Analysis of the Bearing Capacity of Bore Pile Foundation on the C83 Suites Building Countruction Project in Cirebon

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Abstract. In soil testing using sondir in the C83 Suites building construction project in Cirebon City, the lowest soil carrying capacity was found at the S-1 point. In this study, an analysis of the carrying capacity of a bore pile with a diameter of 40 centimeters with a depth of 12 meters was carried out to obtain a comparison of calculation results using three methods, namely the LCPC (Bustamante & Gianeselli) method, the Schmertmann & Nottingham method, and the Direct method. The results of the calculation using the LCPC method (Bustamante & Gianselli) obtained Qu= 232,001 tons, Qa = 92,800 tons. Then using the Schmertmann & Nottingham method, Qu= 301,764 tons was obtained, Qa = 120,705 tons. Meanwhile, using the Direct method, it was obtained at the S-1 point with Qu= 115,158 tons, Qa = 46,063 tons.

Keywords: Bore Pile, Foundation Bearing Capacity

1. Introduction

In the building construction project, there are several procedures that are carried out, one of which is soil testing at the construction site, this is done in an effort to obtain information on soil parameters that can be used in foundation analysis. Soil investigation can be carried out in the field and in the laboratory [1]. Soil investigations are carried out for data in the design of foundations on tall building structures and buildings that have a large load as well as the condition of the soil layer in the field, for example, buildings, pavements or soil retaining walls, dams, roads, docks, and other buildings.

The foundation structure is a structure that is the lowest/lowest part of the building [1]. The foundation itself has the function of transmitting the structural styles of the upper building to the hardest layer of soil or rocks below. There are two classifications of foundations, namely shallow foundations and deep foundations. One type of deep foundation is bore pile foundation, this type of foundation is made of a combination of reinforced iron cast concrete. The carrying capacity of the bore pile foundation is calculated based on the soil data obtained such as the results of the probe test. The calculation can be done using several standard methods by adding the bearing capacity of the end of the pole with the bearing capacity of the side of the pile.

The C83 suites building construction project is a construction project located on Jalan Kedrunan no. 5 Kesenden, Cirebon City Prosecutor's District. The project builds a 5-storey building that will be used as an inn. In this project, soil testing was carried out directly in the field using a sondir tool carried out by PT. Meta Bumi Systema by taking three test points, this was done in an effort to obtain data on the comparative carrying capacity of the soil at the work site. After testing, there is a difference in soil type and cone tip resistance value, this can affect the results in the analysis of the bearing capacity of the bore pile foundation apart from the bore pile design factors and the calculation method used. From the test results, it is indicated that point 1 (S-1) has the lowest carrying capacity compared to the test locations of point 2 (S-2) and point 3 (S-3).

With the problem of differences in soil carrying capacity that occurred in the construction project of the C83 Suites building in Cirebon City, this study intends to analyze the carrying capacity of bore pile poles with a diameter of 40 centimeters at a depth of 12 meters by considering soil testing data factors, bore pile design, and calculation methods. Calculations were made to determine the carrying capacity of the bore pile pole in the sondir test at point 1 (S-1) using the LCPC (Bustamante & Gianeselli) method, the Schmertmann & Nottingham method, and the Direct method.

2. Methods

The research was carried out in the C83 suites building construction project in Cirebon City. In this study, an analysis of the bearing capacity of the bore pile foundation based on soil parameters from the results of the sondir test was carried out using the LCPC calculation method (Bustamante and Gianeselli), the Schmertmann & Nottingham method, and the Direct method. The flow of this research begins with conducting literature studies and field studies in problem formulation, determination of research objectives, and research limitations.

This research was conducted to obtain a comparison of the results of the calculation of the bearing capacity of the bore pile pile in the test of point 1 (S-1) sondir using the LCPC (Bustamante & Gianeselli) method, the Schmertmann & Nottingham method, and the Direct method. The data used in this study is secondary data obtained by means of direct surveys at the construction site. The data obtained from the field is in the form of soil data from sondir testing conducted by the PT. Meta Bumi Systema.

In the data analysis, calculations were made to find out the ultimate bearing capacity/pole limit Q_u which is obtained from the sum of the pole end prisoners and the pole side prisoners then the carrying capacity of the pole permit Q_a which is obtained from the ultimate bearing capacity divided by the safe factor. The equations of the methods used are as follows:

2.1 LCPC method (Bustamante dan Gianeselli)

The formula for calculating the bearing capacity of the pole suggested by Bustamante and Gianeselli [2]
Calculation of the ultimate bearing capacity of the pole:

$$Q_u = Q_b + Q_s. \quad (1).$$

Alternatively:

$$Q_u = A_b \times q_b + A_s \times f_s. \quad (2).$$

Calculation of the ultimate bearing capacity of the pole permit:

$$Q_a = \frac{Q_u}{SF}. \quad (3).$$

Description:
Q_u = Ultimate bearing capacity of the pile (kg/cm²).
Q_b = Bearing capacity of the end the pile (kg/cm²).
Q_s = Bearing capacity of the side of the pile (kg/cm²).
Q_a = allowable bearing capacity of the pile (kg/cm²).
A_b = Base area of the pile (cm²).
A_s = Pile shaft area (cm²).
q_b = Unit end bearing resistence (kg/cm²).

f_s = Unit skin friction resistance (kg/cm²).
SF= Factor of safety.

In the Bustamante and Gianeselli method, the end bearing resistance (q_b). and the skin friction resitance (q_s). are obtained from the cone resistance (q_c)., as show in the following equations:

$$q_b = K_b \times q_{eq}. \quad (4).$$

Meanwhile, the shaft resistance of the pile Bustamante and Gianeselli is calculated using the following equation::

$$f_s = 0{,}05 \times \alpha \times q_c. \text{ } (f_s \text{ maksimum } 1{,}2 \text{ kg/cm}^2). \quad (5).$$

description:
q_b = Unit end bearing resistence of pile (kg/cm²).
K_b = Faktor nilai konus berdasarkan tabel 1. Cone factor value based on table 1.
q_{eq} = Average cone resistance within 1.5 D above and 1.5 D below the pile tip (kg/cm²).
f_s = Unit shaft resistanc of the pile (kg/cm²).
α = Adhesion factor, taken as 1 for normally consolidated clay and 0,5 for overconsolidated clay.

Table 1. Values k_b. Source: Lim, 2014

Soil Type	**Pile Tip Cone Factor**	
	Drillin Pile	**Driven Pile**
[1] Clay and Silt	0,375	0,15
[2] Sand and Gravel	0,600	0,375
[3] Limestone	0,200	0,400

2.2 Schmertmann and Nottingham method

According to Scmertmann and Nottingham, as cited in [3], the ultimate bearing capacity ("Q" _"u") is calculated using the following equation::

$$Q_u = A_b \times f_b + A_s \times f_s. \quad (6).$$

Alternatively:

$$Q_u = A_b \times \omega \times q_{ca} + A_s \times K_f \times q_f. \quad (7).$$

Description:
A_b = Pile cross sectional area (cm²).
A_s = Pile surface area (cm²).
f_b = Unit end bearing resistance (kg/cm²).
f_s = Unit skin friction resistance (kg/cm²).
q_{ca} = Average cone resistance (kg/cm²).
q_f = Cone side friction resistance (kg/cm²).
K_f = Dimensionless coefficient.
ω = Corelation coefficient.

1) Unit end resistance
   The Schmertmann and Nottingham methods for unit area pile tip resistance are obtained from the average values of q_c along 8D above the pile base up to 0.7D or 4D. Here are the steps to determine (q_{ca}). that is:
   a) Refer to the cone resistance diagram (q_c). Based on the depth, select a temporary depth that is considered close to the ultimate capacity of the pile used.
   b) At the depth of the pile being considered, observe the average cone resistance (q_c). Taken at a distance of 8D above the tip depth and 4D below it.
   c) Determine (q_{c1}) by calculating the average cone resistance (q_c). along the broken line in the 8D zone above the base of the pile. The trajectory of the broken line indicates the values of q_c that are representative and estimated to be safe.

d) Trace the trajectory of the broken line down to 4D below the pile. Determine (q_{c2}). by calculating the average q_c along that line.
e) Calculate q_{ca}= ½ (q_{c1}+q_{c2}).
f) Using the values in table 2, determine ω to consider the influence of gravel content or OCR.
g) Calculate the unit tip resistance with the following equation:

$$f_b = \omega \times q_{ca} \leq 150 \text{ kg/cm}^2. \qquad (8).$$

Description:

f_b : Unit end bearing resistance (kg/cm²).
ω : Correlation coeficient dependent on OCR (table 2).
q_{ca} : ½ (qc1 + qc2). (kg/cm²).
q_{c1} : q_c average within the 8D zone above pile tip (kg/cm²).
q_{c2} : q_c average within the 0,7D or 4D zone below the pile base (kg/cm²).

Table 2. Factor ω (deRuiter dan Beringen, 1979).
Source: Hardiyatmo, 2011

Soil Condition	Factor
[1] Normally consolidated sand (ocr = 1)	1
[2] Sand contains many coarse gravel particles; sand OCR = 2 to 4	0,67
[3] Gravel, sand with OCR = 5 to 10	0,5

2) Unit Friction resistance

$$f_s = K_f \times q_f. \qquad (9).$$

Description:

f_s = Unit Skin friction (kg/cm²), whit its value limited to 1,2 kg/cm² (120 kPa).
q_f = Sleeve friction (kg/cm²).
K_f = Dimensionless Coeficient.

When the sand pile, K_f depending on the L/d ratio (L = depth and d = diameter tiang). Whitin the first 8D depth from the ground surface, K_f interpolated from zero at the ground surface to 2,5 at a depth of 8D. Below this depth,the value of K_f decreases from 2,5 to 0,891 at a depth of 20D, or it can be considered overall with a K_f of 0,9. Another method, forsandy soil (does not applay to clay). The unit skin friction can be determined from cone q_c.

$$f_s = K_c \times q_c. \qquad (10).$$

Description:

f_s = Unit friction resistance (kg/cm²), limited to a value of 1,2 kg/cm² (120 kPa).
q_c = Cone resistance (kg/cm²).
K_c = Dimensionless coefficient whose value depends on the type of pile.
Steel column with open bottom end.
K_c= 0,8 %.
Steel column with closed bottom end.
K_c= 1,8 %.
Concrete column
K_c=1,2 %.

2.3 Direct method

In the direct method an internal equation approach in used[4].With the following formula explanation. The ultimate bearing capacity of pile foundation is expressed by the formula:

$Q_{ult} = A_b \times q_c \times A_s \times F_s$. (12).
End bearing capacity of pile:
$Q_b = A_b \times q_c$. (13).
Description:
Q_b = End bearing capacity (kg).
A_b = Cross section area (cm²).
q_c = Average resistance (kg/cm²).
The friction resistance along the exterior vertical wall is:
$Q_s = A_s \times F_s$. (14).
Description:
Q_s = Skin friction capacity/shear capacity (kg).
A_s = Surface area (cm²).
F_s = wall resistance/JHL (kg/cm²).
F_s Can be obtained using the equation = 0,012 × q_c.
$Q_{ult} = Q_b + Q_s$. (15).
$Q_{all} = Q_{ult} / S_f$. (16).
Description:
Q_{ult} = ultimate bearing capacity (kg).
S_f = Safety factor.

2.4 Foundation safety factor

According to H. C. Hardiyatmo (2008). In order obtain the allowable bearing capacity of a pile the ultimate capacity must be divided by a certain factor of safety. The safety factor is a appiled with the purpose of:

1) To ensure safety in consideration of the uncertaintes associated with the applied calculation method.
2) The provide safety against the variability of shear strenght and soil compressibility.
3) The provide assurance that the pile load is sufficienty safe to withstnad the applied loads.
4) To provide assurance that the total settlement occuring in either a singgle pile or a pile group is still within the allowable limits.

Table 3. Safety factor recommended by (Reese & O 'Neill, / 1989). Source: Hardiyatmo, 2008

Structure	Safety Factor (F) Good Control	Normal Control	Bad Control	Very Bad Control
[1] Monumental	2,3	3	3,5	4
[2] Permanent	2	2,5	2,5	3,4
[3] Temporary	1,4	2,0	2,3	2,8

In geotechnical engineering design (SNI-8460, 2017). In foundation work, The bearing capacity of the foundation permit is the ultimate bearing capacity divided by a safety factor with a minimum value of 3 shallow foundations or a minimum of 2,5 for deep foundations.

3. Results and Discussion

In the analysis stage of a bore pile with a diameter of 40 centimeter and depth of 12 meters using the LCPC method (Bustamante and Gianeselli), the Schmertmann and Nottingham method, and Direct method the following results were obtained:

3.1 LCPC (Bustamante dan Gianeselli) Method.
The average cone resistance value q_c at 1,5D above and 1,5D below the pile tip is obtained as follows:
Average cone resistance value q_{eq} = 108,571 kg/cm².

From the calculations using the LCPC (Bustamante dan Gianeselli) method the bearing capacity of the bore pile is obtained as presented in table 4.

Table 4. Recapitulation of bore pile bearing capacity using LCPC method (Bustamante and Gianeselli).

Depth (m)	Q_b **(tons)**	Q_s **(tons)**	Q_u **(tons)**	Q_a **(tons)**
[1] 12,00	80,820	180,864	261,684	104,673

3.2 Schmertmann dan Nottingham Method
The average cone resistance value q_c, taken at a distance of 8d above the pile tip and 4d below the pile tip the results are as follows:
Average cone resistance value q_{ca}= 96,258 kg/cm².

From the calculations using the Schmertmann and Nottingham method the bearing capacity of the bore pile is obtained as presented in table 5.

Table 5. Recapitulation of bore pile bearing capacity using Schmertmann and Nottingham method.

Depth (m)	Q_b **(tons)**	Q_s **(tons)**	Q_u **(tons)**	Q_a **(tons)**
[1] 12,00	120,900	180,864	301,764	120,705

3.3 Direct Method
The average cone resistance value (q_c) the results obtained from the cone penetration test (CPT) are as follows:
Average cone resistance value q_c= 37,576 kg/cm².

From the calculations using the Direct method the bearing capacity of the bore pile is obtained as presented in table 6.

Tabel 6. Recapitulation of bore pile bearing capacity using Direct method.

Depth (m)	Q_b **(tons)**	Q_s **(tons)**	Q_u **(tons)**	Q_a **(tons)**
[1] 12,00	47,196	67,962	115,158	46,063

4. Conclusions

The bearing capaity of a bore pile with a diameter of 40 centimeters and a depth of 12 meters based on the cone penetration test (CPT). at test point 1 (S-1). on the C83 Suites building construction project in Cirebon City, using the LCPC (Bustamante and Gianeselli) calculation method, yealed the following results: ultimate capacity Q_u= 232,001 tons, and allowable bearing capacity Q_a= 92,800 tons. Then using the Schmertmann and Nottingham method the results obtained were: ultimate capacity Q_u=301,764 tons, and allowable bearing capacity Q_a=120,705 tons. Meanwhile using the direct method the results obtained are: ultimate capacity Q_u= 115,158 tons, and allowable bearing capacity Q_a=46,063 tons.

5. References

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