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The Bearing Capacity of Single Piles at the Aek Pardamean Baru Bridge

Bagas Irham Azzahri, Abdul Jalil*, Yovi Chandra
Jurusan Teknik Sipil, Universitas Malikussaleh, Lhokseumawe, Aceh, Indonesia
*Corresponding Author: abduljalil@unimal.ac.id

Abstract
The pile foundation is one of the structural elements of a building, especially the high bearing capacity at the deepest below-the-ground surface such as bridges. Therefore, it is necessary to plan a foundation to maintain the stability of the building. The main purpose of the research is to determine the bearing capacity and deflection of a single pile using the Meyerhof, Vesic methods, and Plaxis software modeling. The skin friction pile was adopted λ and α method. The pile head deflection using Broms method. The end bearing capacity and skin friction of a single pile were obtained 183.86 tons, so the Plaxis software modeling is found 351.8 tons. The results of the bearing capacity between Plaxis and back analysis was differences, since the difference assumes parameter data and calculated process. The pile head deflection was found 10.39 cm movement to a lateral direction.
Keywords: Pile Foundation; Bearing Capacity; Deflection

Introduction
The pile foundation is an important structural element for a building, especially in structures that have a large enough load such as bridges. Therefore, it is important to plan the foundation properly to maintain the stability of the building.

There are two important aspects of pile foundation planning, namely axial and horizontal bearing capacity. The axial bearing capacity of a pile foundation is the ability of a pile to withstand the vertical load that it withstands (E. Bowles 1992). The axial bearing capacity of the pile foundation is obtained based on the bearing strength of the pile end (end bearing) and the friction strength of the pile blanket (skin friction). The horizontal bearing capacity of a pile foundation is the ability of a pile to withstand the horizontal forces acting on the pile (E. Bowles 1992). According to (Braja M. 2019) Pile foundations can resist horizontal forces by distributing passive pressure in the soil along the depth of the pile. The degree of distribution of soil response depends on the flexibility of the pile, the flexibility of the soil and the strength of the pile edges. If the pile foundation cannot withstand the horizontal forces that occur, the pile foundation will deflect. Deflection in pile foundations is a shift that occurs in the pile due to the load acting on the pile. The deflection that occurs in the pile foundation must be within the tolerance limit to avoid collapse of the structure above it. These two aspects are very important in pile foundation planning to prevent collapse of the structure supported by the pile foundation.

In this research, it is carried out by comparing the results of pile foundation capacity calculations with several methods and Plaxis software modeling assistance. As for the results of the deflection of a single pile foundation, only the deflection results are attached. This research was conducted on the Aek Pardamean Baru Bridge in Mandailing Natal Regency, the pile under review was number 16 in Abutment 01. The analysis of bearing capacity and deflection of single piles uses the Mayerhoff method and the Vesic method to calculate the end bearing capacity. For the calculation of pile blanket capacity (skin friction) using Coyle and Castello method, λ method and α method. While for the help of the application using Plaxis software. For the calculation of single pile deflection using Broms method.

Method
Pile foundations can resist horizontal forces by distributing passive pressure in the soil along the depth of the pile. The degree of distribution of soil response depends on the flexibility of the pile, the flexibility of the soil and the strength of the pile edges. If the pile foundation cannot withstand the horizontal forces that occur, the pile foundation will deflect. Deflection in pile foundations is a shift that occurs in the pile due to the load acting on the pile. The deflection that occurs in the pile foundation must be within the tolerance limit to avoid collapse of the structure above it. These two aspects are very important in pile foundation planning to prevent collapse of the structure supported by the pile foundation.

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Meyerhoff Method

According to (Meyerhoff 1976), For piles in cohesive soils, the pile tip capacity is estimated under undrained loading conditions. The equation for pile tip bearing capacity according to Meyerhoff is as shown below:

$$Q_p = 9 * c_u * A_p \quad (1)$$

Caption:

Q_p = pile end bearing (ton)
A_p = surface area at the end of the pile (m^2)
c_u = undrained cohesion of the soil $\left(kN/_{m^2}\right)$

Vesic Method

In clay soil, (Vesic 1977) suggests an end capacity formula as shown below:

$$Q_p = A_p * q_p = A_p * c_u * N_c \quad (2)$$

Caption:

Q_p = pile end bearing (ton)
A_p = surface area at the end of the pile (m^2)
c_u = undrained cohesion of the soil $\left(kN/_{m^2}\right)$
N_c = bearing capacity factor

Coyle dan Castello Method

(Coyle and Castello 1981) formulated for the skin friction capacity of poles in sandy soils as shown below:

$$Q_s = f_{av} * p * L = (K * \sigma'_o * tan\delta') * p * L \quad (3)$$

Caption:

Q_s = skin fricion capacity of pile (ton)
f_{av} = skin friction resistance at each depth $\left(kN/_{m^3}\right)$
σ'_o = average effective pressure of the layer$\left(kN/_{m^3}\right)$
K = coefficient of soil effective pressure
δ' = inner shear angle of the pile in soil
p = perimeter of the pile (m)
L = pile length (m)

λ Method

According to (Vijayvergiya and Foct 1972), the assumption that ground displacement caused by pile driving results in lateral passive soil pressure at each depth. For the skin friction resistance equation according to (Vijayvergiya and Foct 1972) as shown below:

$$Q_s = f_{av} * p * L = (\lambda * (\sigma'_o + 2 * c_u)) * p * L \quad (4)$$

Caption:

Q_s = skin fricion capacity of pile (ton)
f_{av} = skin friction resistance at each depth $\left(kN/_{m^3}\right)$
p = perimeter of the pile (m)
L = pile length (m)
c_u = undrained cohesion of the soil $\left(kN/_{m^2}\right)$

α Method

(Tomlinson 1977) suggested the following formula for the bearing capacity of the pile skin friction:

$$Q_s = f_{av} * p * L = \alpha * c_u * p * L \quad (5)$$

Caption:

Q_s = skin fricion capacity of pile (ton)
f_{av} = skin friction resistance at each depth $\left(kN/_{m^3}\right)$
p = perimeter of the pile (m)
L = pile length (m)
c_u = undrained cohesion of the soil $\left(kN/_{m^2}\right)$

Deflection of Pile (Broms Method)

(Hardiyatmo 2008) argued that the Broms method is a more detailed method for calculating pile deflection because it utilizes a simplified soil stress scheme by assuming that around the pile depth the soil reaction or resistance reaches its ultimate value. (Broms 1964) suggested that in the analysis of pile, deflection is associated with the dimensionless factor (βL). The formula for the dimensionless factor can be seen as follows:

$$\beta = \left(\frac{K_h * d}{4 * E_p * I_p}\right)^{\frac{1}{4}} \quad (6)$$

Caption:

β = dimensionless factor
K_h= soil modulus $\left(kN/_{m^3}\right)$

d = pile diameter (m)
E_p= modulus of pile elasticity $\left({kN}/{m^4}\right)$
I_p = pile moment of inertia (m4)

- Free end piles are just like short piles βL < 1,5
- Restrained piles are like short piles βL < 0,5
- Free end piles are considered as long piles βL > 2,5
- Rsetrained piles are considered as long piles βL > 1,5

For the calculation formula of single pile deflection according to (Broms 1964) is as shown below:

$$y_o = \frac{2*H*\beta*(e*\beta+1)}{K_h*d} \quad (7)$$

Caption:

y_o = deflection of pile (cm)
H = lateral load (kN)
e = distance of lateral load from ground surface (cm)
β = dimensionless factor
K_h= soil modulus $\left({kN}/{m^3}\right)$
d = pile diameter (m)

Plaxis Modeling

In generally, the work to estimate the capacity of a single pile from the Plaxis program is as follows:

1. Soil and Pile Geometry Modeling Step
   Modeling is accomplished by inputting the shape of the soil transverse profile in the form of soil layers, pile shapes, construction levels, loading and other boundary conditions that are carried out in detail.
2. Calculation Step
   After that, the next step is to enter the geometry into the element net generation stage. Then enter the calculation. The calculation stage is the process of calculating the load on the loading with the type of calculation, namely plastic analysis.
3. Output Step
   The output stage is the output of the calculation stage. The estimated output is a graph and the result of the ultimate capacity of a single pile.

Results and Discussions

This research provides results and discussion on the calculation and modeling of Plaxis on the bearing capacity and deflection of single piles. Plaxis calculations and modeling are performed based on methods and soil parameter data. Calculations are carried out in accordance with the theory previously described.

Ultimate Bearing Capacity

The results of the capacity of single piles in pile foundation number 16 on the Aek Pardamean Baru Bridge are based on calculations using the Meyerhoff, Vesic, λ, α methods and also based on modeling using Plaxis. The bearing capacity results on the PDA Test are used as a comparison between calculations and application modeling. The ultimate bearing capacity of a single pile using the calculation of several methods was found to be 183.86 tons. The results of the ultimate bearing capacity of a single pile using Plaxis software modeling is 351.8 tons. While the results of the PDA Test were obtained at 116.04 tons. For a recapitulation of the ultimate bearing capacity results based on the calculation of several methods, Plaxis software modeling and PDA Test results can be seen in Table 1.

Table 1 Recapitulation of ultimate bearing capacity results

Method	Bearing Capacity of Pile (ton)		Ultimate Bearing Capacity of Pile (ton)
	End Bearing	Skin Friction	
Meyerhoff	70,5	#N/A	183,6
Vesic	63,1	#N/A	
λ	#N/A	109,9	
α	#N/A	124,5	
Plaxis	#N/A	#N/A	351,8
Designer	80,05	35,99	116,04

According to table 1 above, it can be seen that the results of the ultimate capacity of single piles using calculations, Plaxis software and PDA Test results obtained quite significant differences. The value of the results of the ultimate capacity of the largest single pile obtained in the Plaxis software is 351.8 tons. This happens because Plaxis modeling uses a collapse curve scheme in the loading plan. Therefore, there is a value that is greater than the results of calculations and planners. So it is necessary to re-control the calculations and planners. The results that are close to the planner's results are the results of calculations with several methods. The difference obtained from the calculation and modeling results of Plaxis software with planners is 17%. For a comparison graph of the results of single pile capacity on the New Aek Pardamean Bridge can be seen in Figure 1 below.

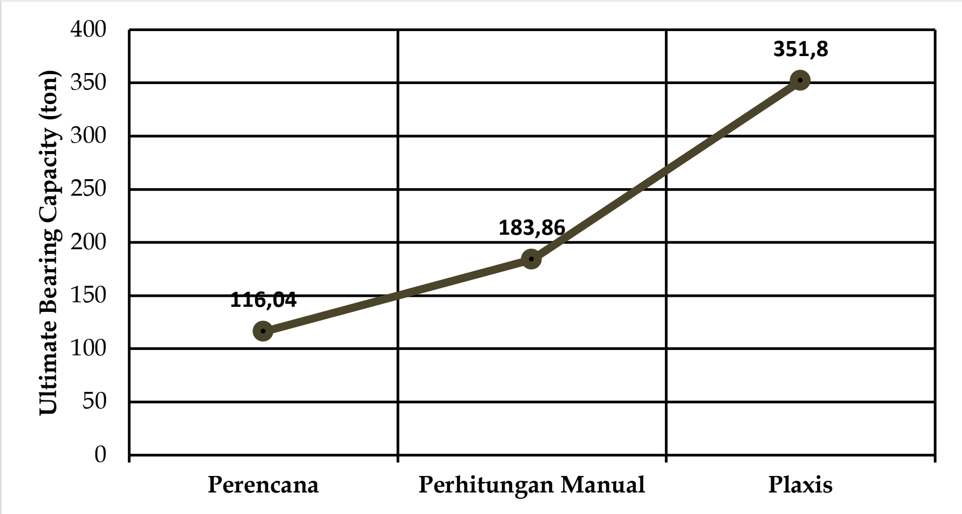

Figure 1 Comparison graphic of ultimate bearing capacity results

Pile Deflection

The results of single pile deflection on pile foundation number 16 on the Aek Pardamean Baru Bridge based on the Broms method. Based on calculations using the Broms method, the results obtained are 10.39 cm. With this result it is concluded that the deflection that occurs when receiving the ultimate lateral force is 10.39 cm. In the planner no deflection results were obtained. Therefore, there is no comparison of the results of the calculation of the deflection of a single pile with the planner.

Conclusion

The results of the calculation of the ultimate capacity of single piles using the Meyerhoff, Vesic, λ and α methods were obtained at 183.86 tons. For the results of the ultimate capacity of a single pile using Plaxis software modeling, the result is 351.8 tons. Meanwhile, the result of the planner is 116.04 tons. There is a significant difference from the calculation and modeling results of Plaxis with the planner. The difference between the calculation and modeling results of Plaxis and the planner is 17%.

The result of the calculation of single pile deflection using Broms method is 10.39 cm. Since there is no single pile deflection result listed in the planner, the deflection value in the calculation with Broms method cannot be compared..

Suggestion

Based on the results of the calculation analysis, modeling, comparison of results and conclusions listed above, the advice that can be given is that accuracy is needed in understanding the values and completeness of the data needed to calculate or in Plaxis software modeling. In analyzing the bearing capacity and deflection of poles, it is recommended to explore more with several other methods in the calculation to serve as a more extensive comparison and reference to consultants or related parties.

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