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Research Paper

Bearing Capacity and Settlement of Bored Pile Foundation Based on SPT Test Data and CPT Test

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Abstract

One form of government effort for the community is the construction of flats. In the construction of Flats X, it is necessary to conduct an analysis in order to minimize the occurrence of foundation collapse beyond the permit limit requirements. In this research analysis using axial and lateral carrying capacity. For axial carrying capacity based on NSPT values using three methods, namely Wright and Reese, Mayerhoff, Luciano Decourt. As well as on shaman power based on the CPT Test using three methods, namely Aoki de Lancer, Mayerhoff, and Schmertmann and Nottingham. For lateral carrying capacity using the calculation of the p-y curve method and using LPille software. For the descent of the foundation using Settle3D. So, obtained in this study for axial carrying capacity taken from three methods in the SPT Test is using the mayerhoff method with the results obtained, namely Q (all press) = 170 tons and Q (all pull) = 85 tons. The axial carrying capacity based on the Cpt Test is obtained from the smallest value in the three methods is the Aoki de Lancer method with the results obtained, namely Q (all press) = 83 tons and Q (all pull) = 14 tons. For lateral carrying capacity using the LPille program, a lateral load of 63.2 kN was obtained. For the number of foundation needed, namely 306 foundations. As well as for the lowering of the foundation obtained using Settle3D which is 96.3 mm.

Keywords: *Bored Pile, Soil Carrying Capacity, LPille, Settle3D*

INTRODUCTION

The soil serves as a support for the foundation. Soil consists of three elements: solid grains, water and air. Soil classification itself is divided into several parts, according to (Das et al., 1995 (page. 64-72)), namely: soil classification based on texture, soil classification based on the AASHTO system, soil classification based on soil unity or UUSC system. Bored pile foundation is a type of pile foundation that is paired by drilling and then filled with reinforcement and then casting. Before conducting a carrying capacity analysis, it is necessary to conduct a soil investigation. Based on National Standardization Agency (2017), things that must be considered are the type of foundation used, soil retaining structure, construction site, and depth of construction. Analysis of soil carrying capacity is the ability of the soil to withstand the weight of structures working on it without collapse due to soil shear.

Soil investigation with CPT Test is a method carried out with emphasis on obtaining parameters of soil layer penetration resistance. Meanwhile, soil investigation with SPT Test is a method carried out by erecting the stem into the ground using a hammer blow and measuring the number of blows per depth of penetration.

Based on the background above, several problem formulations are obtained as follows:

1. What is the bearing capacity of the bored pile foundation in the X Flats construction project based on SPT and CPT data?
2. How much foundation point is needed for the X Flats construction project?
3. How much is the value of the bored pile foundation settlement in the X Flats construction project?

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Based on the existing problem formulation, several purposes and objectives of writing are obtained as follows:

1. Knowing the value of the bearing capacity of the bored pile foundation in the X Flats construction project based on SPT and CPT data.
2. Know the number of bored pile foundation points needed.
3. Knowing the amount of the value of the bored pile foundation reduction (Settlement) in the X Flats construction project.

LITERATURE REVIEW

In this study, the method used in calculating axial carrying capacity uses two methods, namely based on SPT Test and CPT Tests. For the SPT Test in this study, three methods were used, namely the Wright and Reese, Mayerhoff, and Luciano Decourt methods. Meanwhile, the CPT used three methods, namely the Aoki de Lancer, Mayerhoff, and Schmertmaan and Nottingham methods. For lateral carrying capacity used the p-y curve method, and input into LPille software. And for the calculation of foundation settlement from the needs of the foundation used then correlated with the soil data needed by being inputted using Settle3D software

This study aims to obtain the value of axial soil carrying capacity and lateral soil carrying capacity value in Flat X building, obtain the foundation needs needed in Flat X, and find out the value of settlement that occurs in Flat X

Axial Carrying Capacity

Axial Bearing Capacity of SPT Test

1. Wright and Reese Method (1977)

   The equation used to calculate carrying capacity using the Wright and Reese method:

   a. Cohesive Soil

   $$Q_{ult=}\ q_p \times A_p + \alpha\ \times C_u \times P \times L_i$$

   b. Non-cohesive Soil

   $$Q_{ult=}\ q_p \times A_p + \alpha\ \times C_u \times P \times L_i$$

   For N < 60, so q_p = 7 N (kN/m^2) < 400 (kN/m^2)
   For N > 60, so q_p = 400 (kN/m^2)
   For N < 53, so f_s= 0,32 N-SPT(kN/m^2)
   For 53 < N < 100 so fs is obtained from a direct correlation with NSPT (Reese and Wright, 1977) regarding the sliding resistance of pole covers.

   Information:
   Q_P= end bearing capacity (kN)
   q_p= End carrying capacity per unit area (kN/m^2)
   A_p= Cross-sectional area of the mast (m^2)
   α = Adhesion factors (Based on Reese and Wright, 1977 for α = 0,55)
   C_u = Soil cohesion (kN/m^2)
   P = Area of pole blanket (m^2)
   L_i = The length of the soil layer (m)

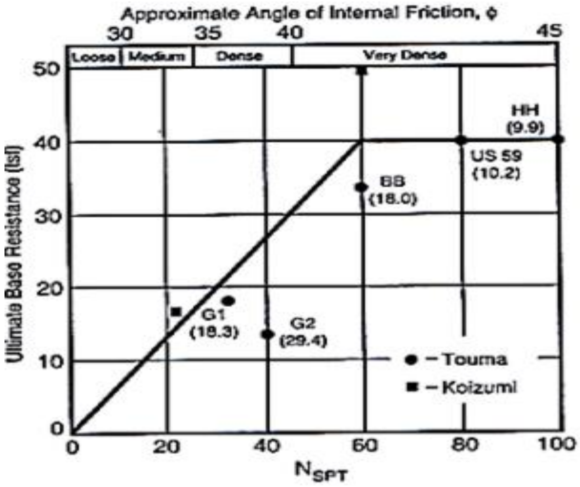

Figure 1. Skin Bearing Capacity Picture

Source: Hardiyatmo, H.C. (2002)

2. Mayerhoff Method

The equation used to calculate the carrying capacity using the Mayerhoff method:

a. Cohesive Soil

$$Q_{ult} \ = \ 9 \ \times C_u \times A_p + X_m \times N - SPT \times p \times L$$

b. Non-cohesive Soil

$$Q_{ult} \ = 40 \times NSPT \times A_p + X_m \times NSPT \times p \times L$$

Information:

C_u = Soil cohesion (kN/m^2)

= $NSPT \ \times \frac{2}{3} \times 10$

A_p = Cross-sectional area of the mast (m^2)

$NSPT$ = Nspt value at pole base elevation (kN/m^2)

L = Display soil layer (m)

P = Perimeter of drill pile (m)

N = The number of statistical average stroke calculations

X_m = 0,2 for *bored pile*

Note: Limit values for 0,2 × N is 10 Ton/m^2

3. Luciano Decourt Method

The equation used to calculate the carrying capacity using the Luciano Decourt method:

$$Q_{ult} \ = \text{Ap} \times \text{Np} \times \text{K} + \left(\frac{Ns}{3} + 1\right) \times As$$

Information:

Ap = Cross-sectional area of the end of the mast (m^2)

Np = The average SPT value starts from 4D below the pole end to 4D above the pole end

K = The value of the soil type coefficient (12 t/m^2 for clay and 40 t/m^2 for sand) skin friction

capacity
Ns = Average value of NSPT along the pole
As = Wide blanket pole along embedded pole (m^2)

Table 1. The value of the soil type coefficient

Soil Type	K (t/m^2)
Clay	12
Silt Clay	20
Sandy silt	25
Sand	40

Source: Ismail & Ryden (2014)

Axial Bearing Capacity Based on CPT Test

a. Aoki de Lancer Method

The equation used to calculate the carrying capacity using the Aoki de Lancer method:

$$Q_U = Q_p + Q_s = q_b.A_p + f.A_s$$

Information:
Q_U = The ultimate bearing capacity of drilled piles (kN)
Q_p = End bearing capacity (kN)
Q_s = Skin friction capacity (kN)
q_p = The carrying capacity at the end of the unity pole is wide (kN/m^2)
A_p = Cross-sectional area of the mast (m^2)
f = Wide unity leather carrying capacity (kN/m^2)
A_s = Area of pole blanket (m^2)

$$Q_b = \frac{q_{ca}(base)}{F_b}$$

Information:
$q_{ca}(base)$ = The average conus resistance of 1.5D above the end of the pole, 1.5D below the end of the pole is empirical the bearing capacity of the end depending on the type of pole.
F_b= Empirical factors of bearing capacity of mast ends depend on pole type (Table 1)
Broad unity skin resistance(f)as follows:

$$f = q_c(side)\frac{\alpha_s}{F_s}$$

Information:
$q_c(side)$ = Average conus resistance in each layer along the pole
α_s = The value of the empirical factor of the soil
F_s = Empirical factor of bearing capacity of pole skin depends on pole type (Table 2)

Table 2. empiric factor F_b and F_s

Piling Type	F_b	F_s
Drill Pole	3,5	7,0
Steel	1,75	3,5
Prestressed Concrete	1,75	3,5

Source: Aoki & Velloso (1975)

Table 3. Empirical Factors of Soil α_s

Soil Type	α_s (%)	Soil Type	α_s (%)	Soil Type	α_s (%)
Sand	1,4	Silted sand	2.2	Sandy loam	2,4
Silt sand	2,0	Sand with loam	2,8	Sandy loam with silt	2,8
Silt sand with loam	2,4	Silt	3,0	Silted clay with sand	3,0
Loamy sand with silt	2,8	Silt loamy with sand	3,0	Silted clay	4,0
Loamy sand	3,0	Clayey silt	3,4	Clay	6,0

Source: Aoki & Velloso (1975)

Mayerhoff Method

The equation used to calculate the carrying capacity using the Mayerhoff method:

$$Q_{ult} = q_c \times A_p + JHL \times K_I$$

Information:

Q_u = Mast bearing capacity (kN)
q_c = Sondir tip resistance (kg/cm^2)
A_p = Cross-sectional area of the mast (m^2)
JHL = Number of sticky barriers (kg/cm^2)
K_I = Pole circumference (m)

With the safety factor of pole bearing capacity

For pure sand SF_1 = 3, SF_2 = 5
For claySF_1 = 5, SF_2 = 10

Schmertmaan and Nottingham Method

The equation used to calculate carrying capacity using the Schmertmann & Nottingham methods:

$$Q_u = A_b \times \omega \times q_{ca} + A_s \times K_f \times qf$$

Information:

Ab = Cross-sectional area of the mast (cm^2)
As = Area of pole blanket (cm^2)
Fb = Unit end resistance (kg/cm^2)
Fs = Unit friction resistance (kg/cm^2)
qca = Average conus resistance (kg/cm^2)

qc = Conus side friction resistance (kg/cm^2)
Kc = Dimensionless coefficient
ω = correlation coefficient

To calculate the average value (qc), it is obtained from along 8D above the base of the pole to 0.7 or 4D below the pole.

Table 4. ω factor (deRuiter & Beringen, 1979)

Soil conditions	ω factor
Normal consolidated sand (0CR = 1)	1
The sand contains a lor of coarse gravel; Sand with OCR = 2 to 4	0,67
Fine gravel; sand with OCR = 6 to 10	0,5

Source: Bowles (1996)

If the pole is in sand, Kf depends on the ratio of L/d (L = depth, and d = diameter of the pole). In the first 8d depth of ground level, Kf is interpolated from zero at ground level to 2.5 at 8s depth. Lower than this depth, the value of Kf decreases from 2.5 to 0.891 at a depth of 20d or is considered as a whole Kf = 0.9.

Another method, for poles in sand soil (not applicable to loam), friction units It can be determined from the QC conus prisoner: Kc = A dimensionless coefficient whose value depends on the type of pole.

a) Bottom end steel pole open, Kc = 0,8
b) Closed lower end pipe pole, Kc = 1,8 %
c) Concrete pole, Kc == 1,2 %

Lateral Bearing Capacity

P-Y Curve Method

According to Hardiyatmo (2008, pp. 233-237), the p-y curve method is a method that connects lateral loads and deflections between the ground and the pole described by a curve. The p-axis represents the lateral resistance of the land of union of the length of the pole. Meanwhile, the y-axis is the lateral deflection of the pole.

The p-y method must pay attention to changes in the p-y curve with depth, can be done by finite difference analysis, which has two conditions, namely shear force and zero moment. In the lateral force analysis power of the pole, the pole is divided into two, namely the free head pole and the fixed head. To calculate lateral carrying capacity, there are several things that must be considered first are the number of poles in a group, pole spacing, pile arrangement, and reduction factors. Based on National Standardization Agency (2017) Article 9.7.3.1, the lateral deformation powder of pole permits is 12 mm for planned earthquakes and 25 mm for strong four in single pole and free head conditions.

Table 5. Comparison of p-Multiplier Values from Various Experimental and Field Studies (LPile Group with Pile Center-to-center spacing of 3 Pile Widths)

Author/soil type and shear strength	Size of pile group	Average *p*-multiplier			
		Lead row	Second row	Third row	Fourth row
Clay					
Present study/normally consolidated clay: undrained shear strength=0–20 kPa	2×1	0.80	0.63		
	2×2	0.96	0.78		
	3×3	0.65	0.50	0.48	
	4×4	0.65	0.49	0.42	0.46
Brown et al. (1987)/overconsolidated clay: strength= 70– 180 kPa	3×3	0.7	0.5	0.4	
Meimom et al. (1986)/silty clay: strength= 25 kPa	2×2	0.9	0.5		
Rollins et al. (1998)/clayey silt: strength= 50– 75 kPa	3×3	0.6	0.4	0.4	
Sand					
Brown et al. (1988)/clean medium sand: friction angle ϕ=38°	3×3	0.8	0.4	0.3	
McVay et al. (1995)/medium dense sand	3×3	0.8	0.4	0.3	
McVay et al. (1998)/medium dense sand	4×3	0.8	0.4	0.4	0.3
Ruesta and Townsend (1997)/loose find sand: ϕ = 32°	4×4	0.8	0.7	0.3	0.3

So, the reduction factor used is 0.4, obtained based on the Cu value on the tax return, mayerhoff method.

1. Mast Efficiency
   a. Converse-Methods Method

$$E_g = 1 - \left[\frac{(n-1)m+(m-1)n}{90.m.n}\right]\theta$$

   b. Los Angeles Method

$$E_g = 1 - \frac{d}{\pi.s.m.n}\left[m(n-1) + (m-1) + (n-1)\sqrt{2}\right]$$

Information:

E_g = Mast Efficiency (%)
θ = Arc tan d/s (in degrees)
E_g = Mast Efficiency (%)
D = Pole diameter
s = Distance between poles
m = Number of poles parallel to the x-axis
n = Number of poles parallel to the y-axis

2. Safety Factors

Table 6. Safety Factor Reese & O'Neill

Structure classification	Safety Factor (F)			
	Good Control	Normal Control	Bad Controls	Very Bad Controls
Monumental	2,3	3	3,5	3,44
Permanent	2	2,5	2,8	2,8
while	1,4	2	2,3	

3. Settlement

Based on National Standardization Agency (2017), the decrease in permits < 15 cm + b / 600 (b with cm units) for tall buildings and proven that the upper structure is still safe. The difference in the decline that will occur and affect the building above must meet the criteria of strength and serviceability of 1/300.

Settle3D is software that functions to analyze foundation subsidence, embankments and surface loads.

Soil parameters used in Settle3D

a. Correlation of N-SPT Value to Cu Value

In general, the Cu value can be taken at 0.6N (Cu = ton/m3)

Table 7. Correlation of N-SPT with Cu Value

Standard Penetration Number, N_{60}	Consistency	Unconfined compression strength, q_u (kN/m^2)
0 – 2	Very Soft	0 – 25
2 – 5	Soft	25 – 50
5 – 10	Medium Stiff	50 – 100
10 – 20	Stiff	100 – 200
20 – 30	Very Stiff	200 – 400
> 30	Hard	> 400

Source: Das et al., (1995)

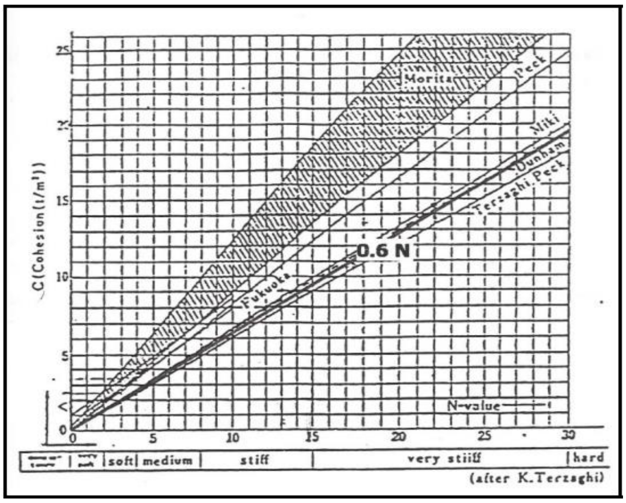

Figure 2. The Relationship of Cohesion Value and NSPT on Cohesive Land

Source: Terzaghi (1943)

b. Correlation of NSPT value to soil content weight (g_{sat})

Table 8. NSPT Value to Cohesive Soil Content Weight (g_{sat})

Cohesive Soil						
Consistency	*Very Soft*	*Soft*	*Medium*	*Stiff*	*Very Stiff*	*Hard*
N (*blows*)	<2	2 - 4	4 - 8	8 - 15	15 - 30	>30
(γ)sat (kN/m3)	16 - 19	16 - 19	17 - 20	19 - 22	19 - 22	19 - 22

Source: Terzaghi (1943)

Table 9. NSPT value to weight of non-cohesive soil content (g_{sat})

Non-cohesive Soil						
State		*Very Loose*	*Loose*	*Medium*	*Dense*	*Very Dense*
Density Relatif (%)		0 – 15	16 – 35	36 – 65	66 – 85	86 – 100
N (*blows*)		0 – 4	5 – 10	11 – 30	31 – 50	>50
Unit Weight	Moist (kN/m3)	<16	15.2 - 20.0	17.6 - 20.8	17.6 - 22.4	>20.8
	Submerged (kN/m3)	<9.6	8.8 - 10.4	9.6 - 11.2	10.4 - 13.61	>12.01

Source: Teng et al. (1962)

c. The correlation of the N-SPT value to the value of the young modulus of soil elasticity, according to Schmertmann (1970), as follows:
   1) Correlation on sand soils Es (kN/m^2) = 766× N-SPT Es = 2 qc
   2) Correlation on clay soils
      a) Normally consolidated clay soils (NC) Es = 250 Cu – 500 Cu
      b) Over-consolidated clay soils (OC) Es = 750 Cu – 1000 Cu

Table 10. Plasticity Index values and soil types

IP	Characteristic	Soil Type	Cohesive
0	Non plastic	Sand	Non cohesive
< 17	Low plasticity	Silt	Partially cohesive
7 – 17	Medium plasticity	silted clay	Cohesive
> 17	High plasticity	Clay	Cohesive

Source: Hardiyatmo (1996)

RESEARCH METHOD

In this study using a quantitative approach. To achieve the aims and objectives of this research, several stages were carried out, namely:

Preparation Stage

Conduct a literature study of textbooks and journal references related to the analysis of carrying capacity and settlement.

Data Collection Stage

Collect the necessary data from the Geotechnical Structure Planning. The data required is in the form of X Flats shop drawing data, SPT Test and CPT Test data, and loading data.

Data Analysis Stage

Conducting analysis of textbook literature and journal references, using three methods for calculating the carrying capacity analysis of SPT and CPT, lateral carrying capacity, the needs of the foundation to be used and settlement in Flats X.

Research Flowchart

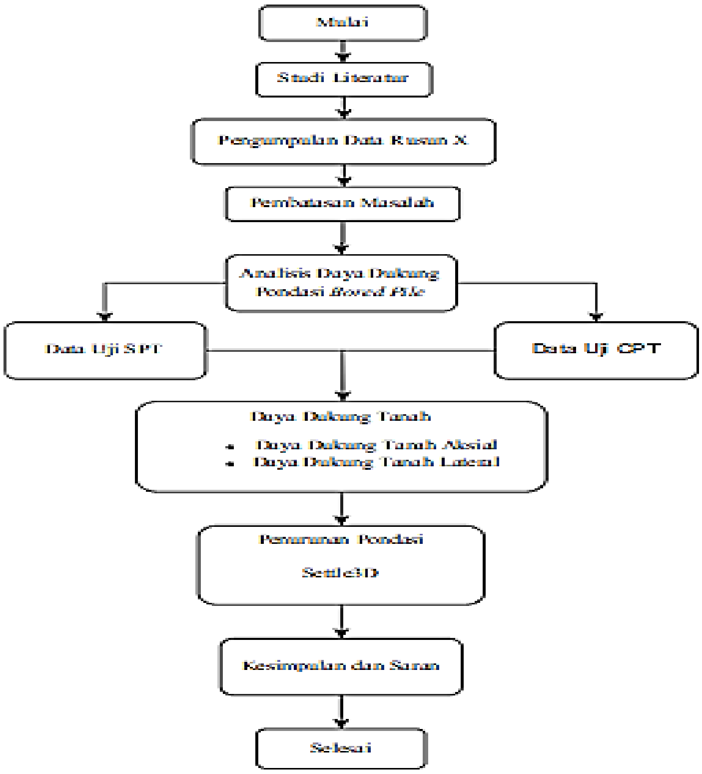

Figure 3. Research Flowchart

FINDINGS AND DISCUSSION

Technical Data

Types of structures : Bored pile
Number of Floors : 24 Lantai
Bore mast depth : 21 m or until it reaches hard ground
Bottom Structure Concrete Quality:

1. Bore pile : fc' 30 MPa
2. PC, Tie Beam, Pelat : fc' 30 MPa
3. Diameter < 10 mm : U-24, Fy 240 MPa
4. Diameter≥ 10 mm : U-40, Fy 420 MPa

Figure 4. Ground Research Point Plan)
Source: Geotechnical Structure Planner

Investigation of acquired land
Standar Penetration Test (SPT) : BH-1; BH- 2; BH-3
Cone Penetration (CPT) : S-1; S-2; S-3; S-7;S-8;S-9; S-10; S-11

Axial Carrying Capacity Based on SPT
Metode Wright and Reese Method (1977)
Based on depth 21 m

Table 11. Resume DDT (Wright and Reese)

NO	Bore hole	Dimension (cm)	Effective length (m)	Press Carrying capacity (ton)		Pull Carrying capacity (ton)	
				Ultimate	Permission	Ultimate	Permission
1	BD – 1	80	21	756,95	302,78	442,08	147,36
2	BD – 2	80	21	763,06	305,22	451,31	150,44
3	BD - 3	80	21	687,29	274,92	397,57	132,52
PERMIT PLANNING				270		130	

Mayerhoff Method
Based on depth 21 m.

Table 12. Resume DDT (Mayerhoff)

NO	Bore hole	Dimension (cm)	Effective length (m)	Press Carrying capacity (ton)		Pull Carrying capacity (ton)	
				Ultimate	Permission	Ultimate	Permission
1	BD – 1	80	21	469,68	187,87	291,97	97,32
2	BD – 2	80	21	485,80	194,32	300,81	100,27
3	BD – 3	80	21	431,22	172,49	262,19	87,4
PERMIT PLANNING				170		85	

Luciano Decourt Method
Based on depth 21 m

Table 13. Resume DDT (Luciano Decourt)

NO	Bore hole	Dimension (cm)	Effective length (m)	Press Carrying capacity (ton)		Pull Carrying capacity (ton)	
				Ultimate	Permission	Ultimate	Permission
1	BD – 1	80	21	560,04	224,01	326,96	108,99
2	BD – 2	80	21	575,57	230,23	342,39	114,13
3	BD – 3	80	21	560,65	224,26	330,65	110,22
PERMIT PLANNING				220		108	

Thus, of the three Resume methods based on BH-1. BH-2. BH-3 with a depth of 21 m, obtained are:

Table 14. Comparison of Carrying Capacity Based on N-SPT Value

Calculation Method	Dimension (cm)	Effective length (m)	Carrying capacity (ton)	
			Press Carrying capacity	Pull Carrying capacity
Wright & Reese	80	21	270	130
Mayerhoff	80	21	170	85
Luciano Decourt	80	21	220	108
PERMIT PLANNING			170	85

Based on the three methods, for the calculation of the carrying capacity of N-SPT, the smallest value can be taken from the Mayerhoff method with the result that the compressive carrying capacity is 170 tons and the tensile carrying capacity is 85 tons.

Axial Carrying Capacity of CPT

Aoki de Lancer Method

Thus, the resume obtained from 8 sondir points based on the Aoki de Lancer Method, as follows:

Table 15. Carrying Capacity (Aoke de Lancer)

No	Sondir Point	Diameter (m)	Effective length (m)	Press Carrying capacity	Pull Carrying capacity
1	S – 1	0,8	4,7	118,81	22,00
2	S – 2	0,8	4,9	123,61	2248
3	S – 3	0,8	4,9	123,61	22,48
4	S – 7	0,8	4,7	124,07	22,76
5	S – 8	0,8	5,3	83,19	14,80
6	S – 9	0,8	4,9	103,89	19,85
7	S – 10	0,8	4,7	124,87	22,44
8	S – 11	0,8	4,9	104,42	19,81
Permit Planning				83	14

Mayerhoff Method

Table 16. Carrying Capacity (Mayerhoff)

No	Sondir Point	Diameter (m)	Effective length (m)	Press Carrying capacity	Pull Carrying capacity
1	S – 1	0,8	4,7	469,12	22,32
2	S – 2	0,8	4,9	470,33	22,88
3	S – 3	0,8	4,9	482,75	28,10
4	S – 7	0,8	4,7	476,04	25,23
5	S – 8	0,8	5,3	370,24	25,95
6	S – 9	0,8	4,9	463,47	20,00
7	S – 10	0,8	4,7	456,01	16,82
8	S – 11	0,8	4,9	488,25	30,41
Permit Planning				370	16

Metode Schmertmann dan Nottingham

Table 17. Carrying Capacity (Schmertmann and Nottingham)

No	Sondir Point	Diameter (m)	Effective length (m)	Press Carrying capacity	Pull Carrying capacity
1	S – 1	0,8	4,7	470,58	162,27
2	S – 2	0,8	4,9	430,84	145,14
3	S – 3	0,8	4,9	418,88	144,40
4	S – 7	0,8	4,7	487,14	167,89
5	S – 8	0,8	5,3	452,68	161,67
6	S – 9	0,8	4,9	241,90	70,36
7	S – 10	0,8	4,7	288,33	84,96
8	S – 11	0,8	4,9	630,94	233,82
Permit Planning				240	70

Lateral Bearing Capacity

Based on the resume of the three SPT carrying capacity methods, the smallest value for lateral carrying capacity data input is taken, namely in the mayerhoff method located at BH-3 depth of 21 m. So, the carrying capacity obtained in the p-y curve method is;

Table 18. Lateral Bearing Capacity

Information	Bore Hole - 3	
	Deflection 12 mm	Deflection 25 mm
Lateral Pile Deflection (m)	4	4,3
Bending Momen (kN.m)	168	225
Shear force (kN)	64	85
Lateral Load	63,2	85

Based on National Standardization Agency (2017) concerning Geotechnical Planning Requirements Article 9.7.3.1. The estimated lateral capacity of the mast corresponds to the lateral deformation difference of the mast head clearance. The lateral deformation magnitude of the clearance pole is 12 mm for planned earthquakes and 25 mm for strong earthquakes in single pole and free-head conditions

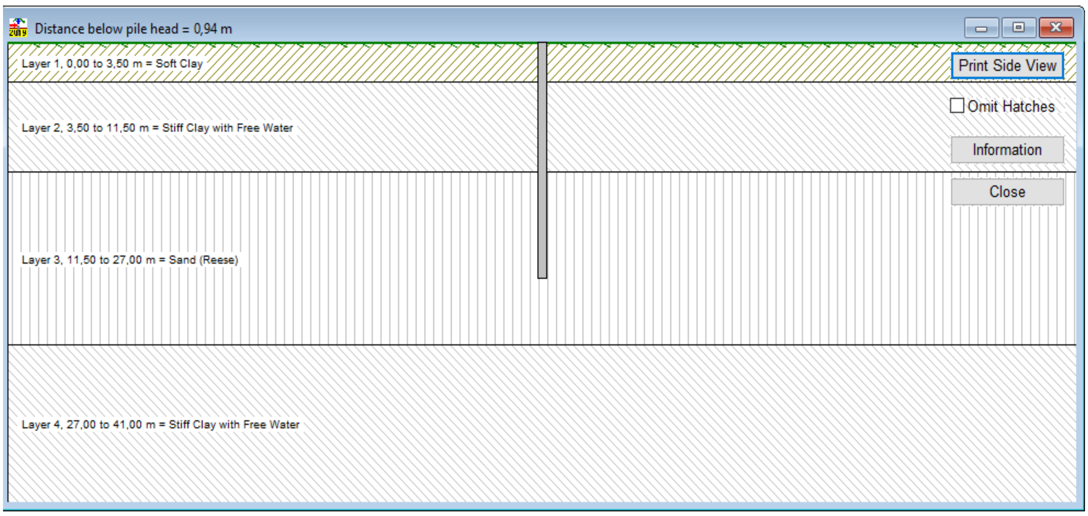

Figure 5. LPile Land Data BH-3 Rusun X

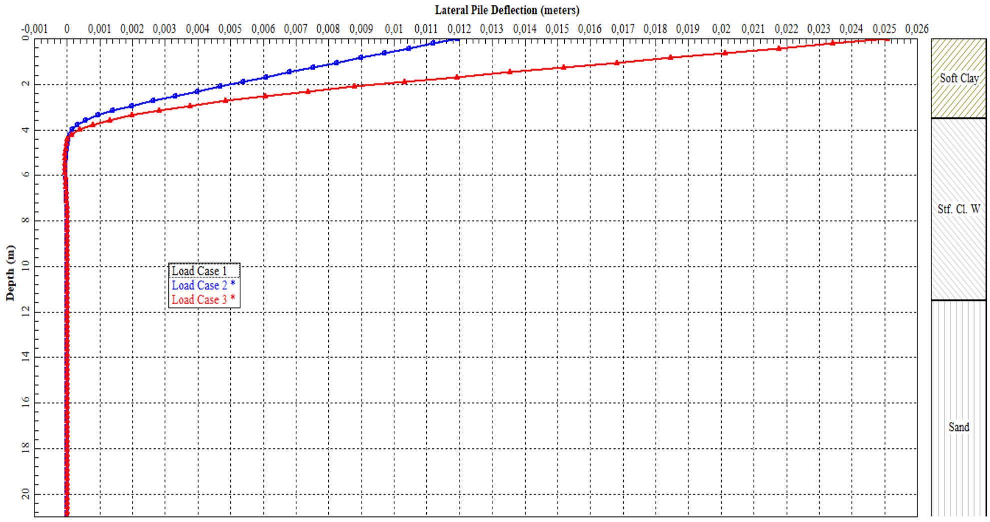

Figure 6. Graphs Lateral Pile Deflection vs Depth

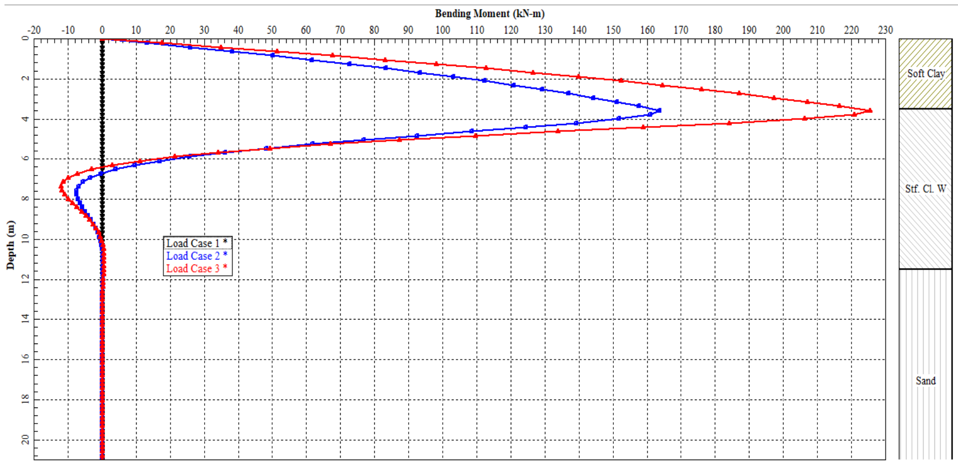

Figure 7. Graphs Bending Moment vs Depth

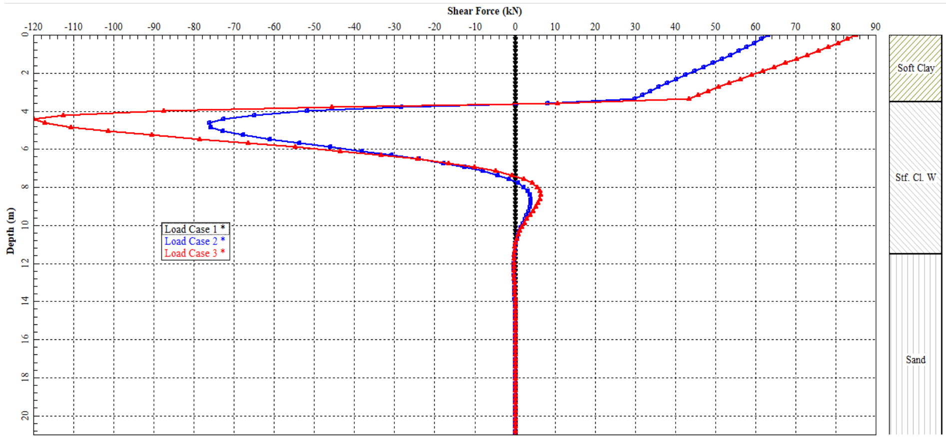

Figure 8. Graphs Shear Force vs Depth

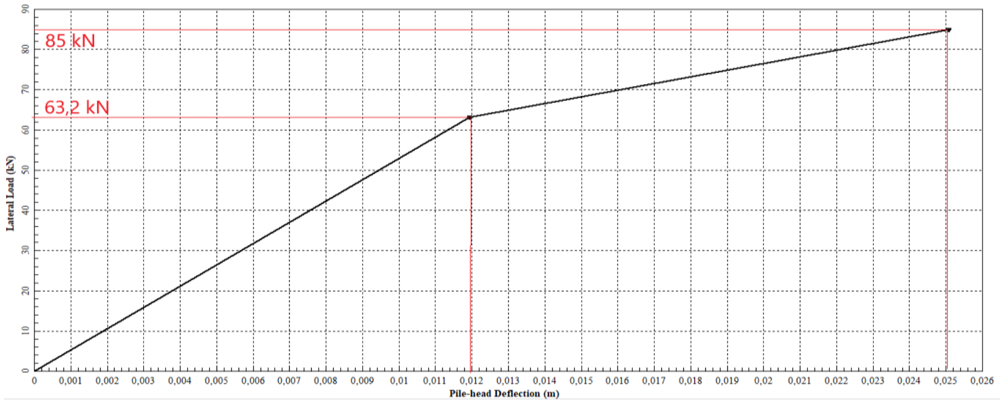

Figure 9. Graph *Lateral Load* vs *Pile Head Deflection LPile* BH-3 Rusun X

Interaction Diagram of Checking Rebar Against Moment

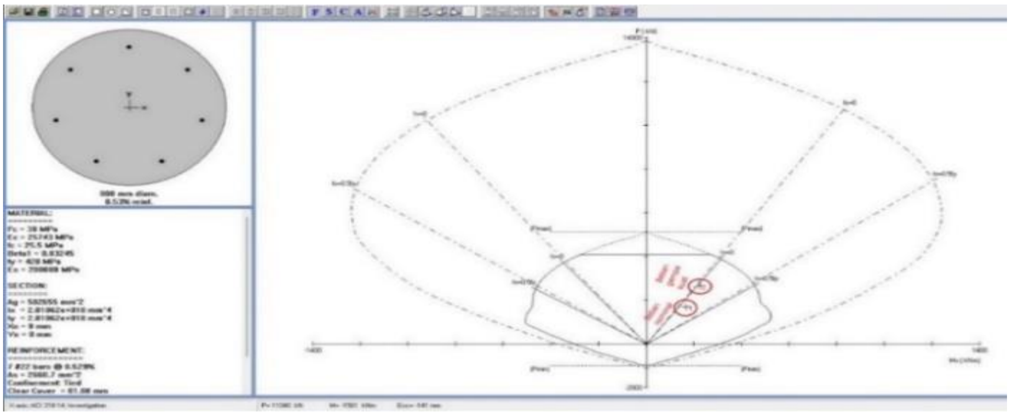

Figure 10. Diagram of the Interaction Diagram of Checking Rebar Against Moment.

In the diagram, the interaction of nominal and ultimate forces is still safe from designs that use 7D22 reinforcement.

Number of foundations based on base shear force

$$\text{Sum} = \frac{\text{V base shear}}{\text{Daya dukung Lateral}} = \frac{10242}{63{,}2} = \mathbf{163\ Foundation\ Point}$$

Based on the calculation of the number of axial foundations, the number of foundations was obtained as many as 306 foundations. So, the number of foundations based on the base shear force against the number of axial foundations is:

306 axial foundations > 163 base shear foundations

a. Converse-Methods Method

$$E_g = 1 - \left[\frac{(n-1)m+(m-1)n}{90.m.n}\right]\theta$$

b. Los Angeles Method

$$E_g = 1 - \frac{d}{\pi.s.m.n}\left[m(n-1) + (m-1) + (n-1)\sqrt{2}\right]$$

Table 19. Foundation Group Efficiency

Type pile cap		Foundation configuration					Eff. Labare	Eff. Los Angeles	Eff. Used
		number of foundations	D (m)	m	n	S (m)			
PC	1	1	0,8	1	1	2	1	1	1
PC	2	2	0,8	2	1	2	0,88	0,94	0,88
PC	3	3	0,8	2	2	2	0,76	0,85	0,76
PC	4	4	0,8	2	2	2	0,86	0,86	0,76
PC	5	5	0,8	2	3	3	0,72	0,83	0,72
PC	6	6	0,8	3	2	2	0,72	0,86	0,72
PC	7	7	0,8	4	2	2	0,70	0,87	0,70
PC	8	8	0,8	4	2	2	0,70	0,87	0,70
PC	9	9	0,8	3	3	2	0,68	0,85	0,68
PC	306	306	0,8	34	9	2	0,55	0,87	0,55

The efficiency table is used for the calculation of the number of foundations. The number of foundations obtained is 306 foundations.

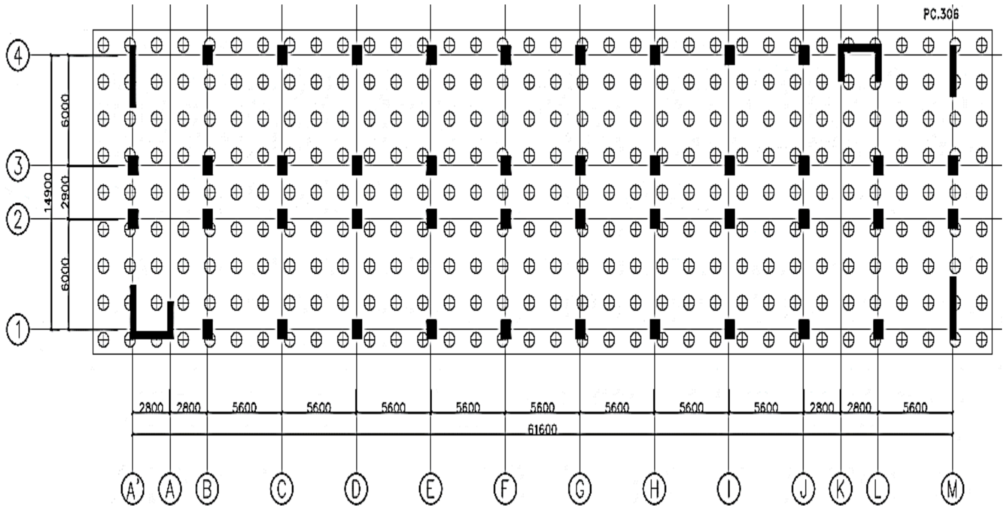

Figure 11. Number of Flat Foundations X

Settlement

Table 20. Correlation of NSPT Value to Soil Elasticity Modulus Value (ES)

Depth (m)	Soil Type	NSPT	ES (kN/m2)	Es NAVFAC (kN/m2)	Es used
0 – 4	Clay (soft)	4	8400	4800	8400
4 – 12	Stone silt (very hard)	34	71400	40800	71400
12 – 27	Sand (Very dense)	50	38300	60000	60000
27 - 41	Stone silt (very hard)	22	46200	26400	46200

Table 21. Correlation of NSPT Value of Soil Fill Weight (γ)

Depth (m)	Soil Type	NSPT	(γ) Lab	(γ) cohesive soil	(γ) non cohesive soil	(γ) used
0 – 4	Clay (soft)	4	-	16 – 19	-	16
4 – 12	Stone silt (very hard)	34	-	19 – 22	-	19
12 – 27	Sand (Very dense)	50	-	-	> 20,8	21
27 - 41	Stone silt (very hard)	22	17,2	19 - 22	-	19

Table 22. Plasticity Index values and soil types

IP	Characteristic	Soil Type	Cohesive
0	Non plastic	Sand	Non cohesive
< 17	Low plasticity	Silt	Partially cohesive
7 – 17	Medium plasticity	silted clay	Cohesive
> 17	High plasticity	Clay	Cohesive

Table 23. Correlation of NSPT value to cc value

Depth (m)	Soil Type	NSPT	IP	Cc Lab	Correlation Cc	Cc Used
0 – 4	Clay (soft)	4	18	-	0,374	0,374
4 – 12	Stone silt (very hard)	34	6	-	0,134	0,134
12 – 27	Sand (Very dense)	50	0	-	0,014	0,014
27 - 41	Stone silt (very hard)	22	-	0,32	-	0,032

Table 24. Correlation of NSPT Value to eo Value

Depth (m)	Soil Type	NSPT	Eo Lab	Eo used
0 – 4	Clay (soft)	4	-	1,10
4 – 12	Stone silt (very hard)	34	-	1,15
12 – 27	Sand (Very dense)	50	-	1,80
27 - 41	Stone silt (very hard)	22	1,193	1,193

Table 25. Data Soil Properties Settle3D

Depth (m)	Soil Type	NSPT	(γ) used	Es used	E50	Eo used	Cc Used
0 – 4	Clay (soft)	4	16	8400	0,03	1,10	0,374
4 – 12	Stone silt (very hard)	34	19	71400	0,005	1,15	0,134
12 – 27	Sand (Very dense)	50	21	60000	0,004	1,80	0,014
27 - 41	Stone silt (very hard)	22	19	46200	0,004	1,193	0,032

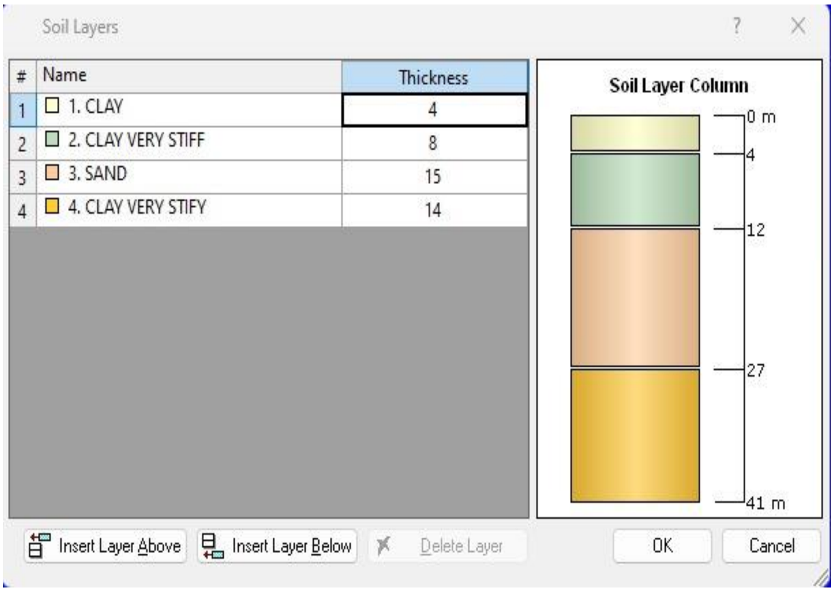

Figure 12. Soil Layer

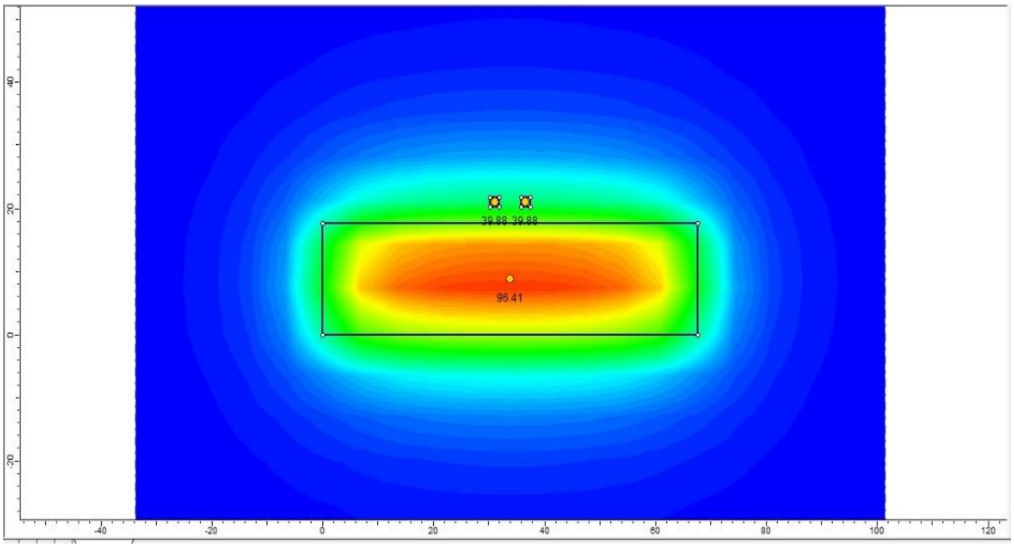

Figure 13. Settle3D Results

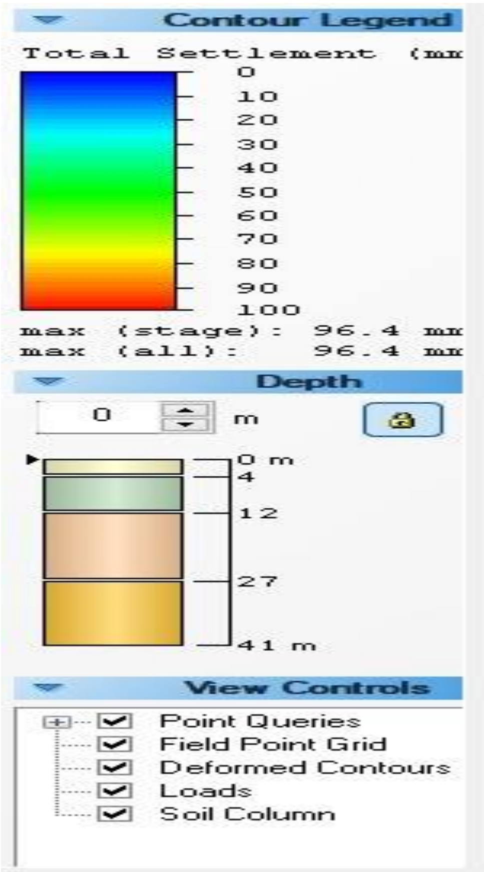

Figure 14. The results of the decline obtained based on the BH-3 that Settle3D has output

Remarks: The result of the decrease for one building of Flats X by 96.4 mm.

So, based on the results of Setlle3D the excel table is 96.4 mm. Based on National Standardization Agency (2017), settle in output yield = 96,4 mm = 9,64 cm

b = Pile cap width (in cm)

b = 67600 mm = 6760 cm

Settle permissions < 15 cm + b/600
= 9,64 cm < 15 cm + 6760/600
= 9,64 cm < 26,2667 cm (SAFETY)

CONCLUSIONS

From the calculation results, conclusions were obtained for the carrying capacity of axial foundations based on SPT Tests from the three Wright and Reese Methods, Mayerhoff, and Lucioano obtained the smallest value, namely in the mayerhoff in borehole-3 method is a compressive carrying capacity of 170 tons and a tensile carrying capacity of 85 tons. Meanwhile, axial carrying capacity based on CPT tests from the three methods of Aoki de Lancer, Mayerhoff, Schmertmann Nottingham obtained the smallest value in the Aoki de Lancer method located in Sondir-8 with a depth of 5.3 m of 83 tons for compressive carrying capacity and 14 tons for tensile carrying capacity. For lateral carrying capacity obtained amounted to 63.2 tons. The number of foundation needs obtained according to the calculation is 306 foundations. And for the lowering of the foundation obtained for one building is 96.4 mm.

LIMITATION & FURTHER RESEARCH

In research on the carrying capacity and lowering of bore pole foundations, complete technical data and laboratory data (test data for each depth of the soil layer) are needed in order to get accurate calculations. Research using the LPille and Settle programs is a calculation tool, so it needs to be adjusted to the conditions in the field. Flexibility in reading, testing, and calculation greatly affects the results of the calculation value. Especially pay close attention to the values of the coefficients and correlations used because they can affect the values obtained.

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