranges from 50 to 100 kN/m^2. The weak clay layer is followed by very dense, fine gray sand with outstanding SPT number till the end of borings at 60 m.



(a) Location of Studied area **(b) Close view for the site location**

Figure (3) Zone of study

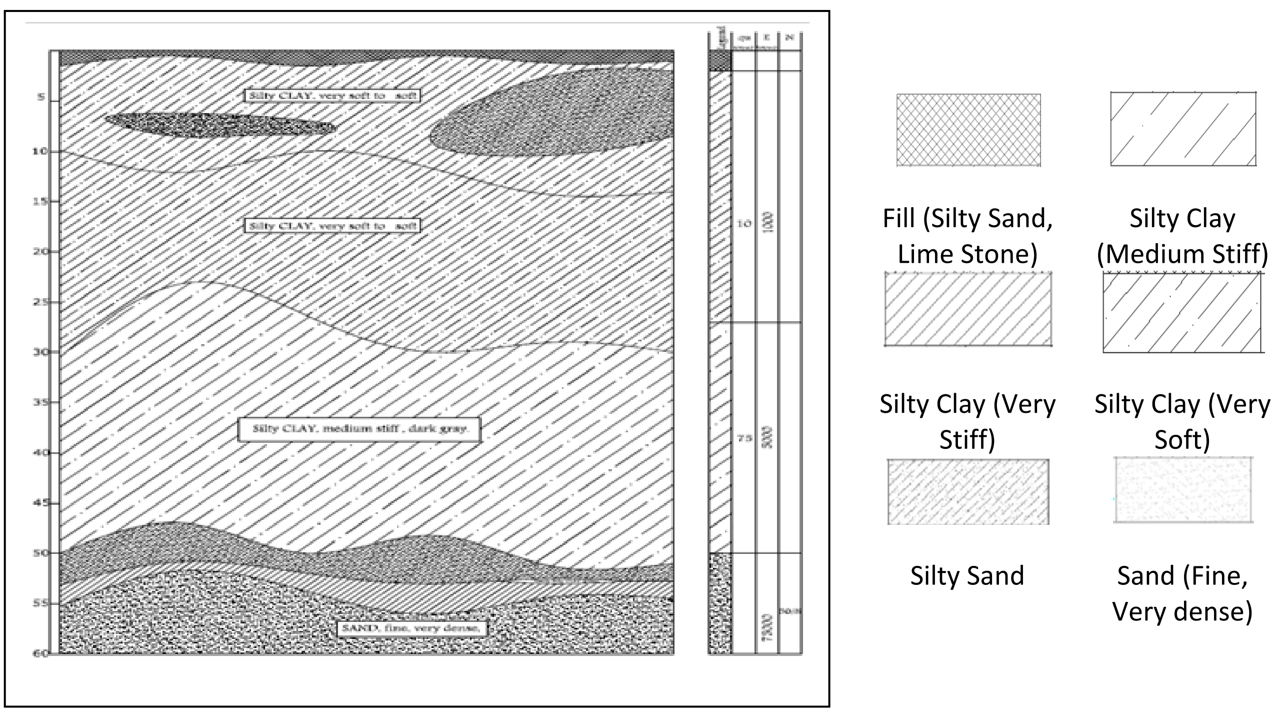


Figure (4) Lithological section for soil stratification at the study site in the north east of Egypt

Figure 4 clarifies the idealized stratification of the successive layers at the studied location. Idealized soil log has been generated for analyses purposes as shown in figure 5.

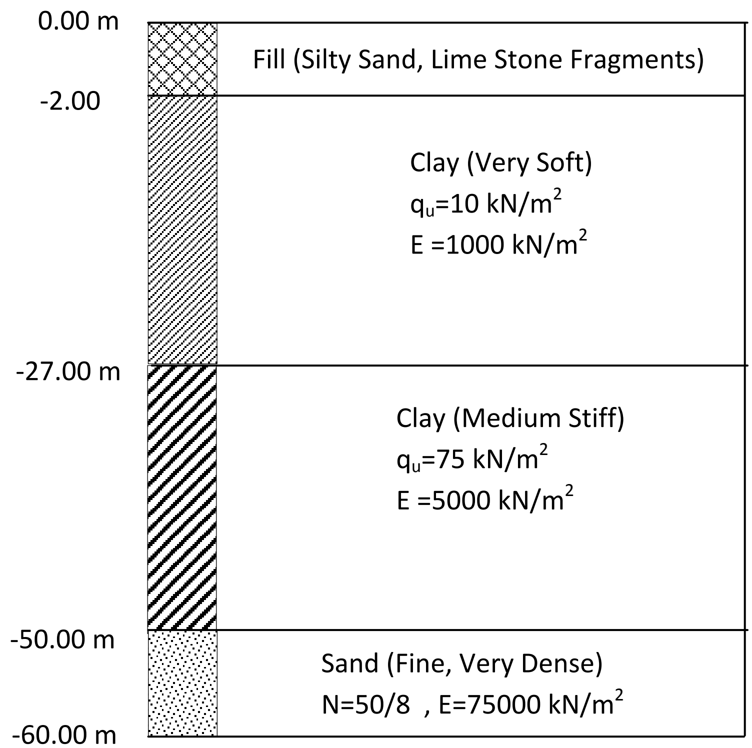
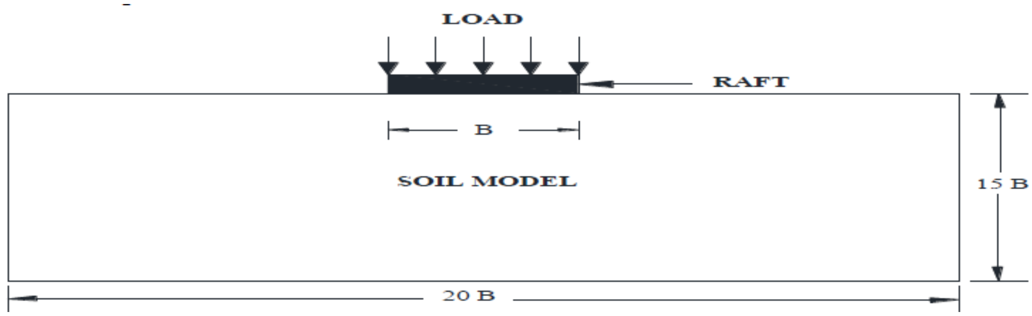


Figure (5) Idealized soil log for numerical modeling

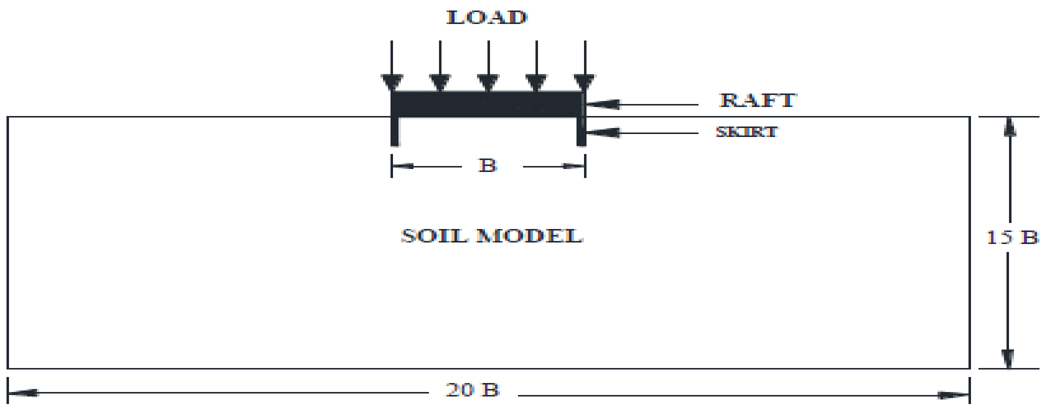
4 NUMERICAL SOIL MODEL

4.1 MODEL VERIFICATION

Square Raft foundations supported on loose sand has been selected for the aim of validation. The raft is having breadth of 10 m and thickness of 0.2 m. The soil model breadth has been taken 20B and depth 15B as the reference study. Hardening soil model has been adopted to simulate the conditions under consideration. The skirt length (Ls) has been taken as 0.25B. The soil as well as skirts properties are shown in table 1. The adopted stress level is starting from 200 kN/m^2 up to 1000 kN/m^2. The accompanying displacement has been predicted for each load level. Figure 6 shows the adopted model with and without skirts. For the sake of comparison, Plaxis 3D has been used to simulate the same condition analyzed using 2D Plaxis. The third dimension of the model has been used as its breadth.



(a) Geometry model of raft foundation without skirts



(b) Geometry model of raft foundation with skirts

Figure (6) Geometry model of raft foundation without and with skirts (After Sunil et al. 2013) [12]

Table (1) Material Properties (After Sunil, et.al, 2013)

Parameter	Value
Type of material	Sand
Material Model	Hardening Soil Model
E_{50} (kN/m^2)	40000
Dry Density (kN/m^3)	17
Power (m)	0.5
Cohesion (kN/m^2)	0.1
Friction Angle (Ø)	32^0
Angle of Dilatancy	2^0
Interface Reduction Factor R_{inter}	0.67
Axial Stiffness for steel skirts EA, (kN/m)	31500

4.2 PROPOSED 3D MODEL

Plaxis 3D has been adopted to develop more accurate and precise model boundary conditions. A 3D model having dimensions of 40 m × 30 m ×18 m has been modeled as single soft clay layer. The model geometry is shown in figure 7, and detailed dimensions are clarified in figure 8. The soft soil layer has a linear increase of $S_{u \cdot inc}$ =1.3 kPa/m. Undrained soil condition has been considered in analysis using Mohr-Coulomb model, as an appropriate model for short term undrained condition. The soil parameters are summarized in table 2. Rectangular foundation 21×9 m has been modeled over the soft soil with and without skirts of length 1 m. The parameters of the base plate and skirts are summarized in table 3. The foundation is assumed to behave elastically and has very rigid stiffness. The foundation has been loaded by incremental load of 2000, 4000, 6000 and 8000 kN respectively. This load procedure has been assumed to study the load-displacement path for soft soil under light to medium loading conditions. The load has been applied as a concentrated load since it represents the reaction applied from the structure supporting points.

Table (2) Soil Properties

Parameter	Name	Soil
Material model	MC	Mohr-Coulomb
Drainage type	Type	Undrained (C)
Unit weight above phreatic level, kN/m^3	γ_{unsat}	15.5
Unit weight below phreatic level, kN/m^3	γ_{sat}	15.5
Stiffness, kN/m^2	E_u	1000
	$E_{u.inc}$	650
Poisson's ratio	υ	0.49
Shear Strength, kPa	$S_{u.ref}$	2
	$S_{u.inc}$	1.3
Lateral earth pressure coefficient	k_o	0.96

Table (3) Base Plate and Skirts Properties

Parameter	Steel Base Plate	Skirts
d (Thickness)	0.2 m	0.015 m
ɣ (Density)	0 kN/m^3	0 kN/m^3
E (Modulus of Elasticity)	1E9 kN/m^2	1E9 kN/m^2
υ (Poisson's ratio)	0.3	0.3

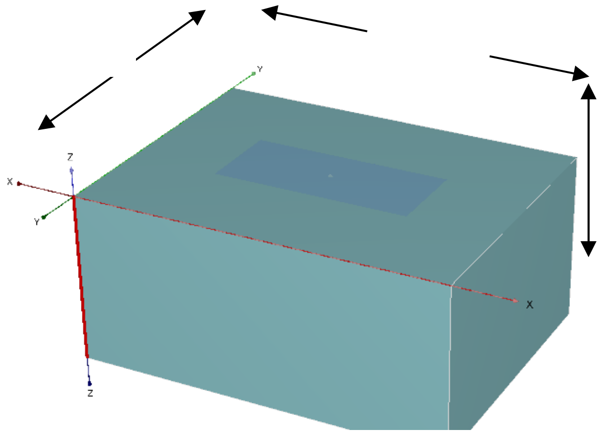


Figure (7) 3D Model geometry

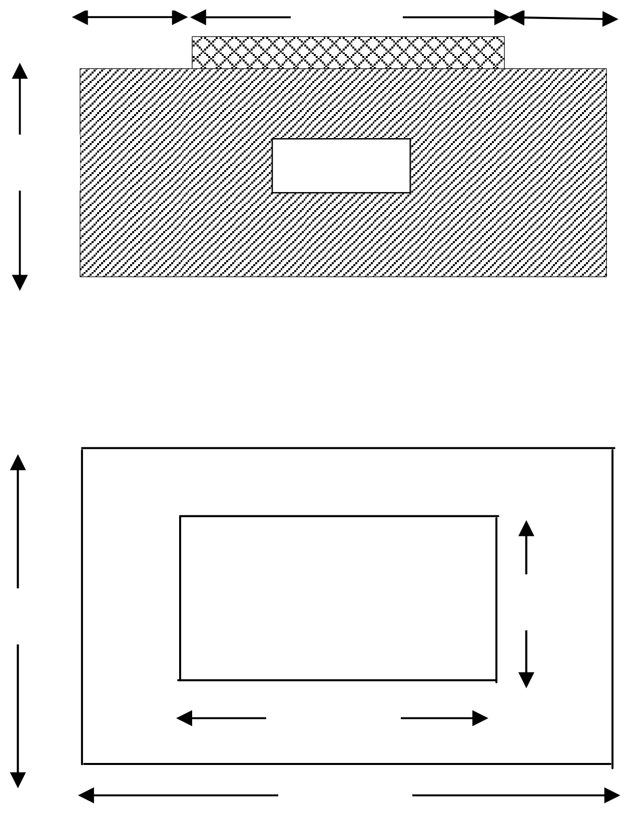
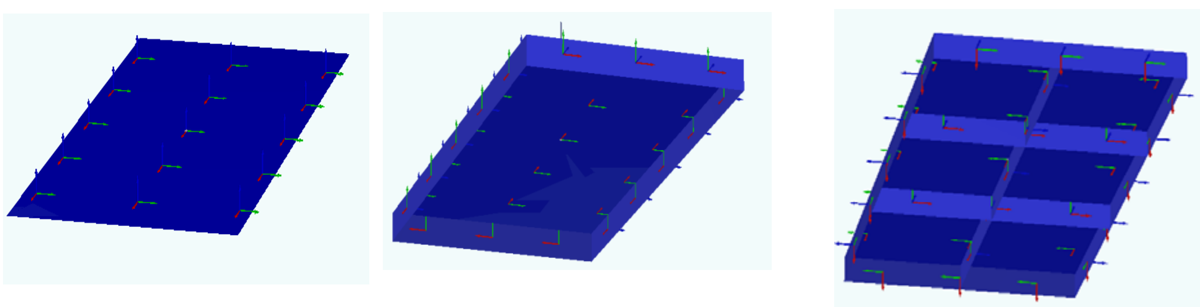


Figure (8) Model dimensions

5. NON-SKIRTED AND SKIRTED FOUNDATIONS ANALYSES

5.1 EFFECT OF SKIRT CONFIGURATION

Different skirts configurations have been modeled and analyzed. Outer skirts distributed on perimeter have been initially used. The second analyses stage included both outer and inner skirts to increase the soil and structure's stiffness. Both cases combined with foundations without skirts have been modeled and analyzed under different stress levels. Figure 9 illustrates the foundation in three cases: (a) without skirts; (b) with outer skirts; and (c) with both inner and outer skirts. The Depth of skirts is 1.0 m representing about 11 % of the raft width (B). These models represent the foundation geometries those have been chosen to study effect of skirts on the settlement of proposed foundation system.



(a) Foundation without skirts **(b) Foundation with outer skirts** **(c) Foundation with outer and inner skirts**

Figure 9: Foundation without and with Skirts

5.2 EFFECT OF SKIRT LENGTH

Skirt length has been increased from 1 m to be 2,3,5,7 and 9 m representing 11, 22, 33, 55, 77, 100 % of the footing breadth respectively. Effect of the increased skirt length depth on the foundation system has been investigated using the 2D and 3D Plaxis programs.

6. RESULTS AND DISCUSSION

6.1 Results of Model Validation

The load-displacement curve has been generated for the studied condition using both 2D and 3D Plaxis as shown in figure 10. There is well agreement between the reference study and the current study curves. 3D Plaxis showed lower displacements than 2D Plaxis under the same load level. This might be attributed to the 3D effect and the soil mass deformation in the third direction which is not considered in 2D analyses. Settlement predicted by 3D program was less than that of 2D Plaxis by about 50% to 60%.for stress level from 200 to 1000 kN/m2.

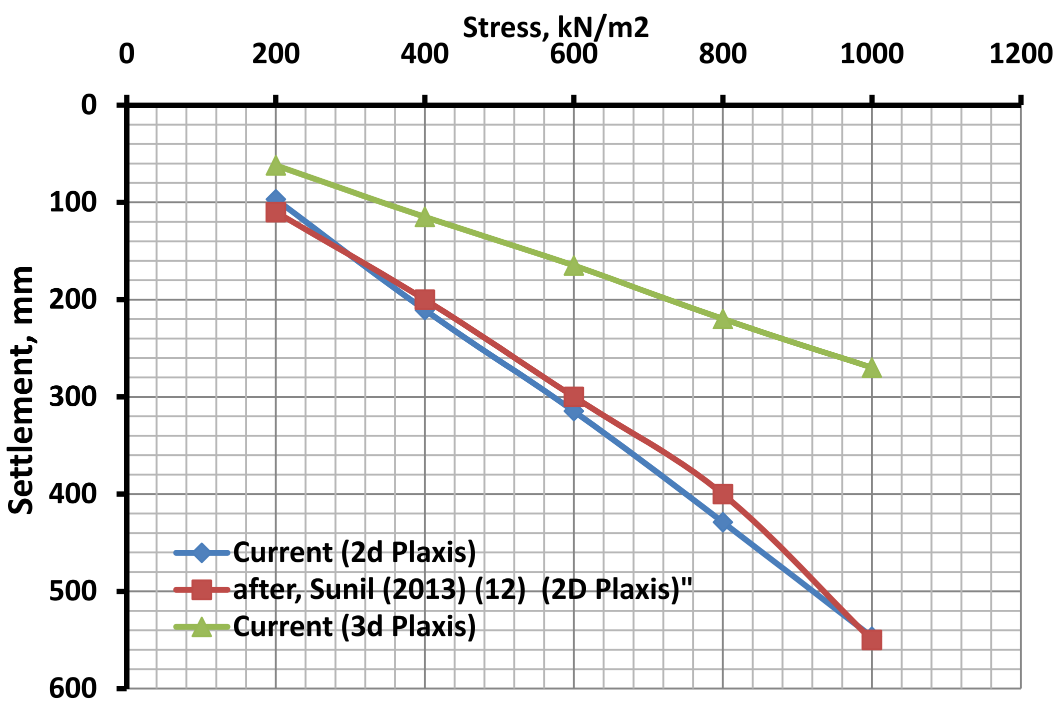


Figure (10) Load-Displacement Curve using 2D and 3D Plaxis

6.2 Non Skirted Versus Skirted Foundations

The load displacement curve for non-skirted, outer skirted and both outer and inner skirted foundations has been generated as shown in figure 11. The versatile scenario has been plotted in which the settlement increases as the load increase. The non- skirted foundation showed the highest level of settlement while skirted foundations exhibited lower settlement values. Both outer and inner skirted foundations showed the lowest settlement values. That is attributed to the effect of skirts on the rigidity of foundations as well as the confinement of the underlying soil.

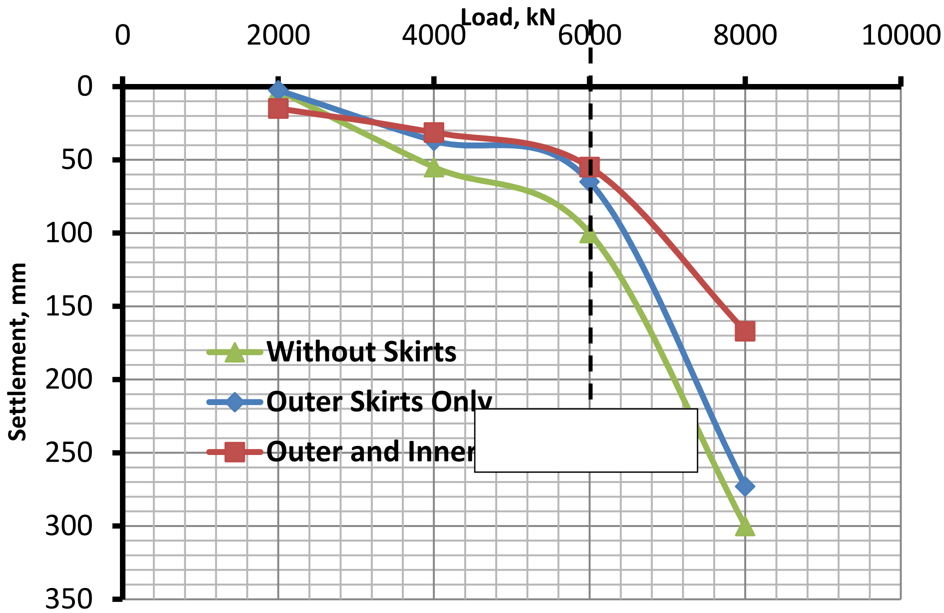


Figure (11) Load-Displacement Curve 3D Plaxis for Skirted and Non-Skirted Foundations

Figure 12 shows the generated mesh for soil cluster and foundation system. The soil near the structure has been refined to get more precise output. Figure 13 illustrates the distribution of displacement in the soil mass for outer skirted foundation and for both outer and inner skirted one. There is a smooth distribution of displacements for the outer skirted foundations. The confined soil behaves as a single mass through which the stresses are distributed while for outer and inner skirted foundations, inner skirts divided the soil mass into segments in which each segment behaves lonely. The existence of skirts intersects the traditional displacement contours resulting in irregular deformation pattern.

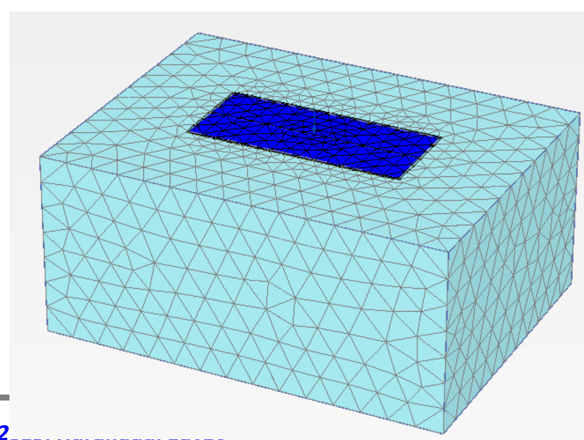
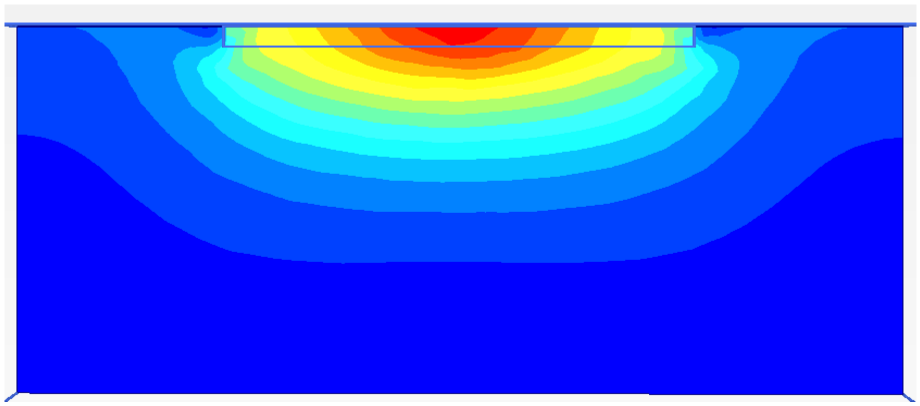
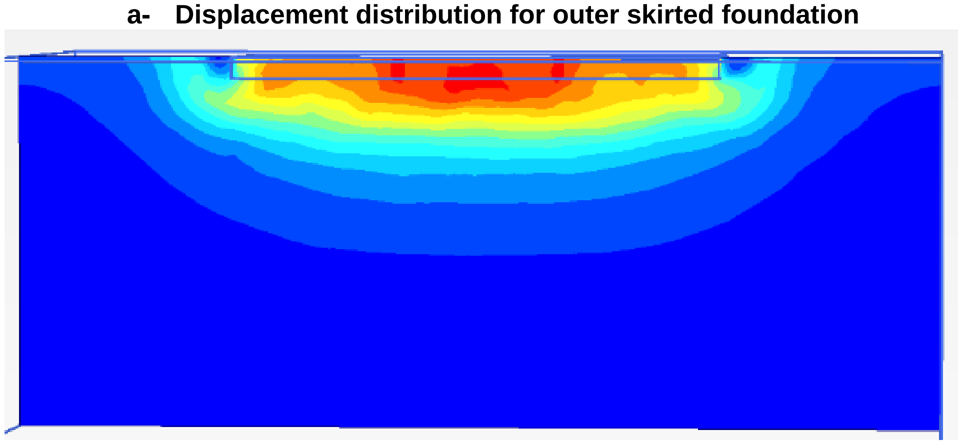


Figure 12: Generated Mesh and Refinement



a- Displacement distribution for outer skirted foundation



b- Displacement distribution for outer and inner skirted foundation

Figure 12: Displacement Distribution for foundations

6.3 Effect of Skirt Length (L_s)

The load-displacement curve has been generated for skirted foundations with different skirt length as shown in figure 14. The settlement decreased considerably as the skirt length increases. It is observed that the settlement decreased by more than 50 % when the skirt length increased from 1 m to 3 m. The rate of improvement decreases as the skirt length increase. Under low loads, the skirt length has lower effect on the settlement but when the load increase, the skirt length effect appears to be considerable.

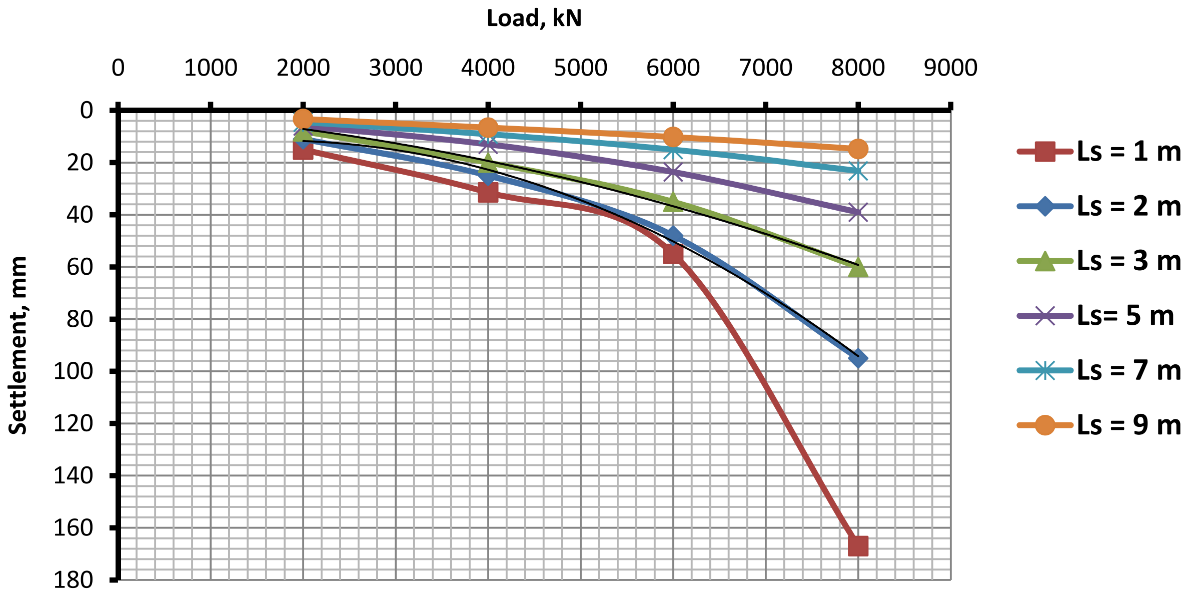


Figure 14: Effect of Skirt Length on Settlement

7 Conclusions

The following conclusions can be drawn from the study:

- The Nile river and delta have undergone considerable changes during ancient times and these changes have a great effect on the current depositional complex northern Egypt.
- Soft soil deposits are concentrated through the north cost of Egypt from Port Saeed in the east to the west of Alexandria and it is challenging to support structures on such deposits.
- Settlement predicted by 2D Plaxis program was about 1.6 to 2.0 times of that estimated by 3D program.
- Using skirts as a structural element to increase the foundations stability is considered an effective method to control the excessive settlement of soft clayey soil.
- Skirted foundations confine the underlying soft soil resulting in higher stiffness and capacity.
- The stiffness of foundations increases as the skirts segments increase which inhibits the settlement considerably.
- Foundation settlement decreased by more than 50 % when the skirt length increased from 1 m to 3 m. The rate of improvement decreases as the skirt length increase.

- At small load level, skirts have no considerable effect on the settlement whereas at medium loading condition, appreciable effect has been observed.
- Skirts started to show considerable effect after stress level of about 30 kN/m^2

REFERENCES

1. Kitazume M., (2016) "Ground Improvement in Japan" Brief country report for TC-17.
2. Indraratna B., Rujikiatkamjorn C. and A.Ghandeharioon A., (2009) "Modelling of soft ground consolidation via combined surcharge and vacuum preloading" Geotechnical of soft soils – Focus on Ground Improvement – Karstunen & Leoni (eds) © 2009 Taylor & Francis Group, London, ISBN 978-0-415-47591-4
3. Olsson M., Edstam T. and Alen C., (2009) "Some Experiences from full-scale test embankments on floating lime-cement columns" Geotechnical of soft soils – Focus on Ground Improvement – Karstunen & Leoni (eds) © 2009 Taylor & Francis Group, London, ISBN 978-0-415-47591-4
4. Gnanendran C.T., Valsangkar A. and Rowe R.K. (2015) " Canadian Case Histories of Embankments on Soft Soils and Stabilization with Geosynthetics" Article (December 2015) DOI 10.1016/B978-0-08-100698-6.00017-9
5. Ismail A.I.M. and Ryden N., (2012) "International Journal of Geological and Environmental Engineering" World Academy of Science, Engineering and Technology. Vol:6 No:5
6. Nazir A.K. and Azzam W.R., (2010) "Improving the Bearing Capacity of Footing on Soft Clay with Sand Pile with/without Skirts" Alexandria Engineering Journal (2010) 49, 371-377.
7. Said R., (1981) " The geology evolution of the Nile River" Springer Heidelberg and New York, 151 pp., DOI: 10.1007/978-1-4612-5841-4
8. Elsohby M.A., Mazen S.O., Abou-Shook M. and Bahr M.A., (1989) "Coastal Development of Nile Delta" Proceedings KNGMG Symposium ' Coastal Low Lands' Geology and Geotechnology' 1987: 175-179 (1989)
9. Benjamin T.P.~~ennington~~, (2017) "The Fluvial Evolution of the Holocene Nile Delta" http://dx.doi.org/10.1016/j.quascirev.2017.06.017
10. Tousson, prince Omar, 1922 "Mémoire sur les anciennes branches due Nile- Mem. Inst. Egypte, IV, Epoque Ancinne, Cairo, 150 pp
11. Elsayed W.R , Ali M A, Iskander M M. and Fanos A M (2007) "Evolution of Rosetta Promontory on Nile Delta Coast During the Period from 1500 to 2005", Egypt 8th
12. Dr. Sunil S. Pusadkar, Ms. Tejas Bhatkar, (2013) "Behavior of Raft Foundation with Vertical Skirt Using Plaxis 2d" International Journal of Engineering Research and

Development" e-ISSN:2278-067X, p-ISSN: 2278-800X, www.ijerd.com Volume 7, Issue 6 (June 2013), pp.20-24

13. International Conference on the Mediterranean Coastal Environment, MEDCOAST 07, E. Ozhan (Editor), 13-17 November 2007, Alexandria, Egypt, 2: 1003-1015
14. Negm M.A., Masria A., Iskander M. and Saavedra O., (2015) " Towards a Sustainable Stability of Coastal Zone at Rosetta Promontory/Mouth, Egypt" Article in Oceanography (Washington D.C.)-March 2015