Analysis of the Bearing Capacity of Piling Foundation for Bridge Structures in Clay Soils

(Case Study: Cibitung - Cilincing Toll Road Project Section 3)

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Abstract

The Cibitung - Cilincing toll road is faced with problems across many rivers and marshlands where the swampland is identified as clay. In building construction, the foundation is very important in bearing the burden of working on the upper construction. This Final Project contains the calculation of the carrying skin capacity and the end resistance of the pile using the Suyono method. S and Nakazawa (1990) based on N-SPT data and dynamic methods using the formula of Hiley (1930) based on the pile driving record data, then proceed to the calculation of the carrying capacity of the pile group, after that calculating the decrease of the pile using the Vesic method (1977). From the results of the analysis conducted by the author in calculating the bearing capacity to using N-SPT data and pile driving record data, the author gets that from the pile diameter of 50 cm, the carrying capacity of a single-pole is 66-ton, obtained using the method of Suyono S and Nakazawa, based on the formula of Hiley, it is obtained 139.34 tons, and settlement that occurred in the pile group foundation was an immediate settlement is 11.2 cm and a consolidation settlement is 6.2 cm.

Keyword: Clay soil, pile carrying capacity, settlement

1 Introduction

The Cibitung - Cilincing Toll Road Project consists of 4 sections, namely section 1 of Cibitung - Telaga Asih, Section 2 of Telaga Asih - Tambelang, Section 3 of Tambelang - Mekar Jaya, and Section 4 of Mekar Jaya - Cilincing.

In the initial planning, the Cibitung - Cilincing Toll Road project used a pile of land, but the land that was passed by the Cibitung - Cilincing Toll Road many of which were previously swamp and agricultural soils had sufficiently deep clay content. If using a pile of solid land will take a long time while the BPJT wants the Cibitung - Cilincing Toll project to be completed quickly because it will later become a busy access for the drivers. Besides that, in the section of the Cibitung - Cilincing toll road section 3, there are many underpass bridges to cross rivers and residents' roads that have high clearance.

Formulation problem:

- a. How is the bearing capacity calculation of the piles group in the Cibitung – Cilincing toll road project section 3?
- b. How is the settlement calculation of the piles in the Cibitung – Cilincing toll road project section 3?
- c. Is the bridge structure able to accept the work load?

Research purpose:

- a. Calculate the bearing capacity of the piles group
- b. Calculate the settlement of the piles
- c. Check whether the foundation power accepts the burden of working

2 Methodology

In compiling this final project report, the writer utilizes data relating to the analyzed project, namely the construction of the Cibitung - Cilincing Toll Road section section 3. Broadly speaking, the data is divided into 2, namely:

- 1) Primary data is data that is directly related to the state of the project being analyzed. The data is in the form of a SPT investigation report, a test report from the soil mechanics laboratory, design drawings and loading planning data from the planning consultant.
- 2) Secondary data is data obtained by the author through intermediary media such as books, research that has been done, journals, etc.

Project data

Project name : Cibitung – Cilincing Toll Road Project Section 3
 Project Location : Tambelang Sub District – Mekarjaya Sub District, Bekasi District
 Building Function : Expressway
 Project Owner : PT. Cibitung Tanjung Priok Port Tollways (CTP)
 Bottom Structure : Driven Piles Foundation
 Planning Consultant : PT. Purna Jasa Bima Pratama
 Supervising Consultant : PT. Virama Karya Join Operation SMEC
 Executive Contractor : PT. Waskita Karya

Figure 1 Research Flowchart

Source : Research data

3 Result and analysis

3.1 Single pile bearing capacity (Suyono S & Nakazawa 1990)

- A. End bearing capacity (Q_b)
 End bearing capacity calculate by equation :

$$Q_b = q_d \times A$$

With :

$$\frac{L}{D} = \frac{0,6}{0,5} = 1,200 \text{ from intensity comparison graph obtained } \frac{q_d}{N} = 12$$

$N1 = 50$ from the results of the N value at the end of the pole

$$N2 = \frac{15 + 9 + 50}{3} = 25$$

$$N = \frac{N1 + N2}{2} = \frac{50 + 25}{2} = 37,5$$

$$q_d = 12 \times 37,5 = 450 \text{ ton/m}^2$$

$$A = \frac{1}{4} \pi \cdot d^2 = \frac{1}{4} \pi \cdot 0,5^2 = 0,196 \text{ m}^2$$

$$Q_b = q_d \times A = 450 \times 0,196 = 88,4 \text{ ton}$$

B. Skin Friction Capacity

$$Q_f = U \cdot \sum li \cdot fi$$

Furthermore, the calculation of the carrying capacity of a single pile blanket is presented in Table 1 according to each N-SPT value for each depth

Table 1 The intensity of the pole friction resistance

Depth	N-SPT Value	N-SPT Rata-rata	Li	Fi	Li x Fi
3 - 4	3	1.50	1	0.30	0.30
4 - 5	1	2.00	1	2.00	2.00
5 - 6	0	0.10	9	0.10	0.90
6 - 7	0				
7 - 8	0				
8 - 9	0				
10	0				
11	0				
12	0				
13	0	4.60	4	4.60	18.40
14	0				
15	5				
16	4				
17	7	6.50	3	6.50	19.50
18	7				
19	1				
20	4	8.33	2	8.33	16.67
21	13				
22	8				
23	5	21.50	3	21.50	64.50
24	12				
25	15				
26	9				
27	50				

$$\sum li \cdot fi = 126,27$$

So, the friction capacity (Qf) is

$$Q_f = U \cdot \sum li \cdot fi = 1,571 \times 126,27 = 198,34 \text{ ton}$$

C. Ultimate Bearing Capacity

In the case of our soil investigation data, the N-SPT is worth 50 at a depth of 27 meters but after that it goes back down to 20, then goes up again and down again, so the authors assume that the pole is only supported by the carrying capacity of the pole blanket. Then the value of Qu is

$$Q_u = Q_f = 198,34 \text{ ton}$$

D. Bearing Capacity Permit

The safety factor used is equal to, n = 3 (Construction of a highway bridge with supporting poles, in terms of fixed loads). So that the bearing capacity of a single pile permit is as big as:

$$Q_a = \frac{1}{FK} \cdot (Q_f) = \frac{1}{3} \cdot 198,34 = 66,11 \text{ ton} = 66 \text{ ton}$$

3.2 Dynamic Bearing Capacity (Hiley 1930)

Piles with 27 m embedded pole length with 12m + 12m + 12m configurations will be built with diesel hammer. Penetration is taken from the calendering data in the field in the last 10 blows is 1.2 cm

- Machine efficiency = 85% (from table)
- Equipment Specify
 - Ram and casing weight (W_r) = 6,5 ton = 65 kN
 - Hammer Height (h) = 2 m
 - Final set penetration (S) = 1,2 cm
- Q_u = 66 ton

Precast spun pile diameter 50 cm with grade k-600 ($F_c' = 55,08$ Mpa), data as follows :

- Pile diameter = 50 cm = 0,5 m
- Pile area (A_s)
 - $= \frac{1}{4} \cdot \pi \cdot 0,50^2 = 0,19635 \text{ m}^2$
 - $= \frac{1}{4} \cdot \pi \cdot 0,41^2 = 0,1320 \text{ m}^2$
 - $= 0,19635 - 0,1320$
 - $= 0,06435 \text{ m}^2$
- Elasticity modulus of pile (E_p) = $4700 \cdot \sqrt{f_c'}$
= 34881473,59 kN/m²
- Weight of pile (W_p) = $290 \text{ kg/m}^3 \times 27\text{m}$
= 7,83 ton

Hiley calculation

$$K1 = \frac{W_r}{A_s} = \frac{65 \cdot 1000}{643,24 \cdot 100} = 1,010 \text{ MPa}$$

$$K1 = 3 \text{ mm} = 0,003 \text{ m}$$

$$K2 = \frac{Q_u \cdot L}{A \cdot E} = \frac{660 \cdot 27}{0,064324 \cdot 34881473,59}$$

$$k_2 = 0,007924 \text{ m} = 7,942 \text{ mm}$$

$$Q_u = \frac{0,85 \cdot 65 \cdot 2}{0,012 + 1/2(0,003 + 0,007924 + 0,0025)} \times \frac{65 + (0,5)^2 78,3}{65 + 78,3}$$

$$Q_u = 3483,59 \text{ kN}$$

$$Q_{all} = \frac{Q_u}{SF}$$

$$Q_{all} = 139,34 \text{ ton}$$

3.3 Bearing capacity of Piles Group

A. Look the number of piles

Known :

$$P = 1006,9 \text{ ton}$$

$$Q_a = 66 \text{ ton}$$

$$n = \frac{P}{Q_a} = \frac{1006,9}{66} = 15,26 \text{ piece (minimum piles)}$$

used : 25 buah

with :

$$m = 5 \text{ (number of rows)}$$

$$n = 5 \text{ (number of columns)}$$

$$d = 0,5 \text{ m}$$

$$S = (2,5-3,0)d \text{ used } S = 2,8 \cdot d = 2,8 \cdot 0,5 = 1,4 \text{ m}$$

A. Efficiency based on Converse – Labarre equation :

$$E = 1 - \frac{19,654}{90} \left[\frac{(5-1)5 + (5-1)5}{5 \cdot 5} \right] = 0,651$$

The efficiency value of the pile according to Converse-Labarre is $E = 0.651$ (taken the smallest). So, the value of the carrying capacity of the vertical pile group is

$$Q_g = n \cdot Q_a \cdot E$$

$$Q_g = 25 \cdot 67 \cdot 0,651 = 1089,753 \text{ ton} \geq P = 1006,9 \text{ ton}$$

3.4 Settlement

Settlement calculation is divided into 2 components, namely: an immediate settlement and a settlement in consolidation. The thickness of the soil layers (H) in calculating the settlement is presented in the figure below

Figure 2 Thickness of soil layers

Source : Research data

3.4.1 Immediately settlement

Calculation for the first layer :

$$Q_{\text{beban}} = 1007 \text{ Ton}$$

$$E = 3317 \text{ kN/m}^2$$

$$H = 3,00 \text{ m}$$

$$B = 6,1 + \left(\frac{1}{4} \cdot (19 - 3) \cdot 2 \right) = 14,10 \text{ m}$$

$$L = 6,1 + \left(\frac{1}{4} \cdot (19 - 3) \cdot 2 \right) = 14,10 \text{ m}$$

$$q_n = \frac{Q_{\text{load}}}{B \cdot L} = \frac{10070}{14,10 \times 14,10} = 49,68 \text{ kN/m}^2$$

$H/B = 0,21$; $L/B = 1,00$; from *janbu et al* equation graph at figure 2.3 got value $\mu_1 = 0,25$ and $L/B = 1,00$; $D/B = 1,13$; from *janbu et al* equation graph at figure 2.3 got value $\mu_0 = 0,72$

$$S_i = 0,25 \cdot 0,72 \cdot \frac{49,68 \cdot 14,1}{3317} = 0,038 \text{ m}$$

Henceforth, the calculation of the immediately settlement in the foundation is presented in Table 2 according to each of these soil layers :

Tabel 2 immediately settlement calculation

Depth (m)	H	B	L	q_a (kN/m ²)	H/B	L/B	μ_1	D/B	μ_0	I	S_i (m)
19 - 22	3.00	14.10	14.10	49.68	0.21	1.00	0.25	1.13	0.72	-	0.038
22 - 24	2.00	17.10	17.10	33.78	0.12	1.00	0.08	0.94	0.75	-	0.009
24 - 28	4.00	19.10	19.10	27.08	0.21	1.00	0.15	0.84	0.77	-	0.008
28 - 33	5.00	23.10	23.10	18.51	0.22	1.00	-	0.69	-	0.87	0.042
33 - 35	2.00	28.10	28.10	12.51	0.07	1.00	0.08	0.57	0.84	-	0.003
35 - 39	4.00	30.10	30.10	10.90	0.13	1.00	0.09	0.53	0.85	-	0.005
39 - 43	4.00	34.10	34.10	8.49	0.12	1.00	0.08	0.47	0.87	-	0.004
43 - 48	5.00	38.10	38.10	6.80	0.13	1.00	0.09	0.42	0.88	-	0.003
Jumlah penurunan segera											0.112

Based on the calculation table 2 obtained the amount of immediately settlement is 0.112 m or 11.2 cm.

3.4.2 Consolidated Settlement

Calculation first layer :

$$\Delta P = \frac{10070}{7.5 \cdot 7.5} = 175,60 \text{ kN/m}^2$$

$$P_0' = \gamma \cdot Z$$

For the overburden stress can be seen in the figure below :

Figure 3 Overburden stress graph

$$S_c = \frac{0,04 \cdot 3}{1 + 1,15} \cdot \log \left(\frac{110,5 + 175,6}{110,5} \right) = 0,023 \text{ m}$$

For the calculation of the consolidation settlement in other soil layers is presented in Table 3

Tabel 3 Consolidation settlement calculation

Depth (m)	eo	Δp (kN/m2)	p0' (kN/m2)	Cc	Cr	Sc (m)
19 - 22	1.15	175.60	110.50	0.20	0.04	0.023
22 - 24	0.9		128.00	0.20	0.04	0.016
24 - 28	1.15		159.00	0.06	0.01	0.007
28 - 33	0.45		213.00	0.05	0.01	-
33 - 35	0.90		254.00	0.05	0.01	0.002
35 - 39	1.15		287.00	0.06	0.01	0.005
39 - 43	1.15		331.00	0.06	0.01	0.004
43 - 48	1.15		380.50	0.06	0.01	0.005
Jumlah penurunan konsolidasi						0.062

Based on table 3 obtained consolidation settlement is 0,062 m or 6,2 cm.

4 Conclusion

- From the results of the analysis, with a diameter of 50 cm piles producing a vertical bearing capacity of 66 tons of single pile (QA), the dynamic bearing capacity derived from the power of the stakes using the Hiley formula is 139.34 tons.
- The settlement that occurs in the pile group foundation in the form of an immediately settlement is 11.2 cm and the consolidation settlement is 6.2 cm..
- The foundation of the pile group is safe in accepting work loads, both vertical and horizontal because the bearing capacity is more than the working load (Q) of 1006.9 tons.

5 Recommendation

- Because the calculation of dynamic bearing capacity using the method of Hiley (1930) has more than double the value of the bearing capacity calculation using the Suyono S and K Nakazawa methods, in my opinion for the piling equipment utilization can reduce the specification of the piling equipment to be more efficient.
- Need to add the other bearing capacity of static methods for comparison.

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