# BEARING CAPACITY OF THE PILE ON THE PILE SLAB STRUCTURE (A CASE STUDY OF BRIDGE APPROACH AT SETURI BRIDGE, BATANG REGENCY)

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## Abstract

A bridge is a structure constructed to span a physical obstacle such as river, valley, irrigation channel, railway etc. without closing the way underneath. Bridges are also part of the land transportation infrastructure which has a very vital role in its function of maintaining the traffic flows. The bridge approach is a road structure that connects a road section with a bridge structure. This section of the bridge approach can be made of landfill, and requires special compaction, because of its location and position which is quite difficult to work on, or it can also be in the form of a pile slab structure, (plates supported by head beams on pillars). The pile slab foundation is a footing structure supported by a pile group system and bound by a pile cap which is used to hold and transmit the load from the upper structure into the soil which has the bearing capacity to hold it. The pile slab structure is in the form of a plate supported by a beam above the head of the post. In connection with this, the author aims to carry out a research on the bearing capacity of the pile slab structure using several analytical methods, namely; N-SPT static analysis method, PDA Test Interpretation, Allpile program and ENSOFT Group program by comparing the bearing capacity of the fabricated piles. Based on the analysis results, the comparison of the bearing capacity of the pile through static analysis using the Allpile program and the ENSOFT Group program with the bearing capacity of the fabricated piles (PT. Wijaya Karya Tbk) with pile type A1, with a diameter of 50 cm, with a concrete quality of Fc' 52 Mpa, with a crack bending moment value of 10.5 ton.m, with a lateral moment of 15.75 ton.m and with an axial allowable force (allowable compression) of 185.30 tonnes, still shows a safe limit with a range of percentage values between 53.64 (Pda test results) up to 79.66 of the lateral mean capacity. Therefore, the bearing capacity of the fabricated piles can still be increased by 1.26 percent through deepening the piles.

**Keywords**: N-SPT bearing capacity of the pile, PDA Test (CAPWAP), Allpile program and ENSOFT Group program.

## 1. Introduction

A bridge is part of the road which functions to pass through obstacles such as rivers, valleys, irrigation canals, railways, etc. that it is possible for traffic to continue to surpass the road as long as the requirements are met in accordance with the permitted limits.

The pile slab foundation is a footing structure to transmit the load from the upper structure into the ground of which it has the bearing capacity to hold. It is supported by the pile group system and bound by the pile cap.

In the case of the bridge of Seturi river in Batang Regency, the use of bridge approach in the form of landfill is not possible, as it is quite high, the use of bridge approach in the form of this landfill can also increase the width of the land due to the very wide foot of the pile and the risk of landslides. To maintain slope, the standard vertical alignment with a maximum expected incline is 7.5%. For this reason, pile slabs in the form of plates supported by head beams above the poles were used in the construction of the Seturi Bridge.

### 1.1. Problem Formulation

Based on the description above, the following problem formulations are obtained:

1. What is the maximum bearing capacity of single and group pile slabs in one segment due to the axial and lateral loads?
2. What is the amount of deflection which occurs in the structure due to the lateral loads as a result in the height difference of the poles above the ground?
3. What is the lateral bearing capacity of a single and group pile(s) due to the height difference of the poles above the ground?

### 1.2. Objectives of the Research

The objectives of this research are:

1. To determine the bearing capacity of a single pile using N-SPT soil data with manual analysis, the Mayerhof method, the Allpile program and the ENSOFT Group program on axial, lateral and pile settlement forces.
2. To determine the carrying capacity of the pile group using the N-SPT soil data obtained through the Allpile program and the ENSOFT Group program on axial, lateral and pile settlement forces.
3. To determine the single pile deflection due to differences in the height of the pile above the ground against the lateral forces performed using the method of Brom, the Allpile program and the ENSOFT Group program;
4. To compare the bearing capacity of the pile from static analysis, the Allpile program and the ENSOFT Group program with the bearing capacity of fabricated pile materials (PT. Wijaya Karya Tbk).

## 2. Literature Review

The classification of the foundation generally falls into 2 types; shallow and deep foundation. Shallow foundation is a foundation whose depth ratio to the width is less than 1 (L/B <1, where L is the depth and B is the width of the foundation).

Deep foundation is a foundation whose depth ratio value is less than 4 (L/B> 4; where L is the depth and B is the width of the foundation).

a. End bearing pile

The driven pile foundation with the end bearing pile is a pile whose bearing capacity is determined by the end bearing of the driven pile. In general, the driven pile end supports are in a soft soil zone which is above hard ground. The driven piles are piled until they reach bedrock or other hard layers that can support loads which are expected not to result in excessive Settlement (Hardiyatmo, 2002).

b. Friction pile

A friction pile is a driven pile whose bearing capacity is determined, the friction resistance is determined between the driven pile wall and the surrounding soil (Hardiyatmo 2002).

### 2.1. Single pile bearing capacity

The ultimate bearing capacity of the pile (Qu), is the sum of the ultimate lower end resistance (Qb) and the ultimate pile friction resistance (Qs) between the side of the pile and the surrounding soil minus the pile's own weight (Wp), which can be expressed in the equation as follow:

$Q_u = Q_b + Q_s - W_p$

Where,

$Q_u$ = Ultimate carrying capacity (KN).
$Q_b$ = Pile end resistance (KN)
$Q_s$ = Friction resistance (KN)
$W_p$ = Pile weight (KN)

The following formula is used to calculate the pile capacity with the intention of obtaining the N value from the SPT test results on non-cohesive soil (sand and gravel):

- End bearing capacity of the driven pile

$$Qp = 40\,.\,Nspt\,.\left(\frac{Lb}{d}\right).\,Ap$$

Where:

Value N-spt = (N1+N2) / 2
N1 = Average value of SPT at 8D depth from pile end to top.
N2 = Average SPT Value at 4D depth from pile end down.
Lb = Soil thickness (m) and d = pile diameter (m)
Ap = Circumference of driven pile (m)

- Blanket sliding resistance of driven pile

$$Qs = 2\ x\ N - SPT\ x\ P\ x\ Li$$

where:

N-SPT = SPT Value
Li = Soil thickness ( m )
P = Circumference of driven pile (m)

The following formula is used to determine the pile capacity as well as the N value of the SPT test results on cohesive soil (clay):

- Bearing Capacity of driven pile end

Qp = 9 . cu . Ap.

- Blanket friction resistance of driven pile

Qs. = α . cu . P . Li

where:

α = Coeficient between soil adhesion and driven pile

cu = Undrained Cohesion (kN / m2)

cu = Nspt x 2/3 x10

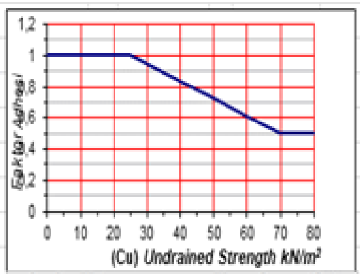
where:

Ap = cross-sectional area of pile (m2)

P = circumference of pile (m)

Li = Soil thickness (m)

| Cu | f. α |
|---|---|
| 0 | 1 |
| 25 | 1 |
| 40 | 0,8 |
| 50 | 0,7 |
| 60 | 0,6 |
| 70 | 0,5 |
| 75 | 0,5 |
| 80 | 0,5 |




Graph of the relationship among the shear strength (Cu)

**Figure 2.1.** Graph of shear strength relationship (Cu)

In obtaining the allowable pile bearing capacity (Qall), the ultimate pile capacity (Qu) can be divided either through a certain safety factor, or can be stated in the following equation:

$Q_a = Q_u / SF$

Where:

$Q_a$ = Allowable pile bearing capacity (KN)

$Q_u$ = Ultimate net bearing capacity (KN)

SF = *Safety Factor*

Tabel 2.1. Safety Factor by Reese dan O'Neill (1989)

| Structure Classification | Safety Factor (*SF*) | | | |
|---|---|---|---|---|
| | Good Control | Normal Control | Poor Control | Very Poor Control |
| Monumental | 2,3 | 3 | 3,5 | 4 |
| Permanent | 2 | 2,5 | 2,8 | 3,4 |
| Temporary | 1,4 | 2,0 | 2,3 | 2,8 |

## 2.2. Pile Capacity of pile driving analyzer (PDA) and CAPWAP field test result

*Pile Driving Analyzer* (PDA) and *CAPWAP* Data were directly obtained from the field test result. The output of CAPWAP are as follows:

- Pile axial bearing capacity (Ru - ton).
- At the maximum reduction of the pile (Dx – mm)
- Permanent reduction (DFN – mm)

## 2.3. Interpretation of pile driving analyzer (PDA) and CAPWAP test results

- Method by Chin F.K. (1971)

From Chin F.K's theory, using the graph in Figure 2.2 below:

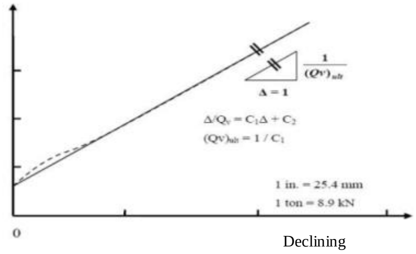



**Figure.2.2. Graph of Chin Method**

Load vs Loss on the graph in terms of the relationship S/Q, where:

S/Q = C1.S + C2

Load failure (Qf) or last load (Qult) is described as:

Qult = 1/C1

where:

S : Settlement

Q : Load increase

C1 : Slope of straight line

- Davisson's (1972) Method

The formula written in Davisson (1972) method is as follows:

$$X = 0{,}15 + \left( \frac{D}{120} \right)$$

$$Sf = \Delta + 0{,}15 + \left( \frac{D}{120} \right)$$

The graph on **Figure 2.3** shows the elastic deformation equation line of the pile obtained from the elastic pressure motion line, with the pile elastic equation as follows:

$$\Delta = \frac{Q \; x \; L}{A.E}$$

Where:

Sf : settlement in failure conditions

D : pile diameter

Q : applied load

L : pile length

E : elasticity modulus of the pile

A : area of the pile

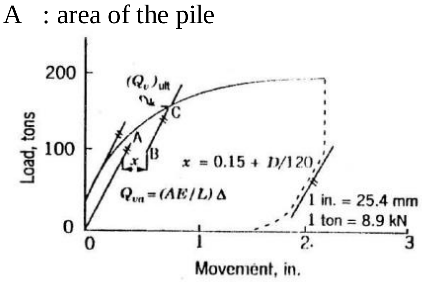



**Figure.2.3. Graph of Davisson Method**

- Mazurkiewicz (1972) Method

According to Prakash, S; and Sharma, H. (1990), the largest ultimate bearing capacity is obtained by pulling several points from the settlement curve to the load by pushing it to the load graph line until it intersects. From this intersection, a line that forms an angle of 40° is drawn to the line of intersection of the next load, then it connects the intersection of these lines to cut the load line. The point of intersection of these loads is the greatest ultimate load. The graphic depiction can be seen in Figure 2.4 below:

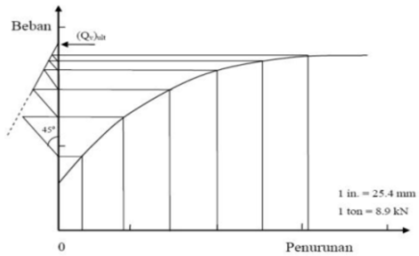



**Figure 2.4.** The Graph of Mazurkiewicz Method

### 2.4. Pile settlement

Criteria of the maximum settlement acceptance are:

For wide pile or Ø < 610 mm

$$.Sf = S + (4.0 + 0,008D)$$

For wide pile or Ø > 610 mm

$$Sf = S + \frac{D}{30}$$

where:

Sf = maximum settlement of pile (mm)
S = elasticity settlement of pile (mm)

While for S formula (elasticity settlement of pile)

$$S = \frac{(Qwp + \xi\, Qws)\, L}{Ap.Ep}$$

where:

Qwp = end bearing capacity of pile
Qws = bearing capacity of pile skin resistence
ξ = 0,5 for loam soil/ 0,67 for sandy soil
L = pile length
Ap = pile cross-sectional area
Ep = elasticity modulus of pile material

While the permanent settlement does not exceed Sp = D/120+4mm or ¼ of maximum settlement was selected the largest.

### 2.5. Pile group bearing capacity

Ultimate capacity of pile group using the pile efficiency factors (Eg) is stated using the following formula:

$Qg = Eg\ .\ n.\ Qa$

where:

Qg = Maximum load of the pile group
Eg = Efficiency of pile group
n = Number of poles per row

The Converse-Labarre method

$$Eg = 1 + \theta \left[\frac{(n-1)\, m + (m-1)\, n^2}{90^o\ m\ n}\right]$$

where:

Eg = Efficiency of pile group
n = Number of pile per row
m = Number of rows
D = Diameter of the pile
s = Maximum pile distance

The calculation of the pile foundation allowable capacity is always based on the pile lowering requirements. The ratio between the pile load and the pile end resistance is the basis of the pile settlement, if the pile end resistance on one pile supports an equal or smaller load than the load received. The relationship between the single pile settlement and pile group settlement (Hardiyatmo, 2010) is as follow:

$$Sg = \frac{2q\sqrt{Bg.I}}{N_{60}}$$

$$q = \frac{Qg}{LgBg}$$

where:

Sg = Settlement of pile group (mm)
q = Pressure at the base of the pile foundation
B = Pile Group area (mm)
S = Single pile settlement (mm)

### 2.6. The bearing capacity of the free head pile and the fixed head pile of Brom method

In calculating this lateral load, the Brom method is used by simplifying the soil pressure conditions to achieve the same ultimate along the pile depth. This method also serves to distinguish the condition of the fixed head and free head on both short and long pile. Brom (1964) argued and considered that the soil was non-cohesive (c = 0) or cohesive (θ = 0). Therefore, the piles for each soil type were analyzed separately. Brom also stated that short rigid pile and long flexible pile are considered separate. A pole is considered a short rigid pile if L / T ≤ 2 or L / R ≤ 2 and is considered a long flexible pile if L / T ≥ 4 or L / R ≥ 3.5.

### 2.7. Lateral bearing capacity of a single pile

Calculation of the lateral bearing capacity using the Broms' method (1964), with fixed head resistance. The approach is influenced by the pile stiffness factor (EI) and soil compressibility (soil modulus), K. If the soil is OC stiff clay, the stiffness factor for the non-constant modulus of soil (T) is expressed by the formula:

$$T = 5\sqrt{\frac{EI}{nh}}$$

*where:*

nh = the modulus coefficient of variation

If L ≥ 4T then the type of pile is categorized as a long / elastic pile, with the maximum moment determined by the pile resistance itself (My).

- *Driven pile* of fixed head

Soil capacity to support lateral force of fixed head pile, is calculated using the following equation of lateral load for the fixed head pile condition:

$$Hu = 1,5.\gamma.L^2.D.K_p \qquad (3.10)$$

Location of maximum moment:

$$f = 0,82\sqrt{\frac{Hu}{D.K_p.\gamma}}$$

Maximum moment:

$$Mmax = \frac{2}{3}\ Hu.L$$

Melting moment:

$$My = (0,5.\gamma.D.L^3.K_p).Hu\ .L$$

where:

Hu = lateral load (kN)
$M_y$= melting moment (kN-m)
$M_{max}$= Maximum Moment (kN-m)

L = pile length (m)
D = pile diameter (m)
Kp = passive earth pressure coefficient
f = Maximum moment distance from ground level (m)
γ = Weight of soil(kN/$m^3$)
e = Distance of lateral load from ground level (m)
if the pile is long, Hu dcan be obtained by the following equation:
*Hu = 2My / (e + 2f/3)*

### 2.8. Deflection due to lateral load

Calculation of the pile deflection of the fixed headed pile at 5 ground level.
Check pile deflection due to lateral loads

$$\alpha = \left(\frac{nh}{Ep\ Ip}\right)^{1/5}$$

Where:
nh = the coefficient of modulus variation
Ep = Modulus of elasticity of the pile material (kg/cm2)
Ip = Moment of Inertia of Piles (I)

### 2.9. Lateral bearing capacity of pile group

Lateral strength of the pile group using the factor graph of the lateral pile group settlement based on NAVFAC and Rees et al. is shown in the following figure (**Figure 2.5**)

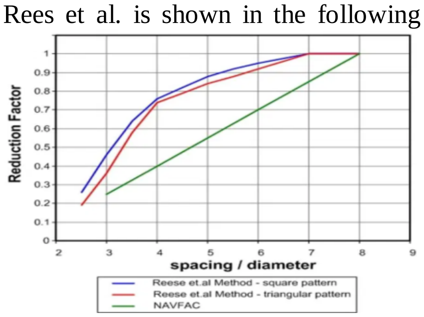



**Figure 2.5. Settlement Factor**

*H(group) = settlement factor x n x Hu*
Dimana :
*H(group) = Lateral bearing capacity of pile group*
*Hu* = Lateral bearing capacity of single pole
*N* = *Number of pile group*

### 2.10. *All Pile Program*

All pile is an analysis software program that is operated via a computer with a windows system aiming of performing an analysis where the analysis results are recognized as having high accuracy, especially in analyzing the efficiency of pile capacity. This program can also be used to analyze several types of deep and shallow foundation materials including: driven piles, drill piles, H and round steel profile piles, and triangular piles. The advantage of this program compared to other pile analysis programs is that it is able to combine several results of foundation analysis into one program. Pile bearing capacity analysis both axial and lateral on a single pile and pile group can be analyzed simultaneously. Compared to other programs for entering data – It only needs to input data once for analysis. It is able to quickly, precisely and well in analyzing piles.

### 2.11. ENSOFT GROUP Program

The ENSOFT Group program is a computer software that can analyze the behavior of piles due to lateral loads and axial loads. This program is able to graphically display the results of data analysis of the relationship among the analyzed parameters, in addition to calculating deflection, shear, bending moment, soil resistance to deflection (p-y), and the t-z curve method as a method of analyzing the lateral and axial bearing capacity of the foundation. In both uniform and layered soil conditions, it is very good at responding to soil depth. The output of the enshof group program observed in this study included:

1. The p-y curve.
2. The relationship between deflection and depth.
3. Relation of pile moment to depth.

## 5. Research Methodology

The following is the flow of activities carried out in this study (Figure 3.1).

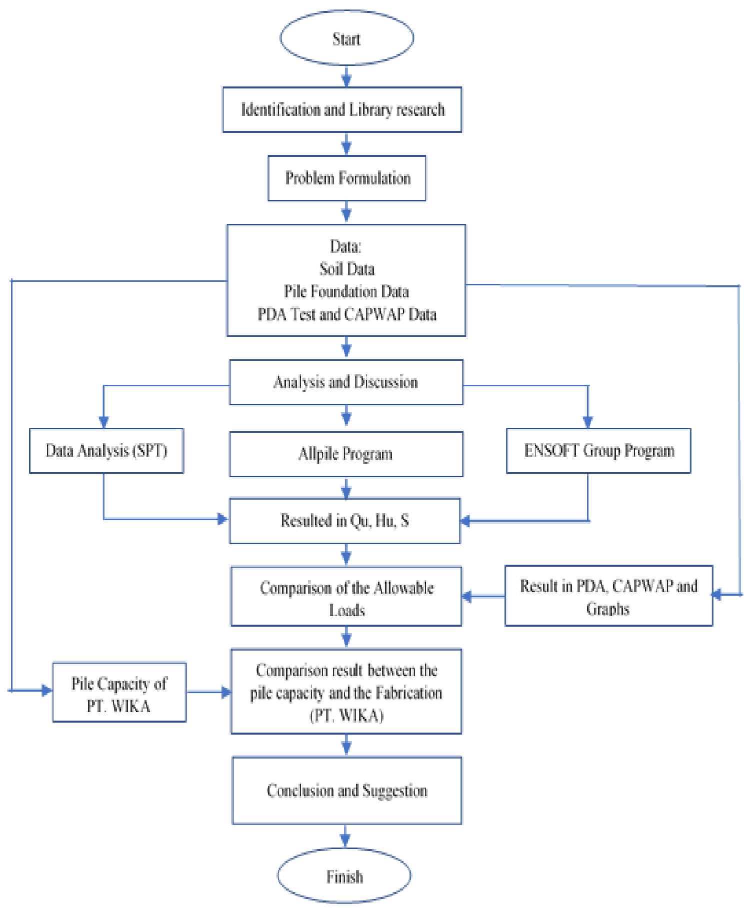



**Figure 3.1.** Flowchart of the Research

## 6. Analysis and Discussion

### 1.1 Data Collection

Data for analysis include:

1. Soil parameter data

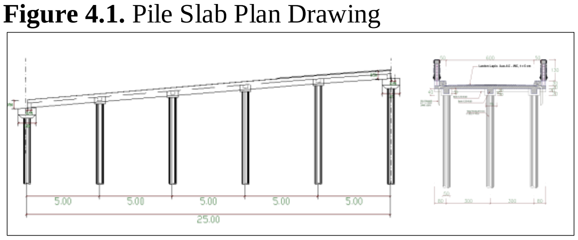
**Table 4.1.** Point BH-01

| H. Plan (m) | *Soil Layer* | N-spt | Pile | $N_1$' | N' Average | θ |
|---|---|---|---|---|---|---|
| | | | m | KN/m3 | | |
| 0 | Clay | | M.Ren | - | 14,50 | 31,35 |
| 2 | | 15 | | 15,00 | | |
| 4 | | 14 | Mat | 14,00 | | |
| 6 | Sand | 5 | | 5,00 | 4,67 | 28,47 |
| 8 | | 4 | | 4,00 | | |
| 10 | | 5 | Constan | 5,00 | | |
| 12 | Clay | 3 | | 3,00 | 2,67 | 28,27 |
| 14 | | 2 | | 2,00 | | |
| 16 | | 3 | | 3,00 | | |
| 18 | | 3 | | 3,00 | 6,33 | 28,63 |
| 20 | | 6 | | 6,00 | | |
| 22 | | 10 | | 10,00 | | |
| 24 | | 11 | | 11,00 | 21,75 | 33,53 |
| 26 | | 16 | | 15,50 | | |
| 28 | Sand | 20 | | 17,50 | | |
| 30 | | 24 | | 19,50 | | |
| 32 | | 28 | 8D 34 | 21,50 | | |
| 34 | | 33 | | 24,00 | | |
| 36 | | 38 | 38 m | 26,50 | | |
| 38 | | 39 | 4D 40 | 27,00 | | |
| 40 | | 40 | | 27,50 | | |

1. Design drawing data

In addition to the data above, there is also data regarding the image on the construction of the Batang Seturi Bridge using a pile slab structure

**Figure 4.1.** Pile Slab Plan Drawing




*Source: Plan Drawing 2019*

2. Pile Data

**Table 4.2.** Pile Data *(Spun pile)*

| Type | Diameter | Concret Quality (Fc') | Unit Weight | Bending Moment | | Allowable Compression | Decompression Tension |
|---|---|---|---|---|---|---|---|
| | | | | Crack | Break | | |
| Class | (mm) | (Mpa) | (Kg/m) | (Ton.m) | (Ton.m) | (Ton) | (Ton) |
| A1 | 500 | 52 | 290 | 10,50 | 15,75 | 185,30 | 54,56 |
| | m | EI | Ton/m | KN.m | KN.m | KN | KN |
| A1 | 0,5 | 33892 | 2,90 | 105,00 | 157,50 | 1.853,00 | 545,60 |

3. Data of field test result using Pile Driving Analyzer (PDA) and CAPWAP

**Table 4.3.** Pile Driving Analyzer (PDA)

| No. Total | Diameter pile | PDA | Analisis Capwap | | | Final set | BTA |
|---|---|---|---|---|---|---|---|
| | | | *Bearing Capacity* | *Skin Friction* | *End Bearing* | | |
| | *cm* | Ton | Ton | Ton | Ton | (mm/Blow) | (mm/Blow) |
| ABT 3d | 50,0 | 255,0 | 255,6 | 153,1 | 102,4 | 33,0 | 100% |

### 1.2 Analysis

Calculation on the ultimate bearing capacity Spun Pile based on SPT (Standard Penetration Test) data using Meyerhof method. There are two applicable formulas to calculate:

A. Cohesive soil (clay)

B. Non – cohesive (sand)

Calculation result of the ultimate and allowable bearing capacity (Spun Pile) can be seen in the table 4.4 below:

**Table 4.4.** Calculation of the ultimate bearing capacity and the allowable bearing capacity (Spun pile)

| H. Plan (m) | *Soil Layer* | N-spt | Pile | Skin Friction | | End Bearing | Qu | *Single Pile* | | | *Pile Group* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Lokal | Cumm | | | Qu | Qall | *S* | Converse-Labarre | Qu | Qall | *S* |
| | | | m | KN | KN | KN | KN | KN | KN | mm | KN | KN | KN | m |
| 0 | Clay | | M.Ren | - | - | - | - | - | - | 0 | - | | - | - |
| 2 | | 15 | | 126,711 | 126,71 | 129,59 | 256,30 | 250,50 | 102,52 | 0,26 | 0,93 | 238,34 | 95,33 | 0,71 |
| 4 | | 14 | Mat | 95,033 | 221,74 | 129,59 | 351,33 | 339,73 | 140,53 | 0,64 | 0,93 | 326,71 | 130,68 | 1,78 |
| 6 | Sand | 5 | | 5,69 | 227,44 | 227,77 | 455,20 | 437,80 | 182,08 | 1,35 | 0,93 | 423,30 | 169,32 | 3,80 |
| 8 | | 4 | | 42,41 | 269,85 | 212,06 | 481,91 | 458,71 | 192,76 | 1,84 | 0,93 | 448,13 | 179,25 | 5,14 |
| 10 | | 5 | Constan | 28,27 | 298,12 | 353,43 | 651,55 | 622,55 | 260,62 | 3,32 | 0,93 | 605,89 | 242,35 | 9,31 |
| 12 | Clay | 3 | | 62,832 | 360,96 | 35,34 | 396,30 | 361,50 | 158,52 | 1,71 | 0,93 | 368,52 | 147,41 | 4,80 |
| 14 | | 2 | | 62,832 | 423,79 | 35,34 | 459,13 | 418,53 | 183,65 | 2,29 | 0,93 | 426,95 | 170,78 | 6,41 |
| 16 | | 3 | | 62,832 | 486,62 | 35,34 | 521,96 | 475,56 | 208,79 | 2,95 | 0,93 | 485,38 | 194,15 | 8,26 |
| 18 | | 3 | | 2,75 | 489,37 | 109,96 | 599,32 | 547,12 | 239,73 | 4,22 | 0,93 | 557,32 | 222,93 | 11,83 |
| 20 | | 6 | | 4,91 | 494,28 | 196,35 | 690,63 | 632,63 | 276,25 | 5,86 | 0,93 | 642,22 | 256,89 | 16,43 |
| 22 | | 10 | | 6,68 | 500,95 | 267,04 | 767,99 | 704,19 | 307,20 | 7,53 | 0,93 | 714,16 | 285,66 | 21,09 |
| 24 | | 11 | | 8,54 | 509,49 | 341,65 | 851,14 | 781,54 | 340,46 | 9,46 | 0,93 | 791,48 | 316,59 | 26,52 |
| 26 | | 16 | | 11,49 | 520,98 | 459,46 | 980,44 | 905,04 | 392,18 | 12,38 | 0,93 | 911,72 | 364,69 | 34,68 |
| 28 | Sand | 20 | | 12,86 | 533,84 | 514,44 | 1048,28 | 967,08 | 419,31 | 14,47 | 0,93 | 974,80 | 389,92 | 40,53 |
| 30 | | 24 | | 14,92 | 548,76 | 596,90 | 1145,67 | 1058,67 | 458,27 | 17,28 | 0,93 | 1065,37 | 426,15 | 48,43 |
| 32 | | 28 | 8D 34 | 16,59 | 565,36 | 663,66 | 1229,02 | 1136,22 | 491,61 | 20,02 | 0,93 | 1142,87 | 457,15 | 56,10 |
| 34 | | 33 | | 18,46 | 583,81 | 738,27 | 1322,09 | 1223,49 | 528,83 | 23,16 | 0,93 | 1229,42 | 491,77 | 64,89 |
| 36 | | 38 | 38 m | 19,93 | 603,74 | 797,18 | 1.400,92 | 1296,52 | 560,37 | 26,16 | 0,93 | 1302,73 | 521,09 | 73,30 |
| 38 | | 39 | 4D 40 | 20,71 | 624,46 | 828,60 | 1453,05 | 1342,85 | 581,22 | 28,66 | 0,93 | 1351,21 | 540,48 | 80,31 |

*Source: Data processed in 2020*

### 1.3 Manual calculation of lateral bearing capacity and single pile foundation deflection

To determine the ultimate pile resistance that supports lateral loads, it is necessary to know the pile stiffness factors, R and T. This factor is influenced by the pile stiffness (EI) and soil compressibility (soil modulus), K. If the soil is OC stiff clay, the stiffness factor for non-constant modulus of soil (T). Types of piles are categorized as long / elastic piles. The resistance of the pile to lateral forces is determined by the maximum moment that the pile can withstand itself (My).

It is assumed that the head of the pile is above ground level with variations in height from the ground range from + 4 meters to + 7 m along 50 m, with an increase of 6.00%/ The length of the piles can be seen in table 4.5 below.

**Table 4.5.** Length of piles from the ground level

| No. | Pile Distance | Percentage Increase | head height from the | Pile Length in soil | Total Pile Length |
|---|---|---|---|---|---|
| 1 | 0 | 6% | 4 | 36,00 | 40,00 |
| 2 | 5 | 6% | 4,3 | 36,00 | 40,30 |
| 3 | 10 | 6% | 4,6 | 36,00 | 40,60 |
| 4 | 15 | 6% | 4,9 | 36,00 | 40,90 |
| 5 | 20 | 6% | 5,2 | 36,00 | 41,20 |
| 6 | 25 | 6% | 5,5 | 36,00 | 41,50 |
| 7 | 30 | 6% | 5,8 | 36,00 | 41,80 |
| 8 | 35 | 6% | 6,1 | 36,00 | 42,10 |
| 9 | 40 | 6% | 6,4 | 36,00 | 42,40 |
| 10 | 45 | 6% | 6,7 | 36,00 | 42,70 |
| 11 | 50 | 6% | 7 | 36,00 | 43,00 |

The results for calculating the lateral force and deflection of a single pile with variations in height from the ground from + 4 meters to + 7 m along 50 m can be seen in Table 4.6 below.

**Table 4.6** Lateral Power and Single Pile Deflection

| No. | head from the ground | M.max | My | Hu | Yo | Yo | Yo |
|---|---|---|---|---|---|---|---|
| | e | KN | KN | | m | mm | cm |
| 1 | 4,00 | 1.424,8 | 579,33 | 43,07 | 0,00027 | 0,268 | 2,685 |
| 2 | 4,30 | 1.424,8 | 588,05 | 43,50 | 0,00027 | 0,271 | 2,712 |
| 3 | 4,60 | 1.424,8 | 596,84 | 43,94 | 0,00027 | 0,274 | 2,739 |
| 4 | 4,90 | 1.424,8 | 605,69 | 44,37 | 0,00028 | 0,277 | 2,766 |
| 5 | 5,20 | 1.424,8 | 614,61 | 44,80 | 0,00028 | 0,279 | 2,793 |
| 6 | 5,50 | 1.424,8 | 623,59 | 45,24 | 0,00028 | 0,282 | 2,820 |
| 7 | 5,80 | 1.424,8 | 632,64 | 45,68 | 0,00028 | 0,285 | 2,847 |
| 8 | 6,10 | 1.424,8 | 641,76 | 46,11 | 0,00029 | 0,287 | 2,874 |
| 9 | 6,40 | 1.424,8 | 650,94 | 46,55 | 0,00029 | 0,290 | 2,902 |
| 10 | 6,70 | 1.424,8 | 660,18 | 46,99 | 0,00029 | 0,293 | 2,929 |
| 11 | 7,00 | 1.424,8 | 669,49 | 47,43 | 0,00030 | 0,296 | 2,957 |

### 1.4 Lateral bearing capacity and pile group deflection

Calculation of the value of the lateral bearing capacity of the pile group using the settlement factor graph.

The value of the deflection due to the lateral force and the deflection of the pile groups mentioned above can be seen in table 4.7 below:

**Table 4.7** Lateral power and pile group deflection

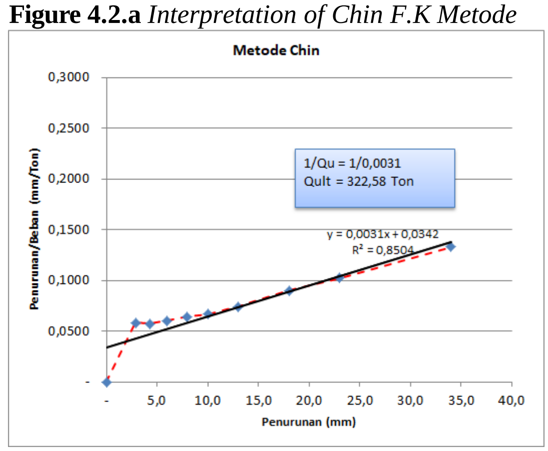
| No. | head from the ground | Hu | Factor Redukcion | Total Pile group | HU. Group | Yo | Yo |
|---|---|---|---|---|---|---|---|
| | e | KN | | Bh | Kn | mm | cm |
| 1 | 4 | 43,07 | 0,95 | 3 | 122,75 | 0,77 | 7,652 |
| 2 | 4,3 | 43,50 | 0,95 | 3 | 122,75 | 0,77 | 7,652 |
| 3 | 4,6 | 43,94 | 0,95 | 3 | 123,98 | 0,77 | 7,728 |
| 4 | 4,9 | 44,37 | 0,95 | 3 | 125,22 | 0,78 | 7,805 |
| 5 | 5,2 | 44,80 | 0,95 | 3 | 126,45 | 0,79 | 7,882 |
| 6 | 5,5 | 45,24 | 0,95 | 3 | 127,69 | 0,80 | 7,959 |
| 7 | 5,8 | 45,68 | 0,95 | 3 | 128,93 | 0,80 | 8,037 |
| 8 | 6,1 | 46,11 | 0,95 | 3 | 130,17 | 0,81 | 8,114 |
| 9 | 6,4 | 46,55 | 0,95 | 3 | 131,42 | 0,82 | 8,192 |
| 10 | 6,7 | 46,99 | 0,95 | 3 | 132,67 | 0,83 | 8,270 |
| 11 | 7 | 47,43 | 0,95 | 3 | 133,92 | 0,83 | 8,348 |

### 1.5 Interpretation of analysis results on CAPWAP PDA Test *(Case Pile Wave Analysis Program)*

PDA Test Analysis result data obtained with the help of CAPWAP software (Case Pile Wave Analysis Program) are interpreted in Figures 4.2.a to 4.2.c as follows:

1. Chin F.K (1971) Method

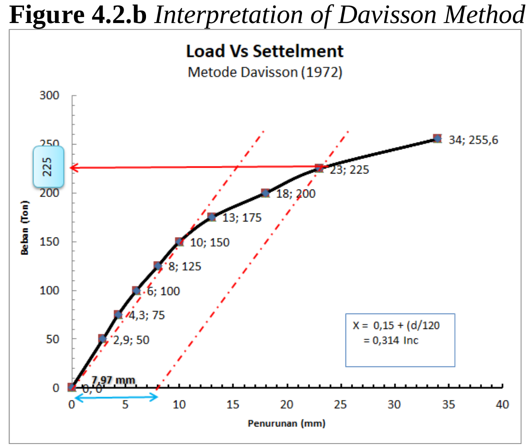
**Figure 4.2.a** *Interpretation of Chin F.K Metode*




*Source: Data Processed in 2020*

2. *Davisson (1972)* Method

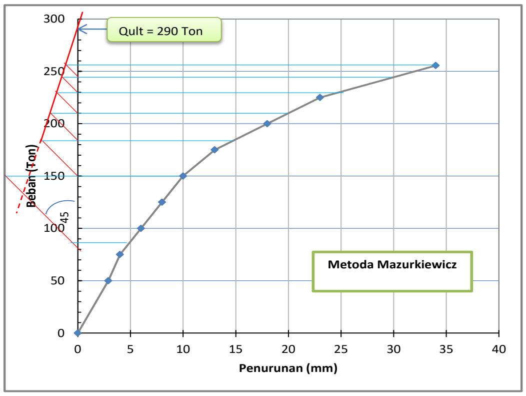
**Figure 4.2.b** *Interpretation of Davisson Method*




*Source: Data Processed in 2020*

3. Mazurkiewicz (1972) Method

**Figure 4.2.c** Interpretation of Mazurkiewicz Method




*Source: Data processed in 2020*

Based on the interpretation of PDA Test and CAPWAP data, the ultimate load can be shown as follows:

**Table 4.8.** Load of PDA Test and CAPWAP Interpretation Results

| Description of Activities | Metode Chin F.K. (1971) | | Metode Davisson (1972) | | Metode Mazurkiewicz (1972) | |
|---|---|---|---|---|---|---|
| 1 Ton = 8,9 KN | Ton | KN | Ton | KN | Ton | KN |
| Acxial Load (Qult) | 322,58 | 2.870,96 | 225,00 | 2.002,50 | 290,00 | 2.581,00 |
| Safety Factor (Fs) | 2,5 | | 2,5 | | 2,5 | |
| Acxial Load (Qall) | 129,03 | 1.148,38 | 90,00 | 801,00 | 116,00 | 1.032,40 |

## 1.6 Calculation of axial and lateral bearing capacity of pile foundation using *All Pile* program

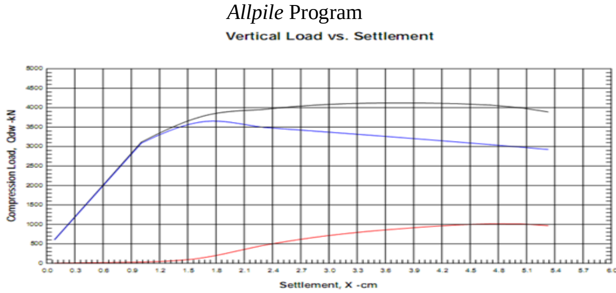
### 1.6.1 Axial bearing capacity of fixed head single pile

Based on the analysis of the ultimate *spun pile* bearing capacity at a soil depth of 36 m', using the *Allpile program*. The axial bearing capacity of the pile foundation with the fixed head pile can be seen in the following table and graph:

**Table 4.9.** Results of the Allpile Program – Axial single pile

| No. | *Total Pile Length* | *Total ultimate Capacity* | | *Total Alloable ultimate Capacity* | | *Qallow* | *Settel ment* |
|---|---|---|---|---|---|---|---|
| | | *(Dwon)* | *(Up)* | *(Dwon)* | *(Up)* | *2,5* | |
| | | Kn | Kn | Kn | Kn | Kn | mm |
| 1 | 40,0 | 4.120,16 | 2.477,86 | 1.648,06 | 1.238,93 | 1.648,06 | 39,00 |
| 2 | 40,3 | 4.120,16 | 2.477,86 | 1.648,06 | 1.238,93 | 1.648,06 | 39,00 |
| 3 | 40,6 | 4.120,16 | 2.479,25 | 1.648,06 | 1.239,63 | 1.648,06 | 39,00 |
| 4 | 40,9 | 4.120,16 | 2.480,64 | 1.648,06 | 1.240,32 | 1.648,06 | 39,00 |
| 5 | 41,2 | 4.120,16 | 2.482,03 | 1.648,06 | 1.241,02 | 1.648,06 | 39,00 |
| 6 | 41,5 | 4.120,16 | 2.483,42 | 1.648,06 | 1.241,71 | 1.648,06 | 39,00 |
| 7 | 41,8 | 4.120,16 | 2.484,81 | 1.648,06 | 1.242,41 | 1.648,06 | 39,00 |
| 8 | 42,1 | 4.120,16 | 2.486,20 | 1.648,06 | 1.243,10 | 1.648,06 | 39,00 |
| 9 | 42,4 | 4.120,16 | 2.487,59 | 1.648,06 | 1.243,80 | 1.648,06 | 39,00 |
| 10 | 42,7 | 4.120,16 | 2.488,98 | 1.648,06 | 1.244,49 | 1.648,06 | 39,00 |
| 11 | 43,0 | 4.120,16 | 2.490,37 | 1.648,06 | 1.245,19 | 1.648,06 | 39,00 |

**Figure 4.3.** Graph of the Relationship between Load and Settlement in *Allpile* Program




*Source: Data processed in 2020*

### 1.6.2 Lateral bearing capacity and fixed head single pile deflection

Based on the analysis of the ultimate *spun pile* bearing capacity at a soil depth of 36 m', using the *Allpile program*. Lateral bearing capacity and Fixed head single pole deflection can be seen in the following:

**Table 4.10** Result of Lateral Allpile and Single Pile Deflection

| No. | Total Pile Length | *Momen Maximum* | *Momen Maximum* | *Pile top deflection* | *Pile top deflection* |
|---|---|---|---|---|---|
| | | Kn. m | Kn. m | cm | cm |
| 1 | 40,0 | 307,00 | 122,80 | 3,16 | 1,26 |
| 2 | 40,3 | 330,00 | 132,00 | 3,87 | 1,55 |
| 3 | 40,6 | 353,00 | 141,20 | 4,68 | 1,87 |
| 4 | 40,9 | 359,00 | 143,60 | 4,94 | 1,98 |
| 5 | 41,2 | 407,00 | 162,80 | 7,02 | 2,81 |
| 6 | 41,5 | 413,00 | 165,20 | 7,36 | 2,94 |
| 7 | 41,8 | 410,00 | 164,00 | 8,48 | 3,39 |
| 8 | 42,1 | 438,00 | 175,20 | 8,66 | 3,46 |
| 9 | 42,4 | 445,00 | 178,00 | 9,08 | 3,63 |
| 10 | 42,7 | 466,00 | 186,40 | 12,20 | 4,88 |
| 11 | 43,0 | 496,00 | 198,40 | 12,30 | 4,92 |

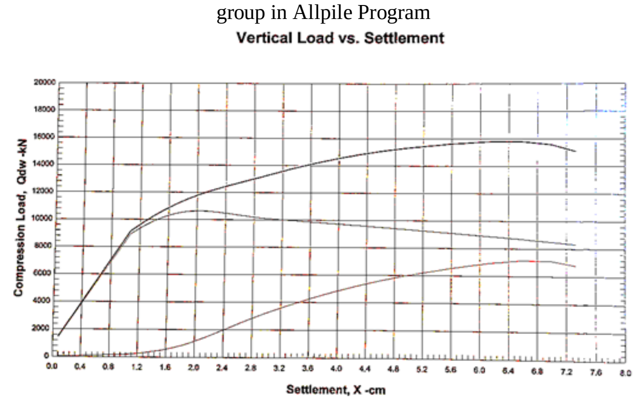
### 1.6.3 Pile group axial bearing capacity on Allpile program

Based on the analysis of the ultimate *spun pile* bearing capacity at a soil depth of 36 m', using *Allpile program*. The axial bearing capacity of the fixed head pile group foundation is presented in the following table and graph:

**Table 4.11.** Results of Allpile Program - Axial load group pile

| No. | Total Pile Length | *Total ultimate Capasity* | | *Total Alloable ultimate Capasity* | | *Qallow* | *Settelment* |
|---|---|---|---|---|---|---|---|
| | | *(Dwon)* | *(Up)* | *(Dwon)* | *(Up)* | | |
| | | Kn | Kn | Kn | Kn | Kn | mm |
| 1 | 40,0 | 15.806,60 | 7.506,47 | 6.322,64 | 3.002,59 | 5.597,20 | 66,10 |
| 2 | 40,3 | 15.806,60 | 7.510,65 | 6.322,64 | 3.004,26 | 5.597,20 | 66,10 |
| 3 | 40,6 | 15.806,60 | 7.514,82 | 6.322,64 | 3.005,93 | 5.597,20 | 66,10 |
| 4 | 40,9 | 15.806,60 | 7.518,99 | 6.322,64 | 3.007,59 | 5.597,20 | 66,10 |
| 5 | 41,2 | 15.806,60 | 7.523,26 | 6.322,64 | 3.009,30 | 5.597,20 | 66,10 |
| 6 | 41,5 | 15.806,60 | 7.527,33 | 6.322,64 | 3.010,93 | 5.597,20 | 66,10 |
| 7 | 41,8 | 15.806,60 | 7.531,50 | 6.322,64 | 3.012,60 | 5.597,20 | 66,10 |
| 8 | 42,1 | 15.806,60 | 7.535,67 | 6.322,64 | 3.014,27 | 5.597,20 | 66,10 |
| 9 | 42,4 | 15.806,60 | 7.539,84 | 6.322,64 | 3.015,94 | 5.597,20 | 66,10 |
| 10 | 42,7 | 15.806,60 | 7.544,01 | 6.322,64 | 3.017,60 | 5.597,20 | 66,10 |
| 11 | 43,0 | 15.806,60 | 7.548,18 | 6.322,64 | 3.019,27 | 5.597,20 | 66,10 |

**Figure 4.4.** Graph of the relationship between load and settlement of pile group in Allpile Program




*Source: Data Processed in. 2020*

### 1.6.4 Lateral bearing capacity and fixed head pile group deflection in Allpile Program

Based on the analysis of ultimate bearing capacity of *Spun Pile* in the soil depth of 36 m', using Allpile program. The lateral bearing capacity and the fixed head pile group deflection can be seen as follows:

**Table 4.12** Result in the lateral and deflection Allpile Program

| No. | Total Pile Length | *Momen Maximum* | *Pile top deflection* |
|---|---|---|---|
| | | Kn. m | cm |
| 1 | 40,0 | 366,00 | 3,68 |
| 2 | 40,3 | 384,00 | 4,44 |
| 3 | 40,6 | 410,00 | 5,42 |
| 4 | 40,9 | 418,00 | 5,69 |
| 5 | 41,2 | 445,00 | 6,81 |
| 6 | 41,5 | 472,00 | 8,12 |
| 7 | 41,8 | 480,00 | 8,49 |
| 8 | 42,1 | 508,00 | 10,02 |
| 9 | 42,4 | 516,00 | 10,47 |
| 10 | 42,7 | 545,00 | 12,34 |
| 11 | 43,0 | 575,00 | 14,22 |

## *1.7* Calculation of the axial and lateral bearing capacity of the pile foundation with Enshof Group Program.

### 1.7.1 Axial bearing capacity of single pile with Enshof Group Program.

Enshof Group 8.0 program is only used in pile group analysis. The minimum poles analyzed using this program are 2 poles. So that the single pile analysis process using the Enshof Group program is based on the pile group by dividing the number of piles in the group.

### *1.7.2* Axial bearing capacity of pile group in *Enshof Group program*

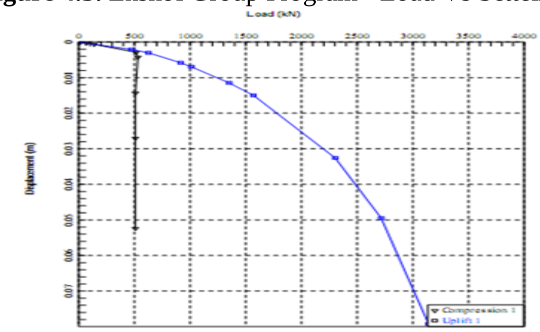
The calculation result of the bearing capacity of the fixed head pile group foundation using the Enshof Group program can be seen in the following table and graph:

**Table 4.13** Result of the axial pile group *Enshof Group Program*

| No. | Total Pile Length | *Axial Load Vs Settlement Group Pile* | | | Total Pile | Axial Load Vs Settlement Single Pile | |
|---|---|---|---|---|---|---|---|
| | | *Aksial Load* | *Settelment* | *Settelment* | | *Aksial Load* | *Settelment* |
| | | KN | m | mm | n | KN | cm |
| 1 | 40,00 | 3.139,45 | 0,0792 | 79,211 | | 1.046,48 | 2,64 |
| 2 | 40,30 | 3.140,29 | 0,0795 | 79,453 | | 1.046,76 | 2,65 |
| 3 | 40,60 | 3.140,27 | 0,0797 | 79,691 | | 1.046,76 | 2,66 |
| 4 | 40,90 | 3.138,43 | 0,0799 | 79,926 | | 1.046,14 | 2,66 |
| 5 | 41,20 | 3.141,94 | 0,0802 | 80,179 | | 1.047,31 | 2,67 |
| 6 | 41,50 | 3.138,35 | 0,0804 | 80,403 | 3,00 | 1.046,12 | 2,68 |
| 7 | 41,80 | 3.140,31 | 0,0809 | 80,893 | | 1.046,77 | 2,70 |
| 8 | 42,10 | 3.137,35 | 0,0811 | 81,115 | | 1.045,78 | 2,70 |
| 9 | 42,40 | 3.137,30 | 0,0811 | 81,115 | | 1.045,77 | 2,70 |
| 10 | 42,70 | 3.139,36 | 0,0814 | 81,368 | | 1.046,45 | 2,71 |
| 11 | 43,00 | 3.141,56 | 0,0816 | 81,615 | | 1.047,19 | 2,72 |

*Source: Data Processed in 2020*

**Figure 4.5.** Enshof Group Program - Load Vs Settlement




*Source: Data Processed in 2020*

### 1.7.3 Lateral bearing capacity and pile group deflection using Enshof Group Program

Based on the analysis results of the ultimate bearing capacity of the *spun pile* at the top end of the pile of the fixed head pile group at a soil depth of 36 m ', and the pile height above the ground of 4 m' using the Enshof Group program, the overall results of the ultimate bearing capacity of the spun pile group can be seen in the following table:

**Table 4.14** Calculation result of the lateral and deflection using *Enshof Group* Program

| No. | Total Pile Length | *Momen* | *Shear Reaction* | *Deflection* | *Deflection* | *Soil Stress* |
|---|---|---|---|---|---|---|
| | | Kn. m | Kn | m | cm | Kn /m2 |
| 1 | 40,00 | 191,70 | 103,72 | 0,031 | 3,06 | 0,000041 |
| 2 | 40,30 | 192,90 | 103,82 | 0,032 | 3,20 | 0,000041 |
| 3 | 40,60 | 212,10 | 104,34 | 0,038 | 3,83 | 0,000043 |
| 4 | 40,90 | 213,40 | 104,47 | 0,040 | 4,01 | 0,000044 |
| 5 | 41,20 | 233,80 | 105,01 | 0,047 | 4,72 | 0,000043 |
| 6 | 41,50 | 255,00 | 105,60 | 0,056 | 5,56 | 0,000049 |
| 7 | 41,80 | 256,60 | 105,74 | 0,058 | 5,79 | 0,000049 |
| 8 | 42,10 | 278,10 | 106,39 | 0,068 | 6,75 | 0,000052 |
| 9 | 42,40 | 298,90 | 107,13 | 0,079 | 7,88 | 0,000054 |
| 10 | 42,70 | 302,20 | 107,37 | 0,081 | 8,15 | 0,000055 |
| 11 | 43,00 | 323,30 | 108,10 | 0,094 | 9,43 | 0,000057 |

## 1.8 Comparison of the analysis results

### 1.8.1 Comparison of axial bearing capacity of the single pile as a result in PDA test CAPWAP

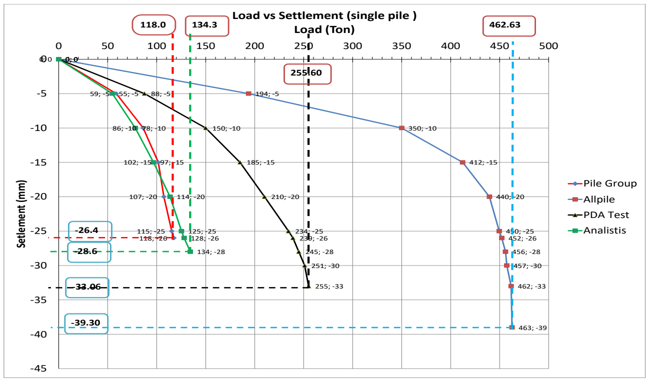
Axial bearing capacity of single piles using N-SPT soil data and analyzed using the Meyerhof method, the Allpile program and the ENSOFT Group program with the results of the CAPWAP PDA test which can be seen in Table 4.15 and graphs in Figure 4.6 as follows:

**Table 4.15** Ratio of the ultimate bearing capacity of the single pile

| DESCRIPTION | Metode Mayerhof | Program Allpile | Program *Enshoft group* | *PDA Test (CAPWAP)* | Kapasitas Tiang PT. WIKA |
|---|---|---|---|---|---|
| | KN | KN | KN | KN | KN |
| | | | | | |
| **Axsial Load Qu (KN)** | **1.400,92** | **4.120,16** | **2.616,21** | **2.550,00** | **4.632,50** |
| | | | | | |
| **Axsial Load Qall (KN)** | **560,37** | **1.648,06** | **1.046,48** | **1.020,00** | **1.853,00** |
| | | | | | |
| **Settelment (cm)** | **2,866** | **3,900** | **2,640** | **3,300** | **5,0000** |
| | | | | | |
| **Settelment (mm)** | **28,663** | **39,000** | **26,404** | **33,000** | **50,000** |
| | | | | | |

*Source: Data Processed in 2020*

**Figure 4.6.** Comparison graph of the single pile ultimate bearing capacity




*Source: Data Processed in 2020*

### 1.8.2 Comparison of the axial bearing capacity ratio of single pile interpreted from PDA Test CAPWAP

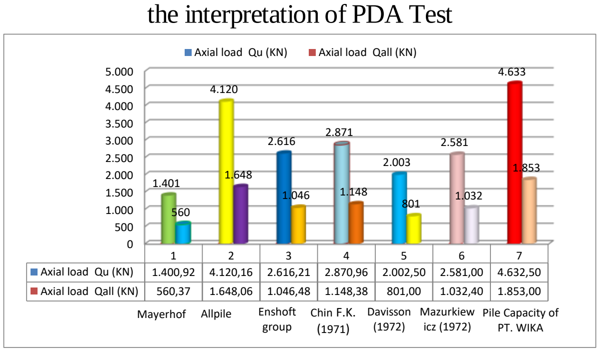
Comparison of the axial bearing capacity of single pile interpreted from PDA Test CAPWAP

The axial bearing capacity of a single pile using N-SPT soil data and analyzed using the Meyerhof method, the Allpile program and the ENSOFT Group program that it can be seen in Table 4.16 and Figure 4.7 below:

**Table 4.16.** Comparison of the ultimate bearing capacity ratio of the single pile

| Calculation Method | Axial load Ultimate | Axial load Allow | Axial load Allow PT. WIKA | Coefficient |
|---|---|---|---|---|
| | KN | KN | KN | % |
| *Results of the N-SPT Analysis* | | | | |
| Mayerhof | 1.400,92 | 560,37 | 1.853,00 | 30,24 |
| Program Allpile | 4.120,16 | 1.648,06 | | 88,94 |
| Program *Enshoft group* | 2.616,21 | 1.046,48 | | 56,48 |
| *Σ average N-SPT* | 2.712,43 | 1.084,97 | | 58,55 |
| *Interpretation of PDA test and CAPWAP results* | | | | |
| Metode Chin F.K. (1971) | 2.870,96 | 1.148,38 | 1.853,00 | 61,97 |
| Metode Davisson (1972) | 2.002,50 | 801,00 | | 43,23 |
| Metode Mazurkiewicz (1972) | 2.581,00 | 1.032,40 | | 55,72 |
| *Σ average PDA test* | 2.484,82 | 993,93 | | 53,64 |

**Figure 4.7.** Graph of bearing capacity of several methods using the interpretation of PDA Test




*Source: Data Processed in 2020*

Based on table 4.16 and Figure 4.7 using N-SPT soil data and analysed using static method of Mayerhof, Allpile program and ENSOFT Group program with the similar coefficient value of 2.5, it is obtained the greatest result of the value of the greatest single pile bearing capacity in the Allpile program with Qall value = 1.600,32 KN and the smallest value of Mayerhof method with Qall value = 1.296,52 KN. The average value of the allowable bearing capacity of Qall pile = 1.055,14 KN. While, the data analysis from the interpretation of PDA Test and CAPWAP using the methods of Chin F.K (1971), Davisson (1972) and Mazurkiewicz (1972), it is obtained that the average value of allowable bearing capacity of Qall pile = 993,93 KN. For the coefficient value of multiplier (kp) from the distance between average Qall of N SPT with the average Qall of PDA Test are:

$$Kp = \frac{\Sigma \text{ average of PDA test}}{\Sigma \text{ average of N-SPT}}$$

$$Kp = \frac{53{,}64}{56{,}94}$$

$$Kp = 0{,}9420$$

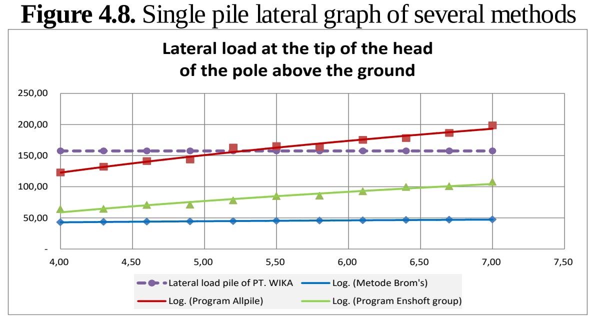
### 1.8.3 Comparison of the single pile lateral bearing capacity ratio

The single pile lateral bearing capacity using N-SPT soil data adopting Brom's method, Allpile program and ENSOFT Group program can be seen in table 4.17 and figure 4.8 as follows:

**Table 4.17.** Comparison of the single pile ultimate bearing capacity

| Mast Height from Ground | Metode Brom's | Program Allpile | Program *Enshoft group* | Lateral load pile of PT. WIKA |
|---|---|---|---|---|
| e (MT) | KN.m | KN.m | KN.m | KN.m |
| **4,00** | **43,07** | **122,80** | **63,90** | **157,50** |
| **4,30** | **43,50** | **132,00** | **64,30** | **157,50** |
| **4,60** | **43,94** | **141,20** | **70,70** | **157,50** |
| **4,90** | **44,37** | **143,60** | **71,13** | **157,50** |
| **5,20** | **44,80** | **162,80** | **77,93** | **157,50** |
| **5,50** | **45,24** | **165,20** | **85,00** | **157,50** |
| **5,80** | **45,68** | **164,00** | **85,53** | **157,50** |
| **6,10** | **46,11** | **175,20** | **92,70** | **157,50** |
| **6,40** | **46,55** | **178,00** | **99,63** | **157,50** |
| **6,70** | **46,99** | **186,40** | **100,73** | **157,50** |
| **7,00** | **47,43** | **198,40** | **107,77** | **157,50** |

**Figure 4.8.** Single pile lateral graph of several methods




*Source: Data Processed in 2020*

Based on Table 4.17 and Figure 4.8 of single pile bearing capacity using soil data of N-SPT adopting the methods of Brom's, Allpile program and ENSOFT Group program of fabricated pile lateral capacity of PT. Wijaya

Karya Tbk. In figure 4.17, single pile lateral graph of several methods intersects with the capacity graphs of the fabrication that is at the lateral capacity graph of Allpile program. Therefore, Allpile program capacity at the height of 5.20 m above the land, the value moment of fabricated piles of PT. Wijaya Karya Tbk has no longer been capable of sustaining the loads as the result in the calculation of the Allpile program. While the graphs which are the result from the methods of Brom's and ENSOFT Group program appear to be below from the fabrication capacity graphs of PT. Wijaya Karya Tbk.

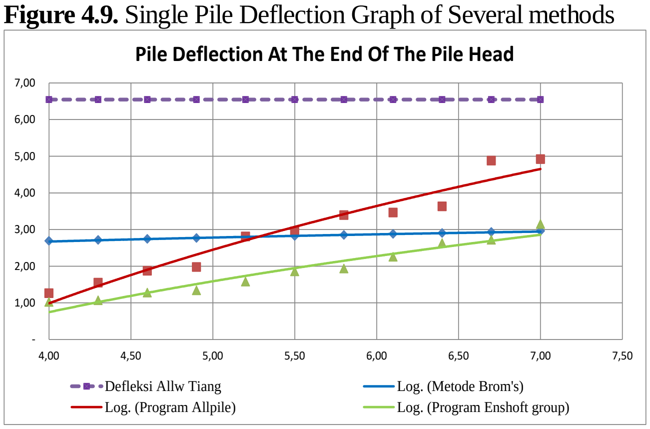
### 1.8.4 Comparison of the single pile deflection

Single pile deflection using N-SPT soil data adopting the methods of Brom's. Allpile program and ENSOFT Group program can be seen in table 4.18 and Figure 4.9 below:

**Table 4.18.** comparison of single pile deflection

| Mast Height from Ground | Metode Brom's | Program Allpile | Program *Enshoft group* | Defleksi Allw pile of PT. WIKA |
|---|---|---|---|---|
| e (MT) | cm | cm | cm | |
| 4,00 | 2,68 | 1,26 | 1,02 | 6,55 |
| 4,30 | 2,71 | 1,55 | 1,07 | 6,55 |
| 4,60 | 2,74 | 1,87 | 1,28 | 6,55 |
| 4,90 | 2,77 | 1,98 | 1,34 | 6,55 |
| 5,20 | 2,79 | 2,81 | 1,57 | 6,55 |
| 5,50 | 2,82 | 2,94 | 1,85 | 6,55 |
| 5,80 | 2,85 | 3,39 | 1,93 | 6,55 |
| 6,10 | 2,87 | 3,46 | 2,25 | 6,55 |
| 6,40 | 2,90 | 3,63 | 2,63 | 6,55 |
| 6,70 | 2,93 | 4,88 | 2,72 | 6,55 |
| 7,00 | 2,96 | 4,92 | 3,14 | 6,55 |

**Figure 4.9.** Single Pile Deflection Graph of Several methods




*Source: Data Processed in 2020*

Based on Table 4.18 and Figure 4.9, of single pile deflection influenced by the lateral power of pile with the height of 4.00 m to 7.00 m above the ground level measured using N-SPT soil data adopting the methods of Brom's, Allpile program and ENSOFT Group program, and the single pile deflection using data from Figure 4.18 of single pile deflection graph of several methods, all are below the fabricated pile deflection. Therefore, the ultimate lateral force (Hu.all) is still safe from the allowable deflection of the fabricated pile with the allowable deflection value of fabricated pile, maximum 6.55 mm.

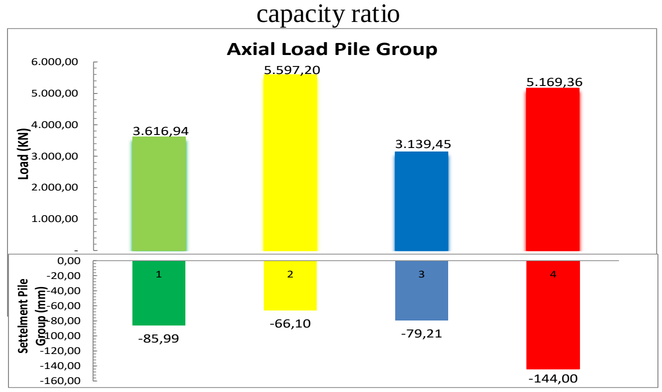
### 1.8.5 Comparison of axial bearing capacity ratio of the pile group

Axial bearing capacity of pile group using N-SPT soil data adopting the methods of meyerhof, Allpile program and ENSOFT Group program can be seen in table 4.19, and figure 4.10. as follows:

**Table 4.19.** Comparison of the Pile Group Ultimate Bearing Capacity

| Metode | Axial Load Ultimate | Settelment | Capacyty Pile of PT. WIKA | Percentage | Percentage Average |
|---|---|---|---|---|---|
| | KN | mm | KN | % | % |
| Mayerhof | 3.616,94 | -85,99 | 5.169,36 | 69,97 | 79,66 |
| Program Allpile | 5.597,20 | -66,10 | | 108,28 | |
| Program *Enshoft group* | 3.139,45 | -79,21 | | 60,73 | |
| Σ *Average* | 4.117,86 | - 77,10 | | 79,66 | |

**Figure 4.10.** Graph of the pile group ultimate bearing capacity ratio




*Source: Data Processed in 2020*

Based on Table 4.19 and Figure 4.10 of the analysis from S-SPT soil data by calculating the static analysis through the methods of mayerhof, Allpile program and ENSOFT Group program with the result in PDA test CAPWAP with the similar coefficient value of 2.5, it is obtained that the greatest value of the greatest single pile bearing capacity is in the Allpile program with Qult value = 5.597,20 KN (1Ton =8,9 KN) with the settlement S = 108 mm. The smallest value of the ENSOFT Group program method with the Qult value = 3.139,45 KN. with the settlement S = 75 mm. While for the average value of allowable bearing capacity of Qult fabricated pile = 5.169,36 KN, with the maximum settlement of pile L/250 from the pile length of 36 m and with diameter of 50 cm as big as = 144 mm. Bearing capacity of pile group using N-SPT soil data adopting the methods of mayerhof, Allpile program and ENSOFT program is still below the fabricated pile capacity, with the average percentage of 79.66% on the pile bearing capacity of PT. Wijaya Karya Tbk. However, overcapacity of pile group from the fabricated pile with percentage of 108.28% occurs only at the pile as the result in Allpile program.

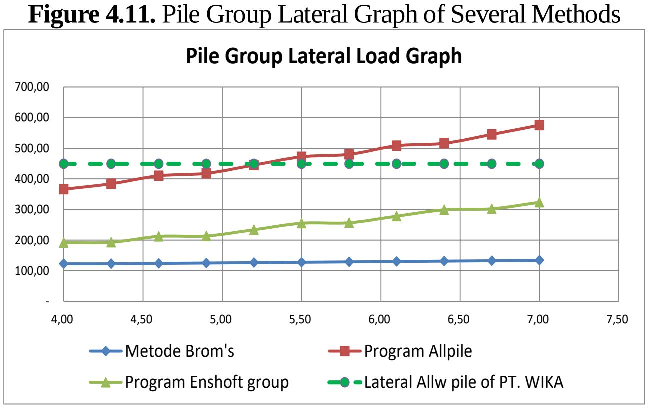
### 1.8.6 Comparison of the pile group lateral bearing capacity

Pile group lateral bearing capacity using N-SPT soil data adopting the methods of Brom's, Allpile program and ENSOFT Group program can be seen in Table 4.20 and Figure 4.11. as follows:

**Table. 4.20.** Comparison of the pile group lateral bearing capacity

| Mast Height from Ground | Metode Brom's | Program Allpile | Program *Enshoft group* | Lateral Allw pile of PT. WIKA | *Prosent* |
|---|---|---|---|---|---|
| e (MT) | KN.m | KN.m | KN.m | KN.m | % |
| | | | | | |
| 4,00 | 122,75 | 366,00 | 191,70 | 448,88 | 50,53 |
| 4,30 | 122,75 | 384,00 | 192,90 | 448,88 | 51,96 |
| 4,60 | 123,98 | 410,00 | 212,10 | 448,88 | 55,40 |
| 4,90 | 125,22 | 418,00 | 213,40 | 448,88 | 56,19 |
| 5,20 | 126,45 | 445,00 | 233,80 | 448,88 | 59,80 |
| 5,50 | 127,69 | 472,00 | 255,00 | 448,88 | 63,47 |
| 5,80 | 128,93 | 480,00 | 256,60 | 448,88 | 64,27 |
| 6,10 | 130,17 | 508,00 | 278,10 | 448,88 | 68,04 |
| 6,40 | 131,42 | 516,00 | 298,90 | 448,88 | 70,27 |
| 6,70 | 132,67 | 545,00 | 302,20 | 448,88 | 72,76 |
| 7,00 | 133,92 | 575,00 | 323,30 | 448,88 | 76,65 |
| | | | | Σ *Average* | 62,67 |

**Figure 4.11.** Pile Group Lateral Graph of Several Methods




*Source: Data Processed in 2020*

Based on Table 4.20 and Figure 4.11 of the pile group bearing capacity using N-SPT soil data adopting the methods of Brom's, Allpile program and ENSOFT Group program of the fabricated pile lateral capacity of PT. Wijaya Karya Tbk., and from Figure 4.21., it appears that the pile group lateral graphs of several methods intersect with the capacity graphs from the fabrication that is in the lateral capacity graph of the Allpile program. Therefore, the Allpile capacity program at the height of 5.8 m from the ground level, moment as the result in the fabricated pile of PT. Wijaya Karya Tbk has no longer capable of sustaining the loads as the result in Allpile program calculation. While for the graphs from the method of Brom and ENSOFT Group program, they are still below the fabrication capacity graphs of PT. Wijaya Karya Tbk.

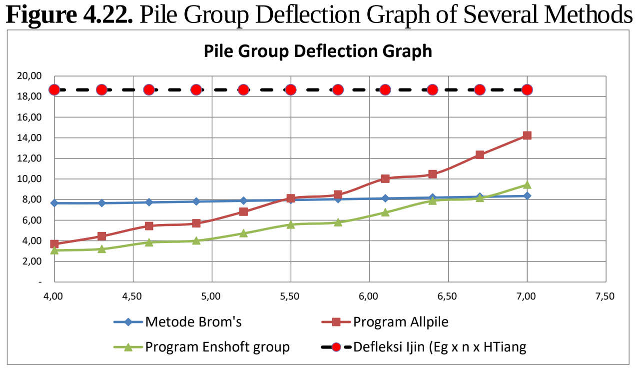
### 1.8.7 Comparison of the pile group deflection

Pile group deflection using N-SPT soil data adopting the methods of Brom, Allpile program and ENSOFT Group program can be seen in Table 4.21. and Figure 4.12 below:

**Table 4.21.** Comparison of Pile group deflection

| Mast Height from Ground | Metode Brom's | Program Allpile | Program *Enshoft group* | Defleksi Ijin *(Eg x n x H $_{Tiang}$* |
|---|---|---|---|---|
| e (MT) | cm | cm | cm | cm |
| | | | | |
| **4,00** | 7,65 | 3,68 | 3,06 | 18,65 |
| **4,30** | 7,65 | 4,44 | 3,20 | 18,65 |
| **4,60** | 7,73 | 5,42 | 3,83 | 18,65 |
| **4,90** | 7,81 | 5,69 | 4,01 | 18,65 |
| **5,20** | 7,88 | 6,81 | 4,72 | 18,65 |
| **5,50** | 7,96 | 8,12 | 5,56 | 18,65 |
| **5,80** | 8,04 | 8,49 | 5,79 | 18,65 |
| **6,10** | 8,11 | 10,02 | 6,75 | 18,65 |
| **6,40** | 8,19 | 10,47 | 7,88 | 18,65 |
| **6,70** | 8,27 | 12,34 | 8,15 | 18,65 |
| **7,00** | 8,35 | 14,22 | 9,43 | 18,65 |

**Figure 4.22.** Pile Group Deflection Graph of Several Methods




*Source: Data Processed in 2020*

Based on Table 4.33 and Figure 4.22 of Pile group deflection influenced by the lateral force of pile with the height of 4.00m to 7.00 m from the ground level measured using N-SPT soil data adopting the methods of Brom's, Allpile program and ENSOFT Group program, and on Figure 4.22 of pile group deflection of several method, all are below the allowable deflection value of the fabricated pile with the allowable deflection value maximum of 18.26 mm, and so the value of deflection is still safe against the effect resulting from the lateral force (Hu all) of the allowable values of the fabricated pile allowable Hu deflection.

Based on the analysis of the pile bearing capacity ratio of the static analysis result using Allpile program, ENSOFT Group program and PDA test (CAPWAP) using the fabricated pile material bearing capacity (PT. Wijaya KaryaTbk.) with the pile type A1, diameter 50 cm with the concrete quality of FC' 52 Mpa, with the value of bending and cracking moment of 10.5 ton m, lateral moment of 15.75 ton m and axial allowable force (allowable compression) of 185.30 ton are still in the safe limit, with range of percentage value of 53.64 (result in PDA test) to

79.66 from the pile group capacity which is below the percentage of 100.00 from the fabricated pile capacity of 79.66 > 100.00. Therefore, the bearing capacity of the fabricated pile capacity can still be increased of:

Fabricated Pile = 100%

Max percentage - 36 m = 79,66

Percentage Value $= \frac{Fabricate\ Pile}{Max\ Percentage - 36\ m}$

$$Percentage\ Value = \frac{100}{79{,}66}$$

$$Percentage\ Value = 1{,}26$$

The Soil bearing capacity can still be increased with the percentage of 1.26 by deepening the pile.

## 7. Conclusions and Suggestions

### 5.1 Conclusions

From the analysis results of the single pile and pile group, the following conclusions are derived:

- Based on the comparison of single pile ultimate bearing capacity result ratio using N-SPT soil data adopting the methods of Meyerhof, Allpile program and ENSOFT program, the average capacity of Qall = 1.084,97 with the greatest settlement at the Allpile program = 39.00 mm, while the data interpretation from PDA Test and CPWAP with the average capacity value of Qall = 993.93 KN, with the settlement at the PDA Test = 33.00 mm. The average capacity is still below the fabricated pile capacity, with the average percentage of 53.64 percent from the N-SPT data and 58.55 percent on the pile bearing capacity (PT. Wijaya Karya Tbk), type A1 with the diameter of 50 cm, with the axial bearing capacity of Qall = 1.853.00 KN and so, the pile is safe for use.
- From the analysis of the average value ratio from N-SPT data with data interpretation analysis result of PDA Test and CPWAP, the multiplier of Kp = 0,942 is obtained.
- Based on the calculation of single pile capacity using the ENSOFT program, the results are not obtained, because the ENSOFT program only functions to analyze the pile group. However, through the pile group analysis, the results of the single pile capacity can be obtained by dividing the number of piles analyzed.
- Based on the analysis result of the pile bearing capacity result, the result in static analysis using Allpile program, ENSOFT Group program and PDA Test (CAPWAP) with the material baring capacity of fabricated pile (PT. Wijaya Karya Tbk) with the pile type A1, with diameter of 50 cm, with concrete quality of Fc' 52 Mpa, with the value of bending and cracking moment of 10.5 ton.m, with lateral moment of 15.75 ton.m and with the axial allowable force (allowable compression) of 185.30 ton, shows that it is still in the safe limits. With the range of percentage value of 53.64 (result in PDA test) to 79.66 from pile group bearing capacity. Therefore, the soil bearing capacity can still be increased by = 1.26 through deepening the pile.

### 5.2 Suggestions

The following are suggestions that can be derived from the research:

- The ENSOFT Group software program only functions to analyze pile group, in other words, to analyze single piles it is suggested to use other suitable programs capable of analyzing single piles.
- If the multiplier coefficient factor (Kp) is to be applied in the field, then the average Qall of various kinds of N-SPT analysis should be used, after which it is just multiplied by this kp value of 0.942, to obtain a load value that is close to the true value.
- Due to limited field data where the results of the PDA test are only 1 sample of data, the multiplier coefficient factor (Kp) only applies to land located on the north coast of Batang Regency. If the multiplier coefficient (kp) is to be developed again in further research, it is necessary to add as many field data as possible both the PDA test and the loading test results.

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