Analysis of Shift Pile Foundation on Mall and Hotel Projects in Bontang, East Kalimantan

Nicholas Joshua and Alfred Jonathan Susilo

July 13, 2021

Analysis of Shift Pile Foundation on Mall and Hotel Projects in Bontang, East Kalimantan

Nicholas Joshua[1] and Alfred Jonathan Susilo[2]

[1] Tarumanagara University, Letjen S. Parman Street No.1, Jakarta
nicholas.325170123@stu.untar.ac.id
[2] Tarumanagara University, Letjen S. Parman Street No.1, Jakarta
alfred@ft.untar.ac.id

Abstract. Indeed, Indonesia has many areas which are dominated by clay soils. Including in the city of Bontang, East Kalimantan. This research focuses on mall and hotel project located at that location. With regard to construction in this project there is a case of shifting of the foundation pile due to several factors, including the soil embakment factor which causes additional loads outside the design of the foundation pile and the clay soil type factor with high moisture content and plasticity, as well as the impact load factor caused by the driving machine foundation pile. So, in this study, an analysis of the foundation piles before and after the addition of the load was carried out using the p-y curve method to find the maximum lateral load. The two analyzes will be compared and searched for the lateral bearing capacity of the two piles and later can improve the case or prevent similar cases in other projects.

1 Introduction

The discussion of this research, it focuses on the case of the shift of the foundation piles in the Mall and Hotel project in Bontang to a distance of approximately 1.5 meter due to the addition of unplanned loads when designing the foundation piles. The load in question is the 5 meter high project land embankment due to the excavated soil that is not removed or moved because of the soil condition is too plastic so that it is difficult to dispose or transfer the excavated soil. Then there is also an additional load in the form of an impact load from the heavy pile driving equipment, namely the 120 Ton Hydraulic Static Pile Driver (HSPD). If the project is continued without any repairs, the building above it will not be able to withstand the load, because the foundation piles are tilted due to the shift of the piles. For this reason, it is necessary to calculate the maximum lateral load that can be received by the foundation piles on the project. This study uses the p-y curve method for calculating the maximum lateral load, besides that there is also a calculation of the addition of lateral loads to the pile due to soil embankment at the project site and also the addition of lateral loads due to the movement of the piling machine (HSPD) by finding the magnitude of the impact load using the method found. by Boussinesq.

1.1 p-y curve Method

In 2010, Georgiadis proposed a p-y curve construction approach compared to the Finite Element approach. Georgiadis modified an equation that has often been adopted to interpret the results of the pile test (Georgiadis & Georgiadis, 2010) This curve has an initial slope of Ki and is described by the hyperbolic equation in equation 1.

$$p = \frac{y}{\frac{1}{ki}+\frac{y}{pu}} \quad \textbf{(1)}$$

Determining the value of Pu based on the depth of the point that is considered important in the construction of the p-y curve. Based on the results of research by Georgiadis (2010), Pu can be calculated by equation 2.

$$pu = Np.Cu.D \quad \textbf{(2)}$$

Where Np is the bearing capacity factor which can be calculated by equation 3.

$$p = Npu - (Npu - Npo\ cos\theta)e^{-\lambda(\frac{z}{D})/(1+tan\theta)} \quad \textbf{(3)}$$

Where Npu is the ultimate lateral bearing capacity factor which can be calculated by equation 4, Npo is the surface bearing capacity factor for horizontal soils, λ is a dimensionless factor, z is the depth point under consideration and D is the pile diameter. Npo and λ are derived from the analysis of the finite element method conducted by Georgiadis (2010) and depend on the pile-soil adhesion factor (α).

$$Npu = \pi + 2\Delta + 2cos\Delta + 4\ (cos\ \frac{\Delta}{2} + sin\ \frac{\Delta}{2}) \quad \textbf{(4)}$$

Which Δ = sin-1α.

The Npo value can be calculated by equation 5.

$$Npo = 2 + 1.5\alpha \quad \textbf{(5)}$$

And the value λ of can be calculated by equation 6.

$$\lambda = 0.55 - 0.15\alpha \quad \textbf{(6)}$$

The pile-soil adhesion factor (α) can be determined from the cu and z/D parameters where z is the depth of the pile under consideration and D is the diameter of the pile with the graph shown in Figure 1.

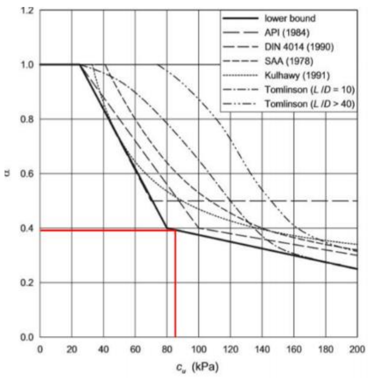

Figure 1. Graph of relationship between α and cu (kPa)

(Georgiadis & Georgiadis, 2010)

In 1961 Vesic proposed the correlation relation of the subgrade reaction ks for beams in elastic half-space to the elastic properties of the beam and soil. (Rajashree & Sitharam, 2001) proposed that the initial stiffness ki of the p-y curve is twice the value of ks determined based on the proposed Vesic correlation as shown in equation 7.

$ki = \frac{1.3\ Ei}{1-\mu^2}\left(\frac{Ei\ D^4}{Ep\ Ip}\right)^{\frac{1}{12}}$ .... **(7)**

Where Ei is the initial modulus of elasticity, is the poisson ratio of the soil, Ep is the modulus of elasticity of the pile, Ip is the moment of inertia of the pile section and D is the pile diameter.

1.2 Vertical Stress Due to Point Load (Boussinesq Metod)

Boussinesq (1883) solved the problem of the magnitude of the stress produced at each point which is homogeneous, isotropic due to the point load applied to the soil surface.

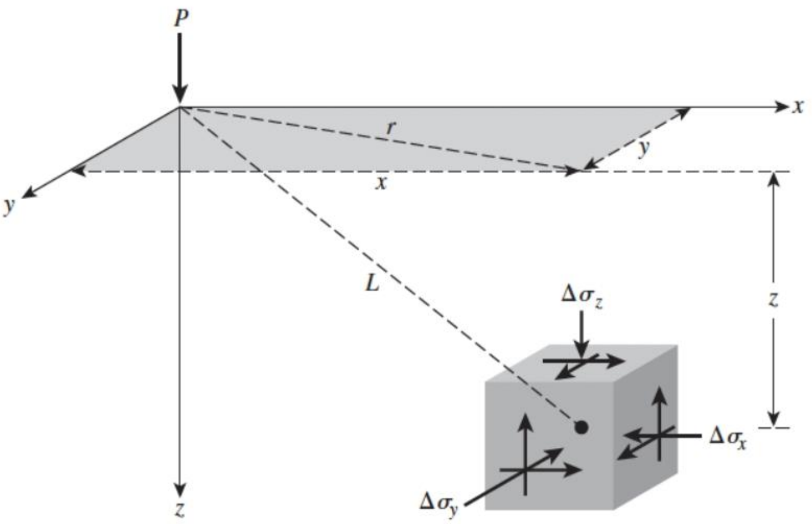

Figure 2. Vertical Stress Due to Point Load (Das & Sobhan, Principles of Geotechnical Engineering, 2014)

$\Delta\sigma_z = \frac{3Pz^3}{2\pi L^5} = \frac{3P}{2\pi}\frac{z^3}{(r^2+z^2)^{\frac{5}{3}}}$ .... **(8)**

$r = \sqrt{x^2 + y^2}$ .... **(9)**

$L = \sqrt{x^2 + y^2 + z^2} = \sqrt{r^2 + z^2}$ .... **(10)**

Description:

$\Delta\sigma_z$: Vertical Stress (kN/m^2)

P : Large Applied Load x$_2$ (kN)

2 Research Methods

In general, the procedures carried out in this study are as follows:

1. The initial stage is to determine the land data to be used.
2. The next step is to check the types of soil and their properties through the results of soil correlation
3. Then carried out a literature study on the shift of the foundation pile and the lateral bearing capacity of the pile.
4. The next stage is to design the foundation piles before and after adding the load.
5. The next step is to analyze the lateral bearing capacity of the pile using the p-y curve method.
6. Then analyze the lateral bearing capacity compared to the lateral load.
7. Next, check the pile foundation that has been added to the load and before it is added.
8. The next stage is to check the applicable terms and conditions. If it does not meet the requirements, then there is a need for additional reinforcement considerations or options and will be rechecked whether it meets the requirements or not.
9. The last stage is to formulate conclusions that can be useful for future planners.

Pile Fondation Design Data

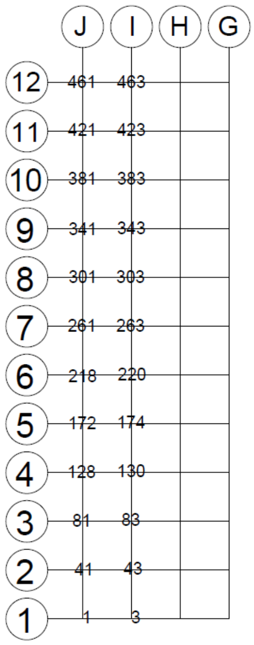

Figure 4. Building Layout

Table 3. Efficiency Pile Group on Axle J

Joint	Force (kN)	n Pile	Efficiency	Force / Pile (kN)	Force of 1 Pile	Need to Add Pile
1	31.7769	2	0.8301	15.88845	28.5235	No
41	58.4156	3	0.8867	19.47186667	30.4700	No
81	58.1832	3	0.8867	19.3944	30.4700	No
128	58.2177	3	0.8867	19.4059	30.4700	No
172	58.2379	3	0.8867	19.41263333	30.4700	No
218	58.2394	3	0.8867	19.41313333	30.4700	No
261	58.2326	3	0.8867	19.41086667	30.4700	No
301	58.2154	3	0.8867	19.40513333	30.4700	No
341	58.1785	3	0.8867	19.39283333	30.4700	No
381	58.1337	3	0.8867	19.3779	30.4700	No
421	58.3549	3	0.8867	19.45163333	30.4700	No
461	31.7021	2	0.8301	15.85105	28.5235	No

Table 4. Efficiency Pile Group on Axle I

Joint	Force (kN)	n Pile	Efficiency	Force / Pile (kN)	Force of 1 Pile	Need to Add Pile
3	0.9585	4	0.7718	0.239625	28.5235	No
43	0.8714	5	0.9010	0.17428	30.4700	No
83	0.6706	5	0.9010	0.13412	30.4700	No
130	0.7238	5	0.9010	0.14476	30.4700	No
174	0.7352	5	0.9010	0.14704	30.4700	No
220	0.7525	5	0.9010	0.1505	30.4700	No
263	0.7893	5	0.9010	0.15786	30.4700	No
303	0.7933	5	0.9010	0.15866	30.4700	No
343	0.7974	5	0.9010	0.15948	30.4700	No
383	0.7407	5	0.9010	0.14814	30.4700	No
423	0.8845	5	0.9010	0.1769	30.4700	No
463	0.9256	4	0.7718	0.2314	28.5235	No

3 Result

3.1 Recap of Maximum Lateral Load Calculation Using the p-y curve Method

This method requires the following data that are useful in calculations:
Cu = 84 kPa
S'vo = 87 kPa
J = 0.5
e50 = 0.02
K = 8140 kPa/m
Nc = 9
Pu = 302.4 kN/m
Depth z= 30 m
B = 0.4 m
k'h = 7560 kN/m^2
k'hi = 244200 kN/m^2
yc = 20 mm
8 yc = 160 mm
From the data above, proceed to the calculation and the results and graphs of the p-y curve are as follows:

Table 5. Results of Calculations Using the p-y curve Method

y (mm)	p (kN/m)
0	0
1	55.70256
2	70.18082
3	80.33699
4	88.4223
5	95.25003
6	101.2183
7	106.5552

From the table above, the allowable deflection is 6.35 mm with a force (P) of 10.3089 tons and divided by a safety factor of 3, so the maximum lateral force of 3,436 tons is used.

3.2 Summary of Calculation of Added Load Due to Land Embankment

After the project took place and the pile shift occurred, there were several speculations about the cause of the pile shift which had previously been designed and calculated that the pile was strong enough to withstand lateral loads. The addition of latera l loads includes soil embankment at the project site with a height of about 5 m. So in this study, the calculation of the addition of lateral loads caused by soil embankment was carried out.

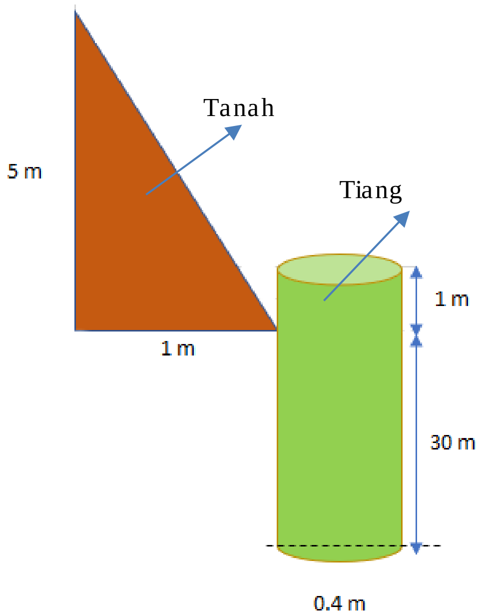

Figure 4. Illustration of Calculation of Added Load Due to Landfill

Assuming the width of the land is 1 m.

Volume	= 0.5 x 5 x 1 x 1
	= 2.5 m^3
λ	= 1.8 Ton/m^3
P	= 1.8 x 2..5
	= 4.5 Ton
Momen	= $\frac{4.5 \; x \; 2}{3}$
	= 3 Ton m
P Lateral	= 3 Ton (Left direction)

So the addition of lateral load due to soil embankment is 3 Tons to the left.

3.3 Summary of Additional Load Due to Impact Load with Boussinesq Method

The addition of lateral loads occurs due to soil movement due to the movement of piling machines such as HSPD and others. This study focuses on the impact of the HSPD Jacking Pile machine with a total machine weight of 54 Tons.

The calculation refers to the Boussinesq method where this method can solve the problem of the magnitude of the stress at each point on the ground surface, following the calculation:

Due to Impact Load (HSPD Machine):

$r_1 = \sqrt{x^2 + y^2} = \sqrt{0^2 + 0^2} = 0$

$L_1 \quad = \sqrt{r^2 + z^2} = \sqrt{0^2 + 2^2} = 2$

$\Delta\sigma_z(1) \; = \frac{3Pz^3}{2\pi L^5} = \frac{3\ x\ 529.74\ x\ 2^3}{2\pi\ x\ 2^5} = 63.233 kN/m^2$

Based on the conditions at this project location, the depth used is 2 m, because at this depth the most extreme pile shift occurs, and refers to Boussinesq's theory that the pressure generated by the impact load is getting smaller and smaller. Furthermore, it is necessary to find the addition of lateral loads due to the impact load by means of stress multiplied by area.

Additional Lateral Load:

$P = \Delta\sigma_z(1)$ x 0.4 x 2

= 63.233 x 0.4 x 2

= 50.586 kN = 5.157 Ton (left direction)

So the total additional load due to soil embankment and also due to impact load is 8,157 Tons to the left.

3.4 Summary of Lateral Efficiency Results of Axle J and Axle I After Adding Load

After calculating the addition of lateral loads to the piles, these loads are included in the calculation of the efficiency of the lateral piles and compared with the results of the p-y curve calculations that have been obtained. Then it will be checked whether the foundation pile is able to withstand the total lateral load that occurs or needs to be added reinforcement or additional pile foundation.

Table 6. Efficiency Pile Group on Axle J After Adding Load

Joint	Force (kN)	n Pile	Effi-ciency	Force / Pile (kN)	Force of 1 Pile	Need to Add Pile
1	111.7971	2	0.8301	55.89855	28.5235	Yes
41	138.4358	3	0.8867	46.14526667	30.4700	Yes
81	138.2034	3	0.8867	46.0678	30.4700	Yes
128	138.2379	3	0.8867	46.0793	30.4700	Yes
172	138.2581	3	0.8867	46.08603333	30.4700	Yes
218	138.2596	3	0.8867	46.08653333	30.4700	Yes
261	138.2528	3	0.8867	46.08426667	30.4700	Yes
301	138.2356	3	0.8867	46.07853333	30.4700	Yes
341	138.1987	3	0.8867	46.06623333	30.4700	Yes
381	138.1539	3	0.8867	46.0513	30.4700	Yes
421	138.3751	3	0.8867	46.12503333	30.4700	Yes
461	111.7223	2	0.8301	55.86115	28.5235	Yes

Table 7. Efficiency Pile Group on Axle I After Adding Load

Joint	Force (kN)	n Pile	Effi-ciency	Force / Pile (kN)	Force of 1 Pile	Need to Add Pile
3	106.4095	4	0.7718	26.602375	28.5235	Yes
43	106.3224	5	0.9010	21.26448	30.4700	No
83	106.1216	5	0.9010	21.22432	30.4700	No
130	106.1748	5	0.9010	21.23496	30.4700	No
174	106.1862	5	0.9010	21.23724	30.4700	No
220	106.2035	5	0.9010	21.2407	30.4700	No
263	106.2403	5	0.9010	21.24806	30.4700	No
303	106.2443	5	0.9010	21.24886	30.4700	No
343	106.2484	5	0.9010	21.24968	30.4700	No
383	106.1917	5	0.9010	21.23834	30.4700	No
423	106.3355	5	0.9010	21.2671	30.4700	No
463	106.3766	4	0.7718	26.59415	28.5235	Yes

4 Conclusions and Suggestions

4.1 Conclusions

Based on the results of the analysis that has been carried out, the following conclusions are obtained:

1. Based on the soil data obtained, the soil type is clay with high plasticity and has a small bearing capacity.
2. Based on calculations using the p-y curve method, the maximum lateral bearing capacity for foundation piles with a diameter of 0.4 m and a depth of 30 m is 3,436 tons.
3. Based on the building data obtained, the calculation results for the maximum lateral pile capacity are sufficient to withstand the load that occurs.
4. After the analysis, the results showed that the pile shift occurred due to the addition of an unplanned load, namely the load of the soil embankment and also the impact load of the HSPD piling machine.
5. Based on the calculation of the additional lateral load from the soil embankment is 3 Tons to the left.
6. Based on the calculation using the Boussinesq method, the additional lateral load from the impact load is 5,157 tons to the left.
7. The total additional load outside the plan is 8,157 tons.
8. Based on the calculation of group pile efficiency and after adding a load of 8,157 Tons, in Axle J all piles are unable to withstand the total lateral load and in Axle I there are 2 piles that are unable to withstand the total lateral load, causing a pile shift in these two axles to occur.

4.2 Suggestions

Based on the results of research and analysis conducted, the following are suggestions to complete this study:

1. The results of the soil test must be reviewed in order to be able to determine with certainty the types of soil and how the properties of the soil. In this project, the type of clay soil with high plasticity properties. So it should be repaired first.
2. The recommended soil improvement is jet grouting, by adding cement material into the soil so that the soil becomes denser and harder. This method also does not cause vibration or noise.
3. If the project is already running without any improvement, it should be strengthened by adding drill piles into the existing pile group foundation.
4. Do not stockpile too much soil at the project site and soil filling should be carried out gradually and removed gradually as well.
5. In the field conditions of this project and based on the type and nature of the soil, a drilled pile foundation should be used, so as not to cause an impact load that can cause additional lateral loads.

References

[1] Bowles, J. (1991). Sifat-sifat Fisis dan Geoteknis Tanah (Mekanika Tanah). Jakarta: Erlangga.

[2] Bustamante, M., & Gianeselli, L. (1982). Pile bearing capacity prediction by means of static . Proc. of the Second European symposium on Penetration Testing, 493-500.

[3] Das, B. M., & Sobhan, K. (2014). Principles of Geotechnical Engineering. Cengage Learning.

[4] Georgiadis, M., & Georgiadis, K. (2010). Undrained Lateral Pile Response in Sloping Ground. Journal of Geotechnical and Geoenvironmental Engineering ASCE.

[5] Hakim, R. A., & Akbar, A. (2018). Analisis Produktivitas Hydraulic Static Pile Driver Pada Pembangunan Apartemen Victoria Square Tower B Tangerang Banten. Jurnal Teknik Sipil ITB, 103-112.

[6] Meyerhof, & Valsangkar. (1981). Lateral Resistance and Deflection of Rigid Walls and Piles in Layered Soils. Ottawa: National Research Council of Canad.

[7] Rajashree, & Sitharam. (2001). Nonlinear finiteelement modeling of batter piles under lateral load. Journal of Geotechnical and Geoenvironmental Engineering.