International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies

http://TuEngr.com, http://go.to/Research

Estimation of Uplift Pile Capacity in the Sand Layers

Weeraya Chim-oye [a*], and Narin Marumdee [a]

[a] *Department of Civil Engineering, Faculty of Engineering, Thammasat University, THAILAND.*

ARTICLEINFO

Article history:
Received 15 August 2012
Received in revised form
01 November 2012
Accepted 12 November.2012
Available online 14 November 2012

Keywords:
Ultimate uplift pile capacity;
Tension pile load test;
Uplift capacity;
Sand layer.

ABSTRACT

There are several methods available to analyze and evaluate the ultimate uplift capacity of pile in the sand layers, based on a homogeneous soil layer. This research compares the three estimations of ultimate uplift capacity of pile developed by Kulhawy *et al* (1979); Das (1983) and Chattopadhyay and Pise (1986). Since the field experiment did not reach the failure state, the Modified Mazurkiewicz method has been used to predict ultimate uplift capacity of piles. It is found that Kulhawy *et al* (1979) ultimate uplift capacity is closed to field data, providing the highest safety. In contrast, the ultimate uplift capacity by Chattopadhyay and Pise (1986) method shows the highest difference from the ultimate uplift capacity.

1. Introduction

In design of the pile foundation in building area located near seashore which is sandy soil, it is found that forces acting on the pile foundation are not only axial compressive force and lateral force, but also uplift force. Analyzing to evaluate of uplift capacity is based on a homogeneous soil layer. But in practical, the nature of sand is divided into several layers. The properties of sand in each layer are different. The result of uplift capacity is a sum total of uplift capacity of soil in each layer, leading to a basis that only one soil layer is analyzed.

*Corresponding author (W.Chim-oye). Tel/Fax: +66-2-5643001 Ext.3166. E-mail addresses: sweeraya@engr.tu.ac.th.

Therefore, the purpose of this study is to compare the three math models of ultimate uplift capacity of pile developed by Kulhawy et al.(1979); Das (1983) and Chattopadhyay and Pise (1986), with the ultimate uplift capacity of pile from the field experiment by Modified Mazurkiewicz method [5] which is used for axial compressive load pile. The field tests are the test results of Static Tension Pile Load Test (Uplift) for Ammonia Storage Tank and Facilities Project in Map Ta Phut, Rayong Province, Thailand. The Modified Mazurkiewicz method [5] is used as a reference since it is consistent with the uplift capacity of model piles in the laboratory experiment in sandy soil [4].

2. Characteristics of the soil layers on the study area

There are three borings for subsoil investigation at building area of Ammonia Storage Tank and Facilities Project in Map Ta Phut, Rayong Province, East of Thailand. The borings are near the positions of three tension pile load test, see Figure 1. The project area is near the seashore and most area is sandy soil and consists of various different soil layers. The top layer is filling sand, about 1.5–2m thick. The lower layer is an original sand layer which has alluvium mixed sand with thickness around 9m. The further layers are clayey sand alternate with silty sand up to the depth of 25m. The pile tip of the construction project is at this layer as shown in Figure 2. The corrected Standard Penetration Number (N') and the engineering properties of each soil layer are summarized in Table 1. The total unit weight γ_T and friction angle ϕ are also given.

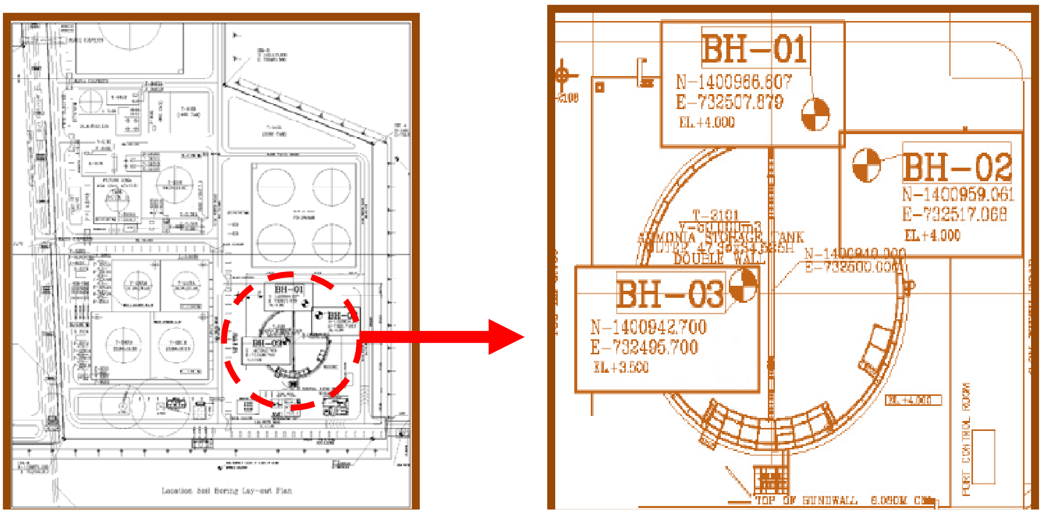


Figure 1: Positions of borehole test and tension pile load test, Map Ta Phut, Rayong Province, Thailand

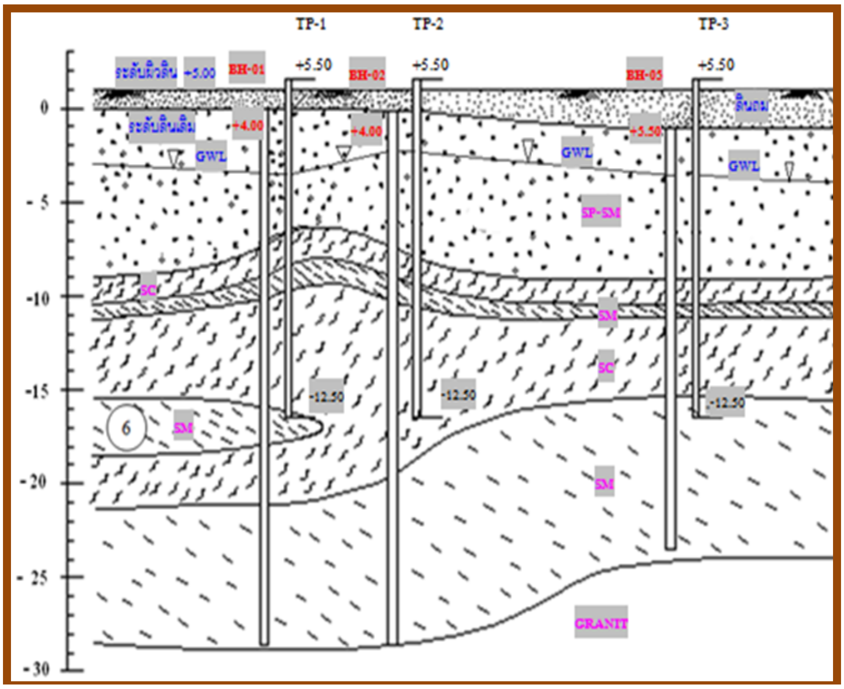


Figure 2: Characteristic details of soil layers, position and level of tension pile load test

Table 1: Summary of test results SPT, γ_T and ϕ of soil layers on the study area.

Depth(m)	Type of soil	SPT N'-value	Avg. γ_T t/m^3	Avg. ϕ degrees
0-9	Medium dense, Poorly graded Sand, (SP-SM)	3-33	1.91	33
9-11	Medium dense to Very dense, Clayey Sand, (SC)	17-33	1.87	33
11-12	Dense, Silty Sand, (SM)	23-33	2.01	34
12-15	Very dense, Clayey Sand, (SC)	29-33	2.10	37
15-19	Dense to medium, Silty Sand, (SM)	20-34	2.19	37
19-25	Very dense, Silty Sand, (SM)	20-33	2.11	35

3. Static Tension Pile Load Test (Uplift)

3.1 Data of Pile Test

The detail of the tested pile of Ammonia Storage Tank and Facilities Project in Map Ta Phut, Rayong Province for 3 piles, TP-01, TP-02 and TP-03 are shown in Table 2.

*Corresponding author (W.Chim-oye). Tel/Fax: +66-2-5643001 Ext.3166. E-mail addresses: sweeraya@engr.tu.ac.th.
© 2013. International Transaction Journal of Engineering, Management, & Applied Sciences & Technologies. Volume 4 No.1 ISSN 2228-9860 eISSN 1906-9642. Online Available at http://TuEngr.com/V04/057-065.pdf

Table 2: Pile test details.

ITEM	DESCRIPTION
Test pile No.	TP-01, TP-02 and TP-03
Pile size	Square pile size 0.40x0.40x18.00 m.
Ground Level	+5.00 m.
Pile Top Elevation	+5.50 m.
Pile Tip Elevation	-12.50 m.
Pile Length	18.00 m.

3.2 Test results uplift capacity of pile in the field

The pile load test follows ASTM D 3689-07 –Standard Test Methods for Deep Foundations under Static Axial Tensile Load. The results of the tension force and movement of the piles are shown in Table 3. The tension force was applied in three cycles and the piles were not tested to failure. The test maximum tension force was 32.5 tons, 2.5 times the design uplift capacity 13 tons.

Table 3: Test results for uplift capacity of pile.

Pile#	Cycle	Max. Test Load (Tons)	Permanent Movement (mm)	Recovery Rebound (mm)	Gross Movement (mm)
TP-01	1	13	0.23	0.08	0.31
	2	26	0.66	0.26	0.92
	3	32.5	1.04	0.31	1.35
TP-02	1	13	0.34	0.12	0.46
	2	26	1.03	0.21	1.24
	3	32.5	1.56	0.42	1.98
TP-03	1	13	0.19	0.15	0.34
	2	26	0.46	0.31	0.77
	3	32.5	0.65	0.32	0.97

4. Evaluation of Ultimate Uplift Capacity of Pile

Since the standard test of the uplift capacity in this case was not tested until the failure, thus the ultimate uplift capacity of pile has to be estimated. We selected the Modified Mazurkiewicz method [5] to estimate the compressive pile capacity, as it can estimate the ultimate uplift capacity consistent with the ultimate uplift capacity of model piles in the laboratory experiment in sandy soil [4]. By this method, the correlations between ratio of increased force (delta tension force) and increased settlement (delta settlement) and tension force are shown in Figure 3. The correlation is trend to intercept with y-axis, which is the ultimate uplift capacity. The criteria is when the pile is failure the settlement is very high and cause the delta tension force and delta settlement become zero, so the intercept of y-axis is ultimate uplift capacity.

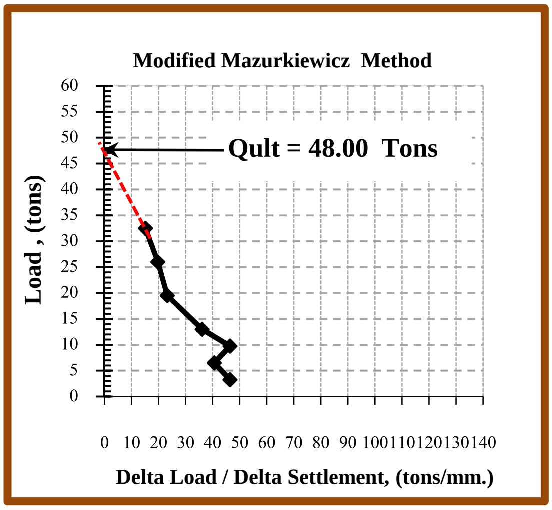


Figure 3: Evaluate ultimate uplift capacity of pile by Modified Mazurkiewicz method [5].

5. Pile Ultimate Uplift Capacity Estimation

In this study, three models are selected to analyze the ultimate uplift capacity – Kulhawy et al. (1979) [3]; Das (1983) [2] and Chattopadhyay and Pise (1986) [1]. Table 4 shows the math models, the assumption of failure surface in soil and the parameters used in these mathematic models.

Table 4 : Summary of equation, the assumption of failure surface in soil and the parameters.

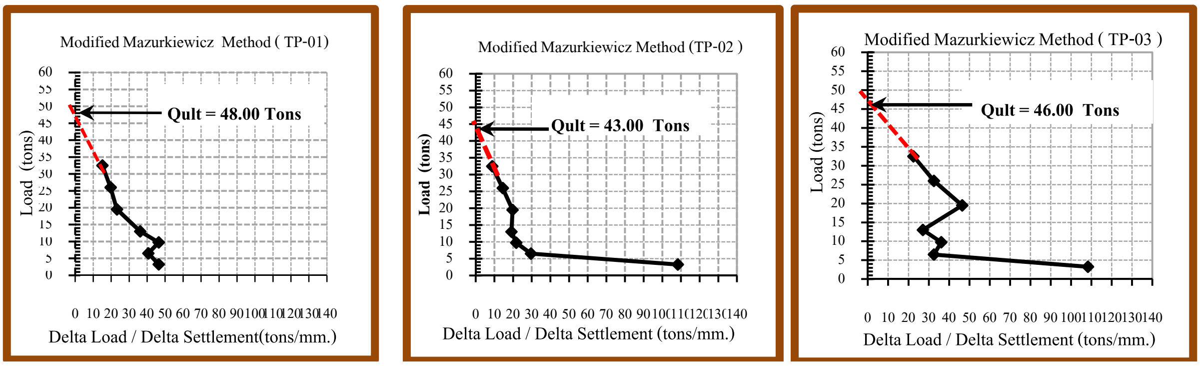
	Kulhawy et al. (1979)	M. Das (1983)	Chattopadhyay and Pise (1986)
Math models	$P_{Unet} = \pi d \frac{L^2}{2} K\gamma' \tan\delta$	(1) $P_{Unet} = \frac{1}{2}\rho\gamma' L^2 K_u \tan\delta$ when ;$(L/d) \leq (L/d)_{cr}$ (2) $P_{Unet} = \frac{1}{2}\rho\gamma' L_{cr}^2 K_u \tan\delta + \rho\gamma' L_{cr} K_u \tan\delta (L - L_{cr})$ when; $(L/d) > (L/d)_{cr}$	$P_{Unet} = A_1\gamma'\pi d L^2$
Failure surface	Cylindrical shear	Cylindrical shear	Curve surface
Parameters	1. Friction Angle (ϕ) 2. Effective Unit Weight (γ') 3.Angle of pile friction (δ) 4.Coefficient of earth pressure (K) $K=K_a$ for Loose Sand $K=\sqrt{K_p}$ for Dense Sand when; K_a and K_p are Rankine active and passive earth pressure coefficient	1. Friction Angle (ϕ) 2. Effective Unit Weight (γ') 3.Angle of pile friction (δ) 4.Coefficient of earth pressure (K) by uplift coefficient (K_U) from graph which depend on friction angle (ϕ) by values between 1-4	1. Friction Angle (ϕ) 2. Effective Unit Weight (γ') 3.Angle of pile friction (δ) 4.Net uplift capacity factor (A_1) from graph which depend on angle of pile friction (δ) and slenderness ratio (λ)

*Corresponding author (W.Chim-oye). Tel/Fax: +66-2-5643001 Ext.3166. E-mail addresses: sweeraya@engr.tu.ac.th.

6. Results and Discussion

6.1 The Ultimate Uplift Capacity of Piles by Modified Mazurkiewicz Method

From the result of field tension piles load test, Figure 4 shows the correlation between ratio of delta tension force and delta settlement and tension force for three tested piles. The ultimate uplift capacities are summarized in Table 5. It is found that the ultimate uplift capacities are almost the same, in the range 43 – 48 tons. Comparing with the design uplift capacity 13 tons, the factor of safety of these pile is about 3.3–3.7.



(a) TP-01 (b) TP-02 (c) TP-03

Figure 4: Ultimate uplift capacity estimation by Modified Mazurkiewicz method**.**

Table 5: Ultimate uplift capacity result of three piles by Mazurkiewicz modified method [5].

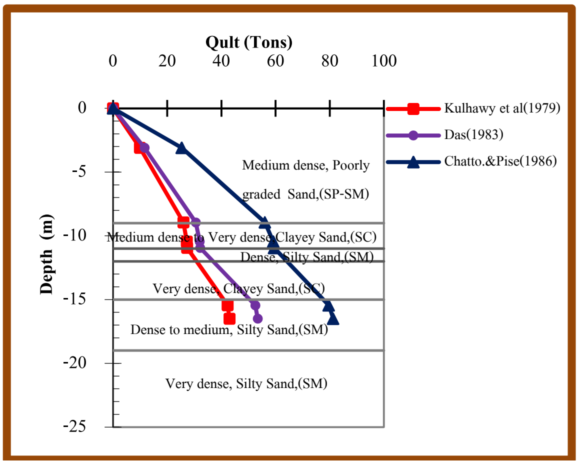
Pile No.	TP-01	TP-02	TP-03
Ultimate uplift capacity (Qult) tons.	48	43	46

6.2 Results of ultimate uplift capacity by theory

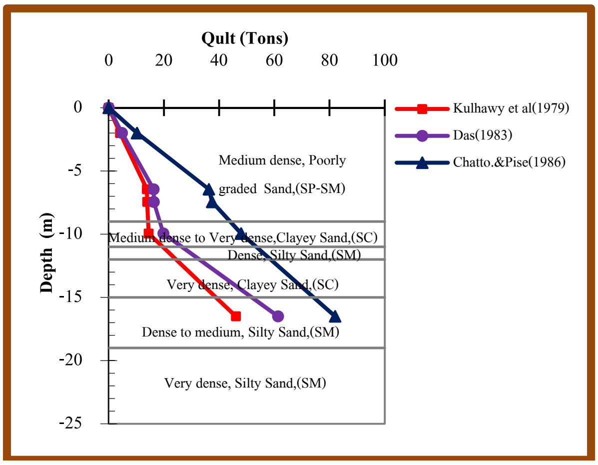
Figure 5 shows the relation between the ultimate uplift capacities that are analyzed from three models varied with depth. It is found that the uplift capacity of pile increases with depth and depends on the properties of soil in each layer. Table 6 shows the results of ultimate uplift capacity analyzed from three models. It can be seen that the ultimate uplift capacities by Chattopadhyay and Pise (1986) [1] are highest values, 80-85 tons. The ultimate uplift capacities that analyzed from Das's method(1983) [2] (50-65 tons) and Kulhawy et al.'s (1979) [3] method (40-50 tons) are close together since the same failure surface and parameter are used in the math models, see Table 4. The values of the earth pressure coefficient K are in the range (1 – 4) for dense sand, even though the (K) is based on different criteria.

Table 6: Estimated ultimate uplift capacity.

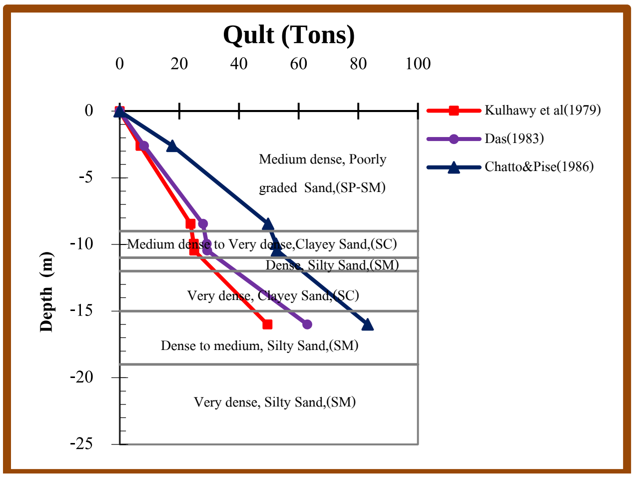
Pile #	Ultimate Uplift capacity, tons			
	Modified Mazurkiewicz (1997)	Kulhawy et al. (1979)	Das (1983)	Chattopadhyay and Pise (1986)
TP-01	48	43.0	53.4	81.3
TP-02	43	46.1	61.4	82.1
TP-03	46	49.5	62.9	83.2



(a) TP-01



(b) TP-02



(c) TP-03

Figure 5: Relation between the uplift capacity with depth.

Figure 6 shows the relation between predicted ultimate uplift capacity from field load test and analyzed ultimate uplift capacity from theories. It is found that the ultimate uplift capacity by Kulhawy et al. (1979) [3] is closed to the estimation ultimate uplift capacities which give the

*Corresponding author (W.Chim-oye). Tel/Fax: +66-2-5643001 Ext.3166. E-mail addresses: sweeraya@engr.tu.ac.th.

most safety to be used in engineering design. The ultimate uplift capacity by Chattopadhyay and Pise (1986) [1] is too high and much different from the estimated ultimate uplift capacities.

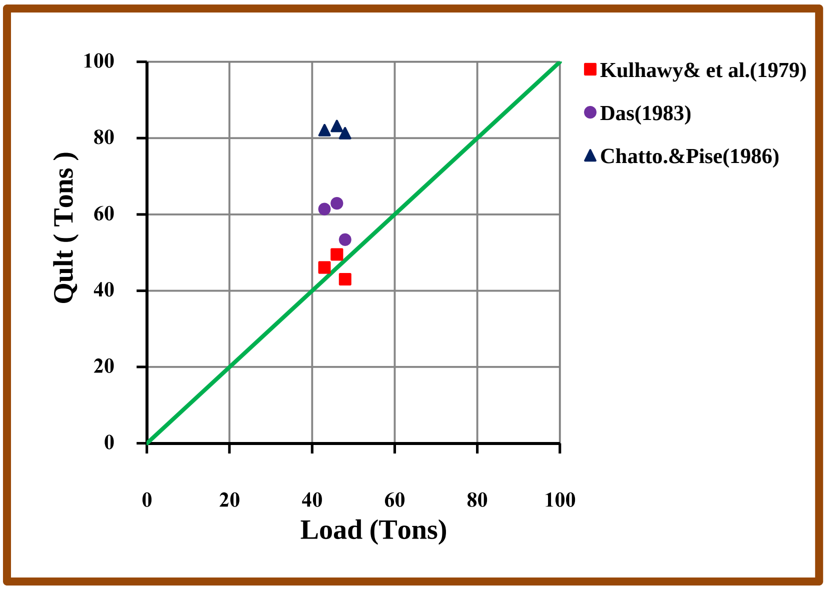


Figure 6: Load and ultimate pile capacity estimations

7. Conclusion

The Modified Mazurkiewicz method [5] can estimate the ultimate uplift capacity that is consistent with the ultimate uplift capacity of model piles in the laboratory experiment in sandy soil [4]. Among three math models, the Kulhawy et al. (1979) model [3] is the most appropriate method to analyze the ultimate uplift capacity, as it closes to Modified Mazurkiewicz method. It can also be used for multi-layer soil by summation of the uplift force of each layer of the soil.

From this study, we find that the ultimate uplift capacity in dense sand depends upon the properties of soil in each layer. Thus, this important factor should be further studied by Finite Element method to confirm soil parameters affected the pile capacity. The effect of the sequence of the soil layer on the ultimate uplift capacity should also be studied.

8. Acknowledgement

The authors are thankful to Bang pa-in Concrete Pile Co., Ltd. for supporting soil boring data, tension pile load test results.

9. References

[1] Chattopadhyay, B.C., and Pise, P.J. (1986). Uplift capacity of piles in sand, Journal of Geotechnics Engineering, Vol.112, No.9, pp. 888-904.

[2] Das, B.M. (1983). A procedure of estimation of uplift capacity of rough piles, Soil and Foundation, Vol.23, No.3, pp.122-126.

[3] Kulhawy, F.H., Kozera, D.W., and Withaim, J.L. (1979). Uplift Testing of Model Drilled Shafts in Sand, Journal of Geotechnics and Environmental Engineering, American Society of Civil Engineers, Vol.105, pp.31-47.

[4] Sottiponth O. (2005). Behavior of Model Pile in Sand under Uplift Force. M.Eng. Thesis, Faculty of Engineering, Thammasat University, Bangkok, Thailand.

[5] Thanadol K. (1998). Study of Pile Capacity from Ultimate Pile Load Test. M. Eng. Thesis, Faculty of engineering, Kasetsart University, Bangkok, Thailand.

Dr. Weeraya Chim-oye is an Associate Professor of Department of Civil Engineering at Thammasat University. She received her B.Eng. from Kasatsart University in 1987. She continued her Ph.D. study at Hiroshima University, Japan, where she obtained her Ph.D. in Geotechnical Engineering.

Narin Marumdee earned his bachelor degree from King Mongkut's Institute of Technology North Bangkok Thailand, in 2000. He has been studying for the M. Eng. Degree in the Department of Civil Engineering, Thammasat University. He is currently working at the Crown Property Bureau.

Peer Review: This article has been internationally peer-reviewed and accepted for publication according to the guidelines given at the journal's website.