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EFFECT OF FOUNDATION DEPTH AND DIMENSIONS ON PILE FOUNDATION DESIGN HOLD LATERAL FORCE
(Case Study: Foundation of the Customs Building in Banjarmasin)

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ABSTRACT

The function of the foundation is very important in building construction. Foundation planning is intended so that a load can be supported up to a certain safety limit and the maximum load that may occur. The upper structure is supported by the lower structure as a foundation that interacts with the soil and will provide security for the superstructure. This plan analyzes the bearing capacity of the pile foundation due to lateral forces. The method is the Brinch Hansen method to determine the value of the lateral bearing capacity of the permit and the Allpile V 7.3B computer application method to determine the results of calculating the lateral deflection with variations in the length of the pile 20m, 25m, 30m, 34m, 40m and variations in the dimensions of the circular pile. D30, D35, D40 and square 30x30, 35x35, 40x40. Based on the calculation analysis, the square cross-section produces a larger permit lateral bearing capacity than the circular cross-section, while the lateral deflection produced by the square section is smaller than the circular section.
Keywords: Pile Foundation, Lateral Load, Deflection, Brinch Hansen Method, Allpile V 7.3B Computer Application Method

1. INTRODUCTION

The function of the foundation is very important because it is an underground structure that transmits the load originating from the weight of the foundation structure itself and the weight of the building above it to the subsoil below. The construction of a civil construction consists of a lower structure and an upper structure. The lower structure is supported by a foundation that interacts with the soil and will provide security for the upper structure.

Piles are one type of deep foundation where judging from the type of material, they can be wooden piles, concrete piles, steel piles, composite piles. Besides being designed to withstand axial loads, pile foundations also often have to be designed taking into account lateral loads. The sources of lateral loads themselves include earth pressure on retaining walls, wind loads, earthquake loads and eccentric loads on columns.

Estimated value of the lateral bearing capacity of the pile foundation, can be calculated from the physical data of the foundation and soil parameters, by applying the principles of mechanics. One method that can be used is the conventional method (Brinch Hansen) because it can be used to calculate the ultimate lateral resistance of short piles and has the advantage that it can be applied well to homogeneous soils, soils with c-Ø and layered soils, but only applies to piles short.

This case examines the effect of pile depth and dimensions on the design of pile foundations to withstand lateral forces at the Customs Building in Banjarmasin. This planning was carried out to develop knowledge and determine the influence of the length of the pile and the dimensions of the foundation on the design of the pile foundation to withstand lateral forces on the foundation using the Conventional Brinch Hansen method and the Allpile V 7.3B Computer Application method.

2. THEORITICAL STUDY

Conventional Method (Brinch Hansen)

This method is useful for checking the deflection of piles that experience not so large lateral loads. In the calculation, the pile is considered as a cantilever structure clamped at a depth of zf.

Free pile deflection can be expressed by the equation:

$$y = \frac{H(e + Z_f)^3}{3\,Ep\,Ip}$$

The deflection of the fixed end pile is expressed by the equation:

$$y = \frac{H(e + Z_f)^3}{12\,Ep\,Ip}$$

Where: H = lateral load (kN), Ep = elastic modulus of pile, Ip = inertia of pile, E = distance of lateral load on ground surface, zf = distance of pinch point from ground surface

The Brinch Hansen (1961) method can be used to calculate the ultimate lateral resistance of short piles.

The method is based on earth pressure theory and has the advantage of being applicable to both homogeneous soils, c-Ø soils and layered soils, but is only applicable to short piles. The ultimate soil resistance at any depth is calculated using the equation:

$$Psu = \sigma_1\, v\,.Kq + c\,.Kc$$

Where Kc and Kq are functions of Ø and x/D, the terms of which are as shown in Figure 1 below.

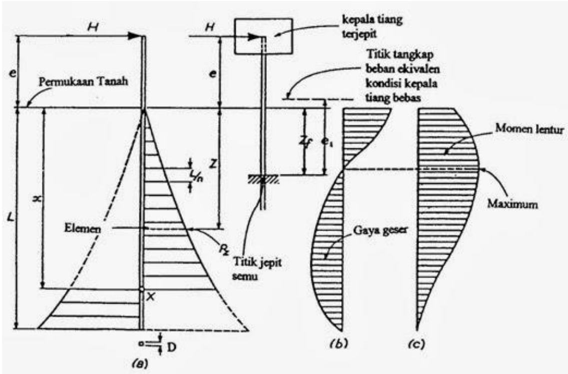

Figure 1 The Brinch Hansen method (1961)

In terms of piles that resist lateral forces, and are located on soils that have cohesion and friction (soil c – φ). The ultimate lateral soil resistance equation at any depth z based on the lateral earth pressure theory is as follows:

$$pu = p_o\, K_q + c\, K_c$$

Where: Po = vertical overburden pressure, c = cohesion, Ko Kq = function factor φ and z/d

If the pile head is clamped (pin pile), the equivalent height e1 of the force H on the ground surface is expressed by:

$$e_1 = \frac{e + zf}{2}$$

Where: e = distance of the force H from the ground surface, zf = distance from the ground surface to the pinch point

The zf distance is unknown at this stage. For practical purposes, zf is taken to be 1.5 m for sandy/stiff clay soils and 3 m for soft clay/silt soils.

P-Y Method with Computer Application (Allpile V 7.3B)

The p-y curve method is one of the settlement methods to analyze the lateral deflection of the pile. This method defines the lateral load and deflection relationship between the soil and the pile which is depicted in the p-y curve. The p-axis is the lateral soil resistance per unit length of the pile and the y-axis is the lateral deflection of the pile.

The formula for solving using the p-y curve method is as follows:

$$\frac{d^2}{d^2}\left(E_p I_p \frac{d^2y}{dx^2}\right) + P_x\left(\frac{d^2y}{dx^2}\right) - p - W = 0$$

With: Px = axial load, y = lateral deflection that occurs in depth x at the length of the pile

L, p = soil resistance, W = lateral load distributed along the pile Ep = elastic modulus of the pile, Ip = pile moment of inertia

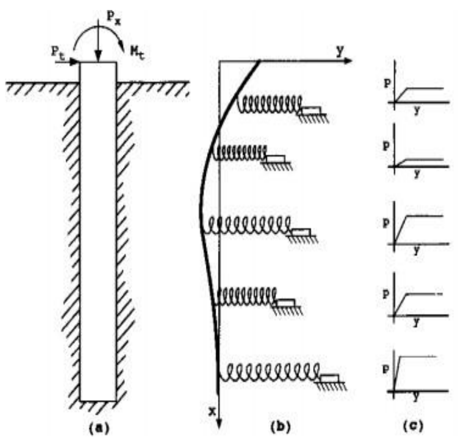

Figure 2 Illustration of lateral loading on a pile (Prakash dan Sharma, 1990)

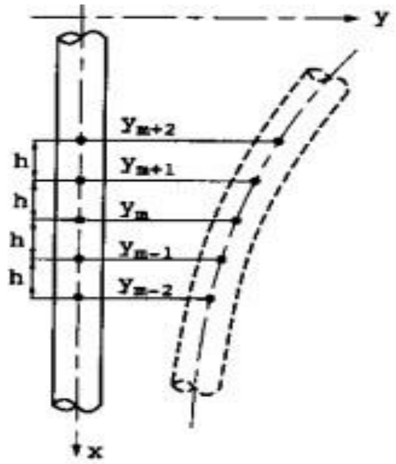

Figure 3 The deflection that occurs in the pile per depth (Prakash dan Sharma, 1990)

Figures 2 and 3 show that the pile will experience deflection due to pressure or lateral loads acting on the pile and the presence of soil pressure which causes the shape of the pile deflection to be not the same at each depth.

Solving the p-y curve method can also be solved numerically, namely with the help of the Allpile V 7.3B computer program. Allpile V 7.3B is a program in the field of geotechnical engineering specifically designed to efficiently and accurately analyze pile loading capacity. Allpile can handle all types of foundations such as drilled piles, piles, steel pipe piles, H piles, wooden piles, shallow foundations and others, so it can define new pile types and input parameters based on local habits and experience. The output of the Allpile V 7.3B program is in the form of a p-y curve and several pile behaviors which are described in the graph, such as the relationship between the load and the deflection that occurs at each depth, the bending moments, and the shear force that occurs on the pile. Analysis using the p-y curve method produces a graph of the relationship between the lateral loads and the deflections that occur on.

3. DESIGN METHOD

Design Location

The design location or object being analyzed is the Customs Office Development Project on Jl. A. Yani KM. 2 City of Banjarmasin, South Kalimantan.

Figure 4 Planning location of the Banjarmasin Customs Building

Figure 5 The current Customs Building

Design and Analysis Methods

An analysis was carried out to determine the calculation value of the bearing capacity of the allowable lateral pile and lateral deflection using the P-Y method with Computer Applications, Allpile V 7.3B and the Conventional method, Brinch Hansen with D30, D35, D40, 30x30, 35x35, 40x40 for a length (L) of 20m, 25m, 30m, 34m, 40m.

The analysis to be carried out in the design using the Conventional, Brinch Hansen method is a graph of the relationship between Permitted Lateral Bearing Capacity Vs Pile Length, L (for all variations of Circular and Square type pile dimensions). While the analysis that will be carried out in the design using the P-Y method with a computer application, Allpile V 7.3B is a graph of the relationship of Lateral Deflection Vs Pile Length, L (for all variations of Circular and Square type pile dimensions).

4. RESULT AND DISCUSSION

The soil investigation data used includes 2, namely sondir data and NSPT data. The two investigation data are included in Figure 6 which was carried out by the service provider PT. Somif Borneo Perkasa on August 2, 2020. And other supporting data such as the parameter values for each soil layer as shown in Table 1.

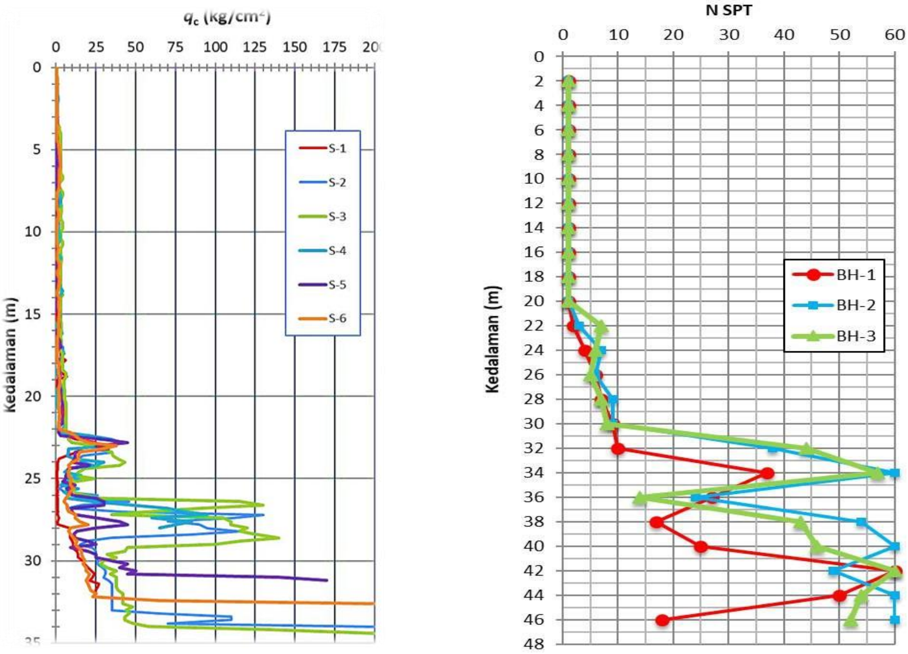

Figure 6 Sondir Soil (CPT) and the N value from the SPT test

Table 1 Parameter values for each layer of soil

Type of Soil	H (m)	γ (kN/m^3)	c_u (kN/m^2)	ϕ (°)
Silt	25	16	24	20
Clay	9	16	96	22
Sand	12	18	0	25

Source: Land Investigation Report on the Planning of the Banjarmasin Customs and Excise Building

To obtain secondary data on the lateral load of a single pile, a recalculation is carried out based on the values of the group lateral load, namely V = 50 kN, H = 1500 kN, and M_{max} = -67.6761 kN.m and the calculation results are obtained in Table 2 below.

Table 2 Secondary data of single pile lateral load

V (kN)	H (kN)	M_{max} (kN.m)
5,55	166,7	-7,519

After obtaining the secondary data on the lateral load of a single pile, the data is then input into the Allpile V 7.3B software to obtain the calculation of the lateral deflection.

Result of Calculation of Lateral Bearing Capacity

From the calculation of the lateral bearing capacity for all types of pile dimensions (circular and square), with circular pile sizes D30, D35, D40 and square types 30x30, 35x35, 40x40 and with variations in pile lengths of 20m, 25m, 30m, 34m and 40m , the calculation results are obtained in Table 3 below.

Table 3 Calculation results of lateral bearing capacity with variations in pile dimensions and the length of the pile L

L (m)	H permit (ton)					
	Circular			Square		
	D30	**D35**	**D40**	**30x30**	**35x35**	**40x40**
20	2.04	2.78	3.63	2.90	3.95	5.16
25	2.04	2.78	3.63	2.90	3.95	5.16
30	2.31	3.14	4.11	3.33	4.54	5.93
34	2.43	3.30	4.31	3.53	4.81	6.28
40	2.32	3.16	4.13	3.35	4.56	5.96

- Checking the Safety of Lateral Forces on Pile

  Maximum lateral force in the x direction on the pile, Fx = 0,55 ton, h_{ux} = 0,06 ton

  Maximum lateral force in the y direction on the pile, Fy = 0,55 ton, h_{uy} = 0,06 ton

  two-way combined lateral force, $F_{kombinasi} = h_{umax}$ = 0,09 ton

  Requirement: $\mathbf{h_{umax}} \leq$ f. $\mathbf{H_n}$

  0.09 ton < **5,96 ton** → **Fulfills SAFE Requirements (OK)**

Graph of Permitted Lateral Bearing Capacity and Pile Length Relationship

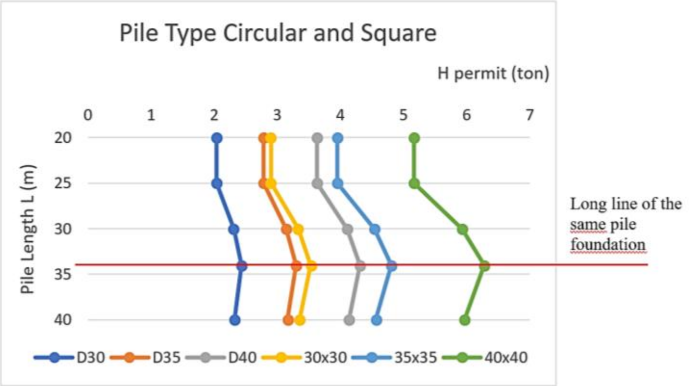

Figure 7 Graph of the relationship between the allowable lateral bearing capacity and the length of the pile, circular and square type piles

The results of the graphical analysis of the relationship between the lateral bearing capacity of the permit and the length of the pile are shown in Figure 7 for circular and square cross-sections. The D30 circular cross-section produces the smallest permitting lateral bearing capacity, while the 40x40 square pile cross-section produces the largest permitting lateral bearing capacity. The D35 circular cross-section and the 30x30 square cross-section have not significant differences in the lateral bearing capacity of the permit. In view of the same foundation pile length, the 40x40 pile cross-section produces the largest permit lateral bearing capacity, while the D30 pile section produces the smallest permit lateral bearing capacity.

Calculation Result of Pile Head Lateral Deflection

The following table 4 results of the calculation of the lateral pile deflection using the P-Y method with the Allpile V 7.3B application for all pile variations, circular type piles with in diameter D30, D35, D40 and square type piles with in cross-sectional sizes 30x30, 35x35, 40x40 with pile length 20m, 25m, 30m, 34m and 40m.

Table 4 Calculation results of lateral deflection with variations in pile dimensions and the length of the pile L

L (m)	Deflection (10^{-3} mm)					
	Circular			Square		
	D30	D35	D40	30x30	35x35	40x40
20	1.81	0.49	0.42	1.04	0.48	0.22
25	1.91	1.02	0.36	1.16	0.41	0.23
30	1.95	1.10	0.34	1.15	0.40	0.24
34	1.85	1.06	0.33	1.09	0.39	0.25
40	0.68	0.68	0.36	0.73	0.40	0.27

Based on the provisions of SNI 8460 of 2017, the maximum lateral deflection that occurs must not exceed the permissible lateral deflection. In general, the permissible lateral deflection of pile foundations should not be more than 2.50 cm or 0.25 mm. Calculation results for all variations in pile length and pile dimensions can be seen in the appendix.

Graph of Lateral Deflection and Pile Length

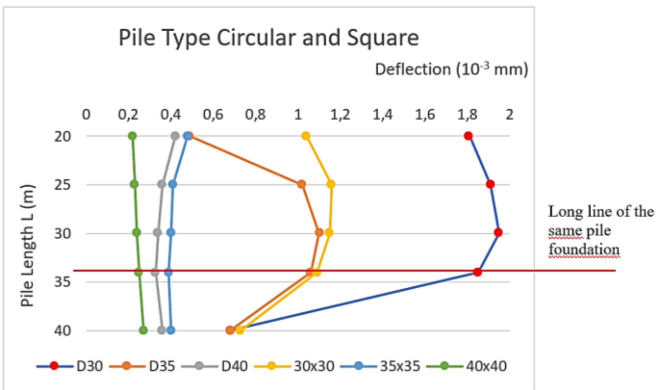

Figure 8 Graph of the relationship between the lateral deflection and the length of the pile, circular and square pile types

Figure 8 shows the relationship between foundation pile length and lateral deflection for square and circular cross-section types. The results of the graphical analysis of the relationship between the lateral deflection and the length of the pile for circular and square cross-sections show that the 40x40 square-section produces the smallest lateral deflection while the D30 circular-section produces the largest lateral deflection. Meanwhile, the 35x35 square cross-section is slightly larger, producing lateral deflections compared to the circular D40 cross-section. Then for a comparison of the 35x35 square cross-section, the D35 circular cross-section and the 30x30 square cross-section, it is shown that the D30 circular cross-section has a relatively very large lateral deflection value at variations in the length of the foundation piles L= 20m to L=35m. If we look at the length of the 40m pile (the same), it can be seen in the graph that the pile foundations with circular sections D30, D35 and square sections 30x30 are at points that are close together because they have different deflection values that are not too far apart.

5. CONCLUSION

Based on the results of calculations and graphical analysis, the effect of foundation depth and dimensions on the design of pile foundations withstanding lateral forces in the case study of the foundations of the Customs Building in Banjarmasin, South Kalimantan using the Allpile V 7.3B application method and the Brinch Hansen method, it can be concluded:

1. The comparison between circular and square cross-sections is that a square cross-section produces a larger permit lateral bearing capacity than a circular cross-section. Meanwhile, the lateral deflection produced by the square section is smaller than the circular section.
2. The longer the pile, the greater the allowable lateral bearing capacity and the smaller the resulting lateral deflection.
3. The cross-section is square where the larger the cross-section size and the longer the pile, the greater the allowable lateral bearing capacity and the smaller the lateral deflection.
4. In circular section, the smaller the cross-section size and the longer the pile, the greater the lateral deflection and the smaller the permitive lateral bearing capacity generated by the pile.

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