ANALYSIS OF THE CARRYING CAPACITY OF THE PILE FOUNDATION COMPARED TO JACKING SYSTEM & PILE DRIVING ANALYZER (PDA) TEST (Case Study of Building Construction Projects in the District of DPRD Bangkalan)

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ABSTRACT

The foundation is a structure under the building that serves as a distributor of the load on it to the supporting ground layer. The pile capacity is obtained from the soil investigation results which is sondir test. Sondir test is a technique of soil layer estimator to determine the type of foundation that will be used such as pile foundation. Hydraulic Jacking System is an equipment to pressure the pile. Pile Driving Analyzer Test is a system used for test the pile dynamically after erection. The purpose of this research is to know the method of bearing capacity of pile foundation calculation based on sondir data which approach Hydraulic Jacking System capacity and Pile Driving Analyzer Test capacity. This research method is quantitative. Data were collected using survey techniques. The survey technique is used to obtain generat data from the field. The data is processed using Schmertmann’s method, Philipponant’s method, and Andina’s method, and the results is compared with the Hydraulic Jacking System capacity and Pile Driving Analyzer Test capacity.

Keywords: Sondir Data, Hydraulik Jacking System and Pile Driving AnalyzerTest

INTRODUCTION

Construction of a construction, first carried out and carried out in the field is the work of the new foundation then carry out the work of the upper structure. The construction of a very large foundation functions in a construction. In general, the foundation is defined as an underground building which forwards the burden that comes from the weight of the building itself and the external load acting on the building to the surrounding land. The foundation as a structure can generally be divided into 2 (two) types, namely deep foundations and shallow foundations. The choice of foundation type depends on the type of upper structure whether it includes light or heavy load construction and also depends on the type of soil. In general the problem of deep foundations is more complicated than shallow foundations. Pile foundations are relatively long and slender stems which are used to channel foundation loads through layers of soil with low carrying capacity of hard soil layers that have high bearing capacity that is relatively deep enough compared to shallow foundations (Terzaghi, 1996).

In this study the author tries to concentrate on the pile foundation. The data used are soil data obtained from the Bangkalan Regency DPRD Building Construction Project, namely sondir data, reading data from the Hydraulic Jacking System and the Pile Driving Analyzer (PDA) Test.

To determine the carrying capacity of land, sondir data is calculated using several methods including the Schmertmann method, the Philipponant method, and the Andina method. With so many methods used there will be a variety of different results, therefore the right method is very influential with the results of foundation planning so that the results are maximized. The results of the following methods are compared with the Hydraulic Jacking System (HJS) and Pile Driving Analyzer (PDA) Test data. From the results closest to the results in the field is the right method and can be used as a reference for planning consultants in planning the deep foundations in the Bangkalan District Parliament Building.
Investigation of soil in the field is needed for data on the design of foundations of buildings, such as buildings, retaining walls, dams, roads, docks, and others. Depending on the intent and purpose, the investigation can be carried out by means of digging test holes (test-pits), drilling and testing directly in the field (in-situ test). From the data obtained, the technical properties of the soil are studied, then used as a material consideration in analyzing the carrying capacity and decline.

The accuracy of the land investigation depends on the size of the building load, the desired level of security, the condition of the ground, and the costs available for the investigation. Therefore, for simple or lightweight buildings, sometimes land investigations are not needed, because the condition of the land can be known based on local experience (Christady, 2011).

This sondir test is a representation or model of the pile foundation on a small scale. The technique of estimating the location or depth of hard soil with a stem has long been practiced since ancient times. An early version of this estimation technique was developed in Sweden in 1917 by Swedish State Railways and by the many uses of pile foundations, in 1934 the Dutch introduced sondir as we know it today (Barentseen, 1936). This method came to be known by various names such as: "Static Penetration Test" or "Duch Cone Statick Penetration Test" and briefly called sounding which means estimation. In Indonesia later called sondir taken from the Dutch language.

The sondir test is one of the tests in the field of civil engineering that serves to determine the location of the depth of hard soil, which can later be estimated how strong the soil is in bearing the weight established on it. This test is usually done before building a pile foundation, or other deep foundations. The data obtained from this test will be in the form of the magnitude of the resistance force from the soil to the conus, as well as the adhesive barrier from the soil to determine the conus penetration resistance ($q_c$), the sticking resistance ($f_s$) of the soil and the friction ratio ($r_f$) to estimate the type of soil under investigation.

The basic principle of the static penetration test in the field is to assume the applicable Law of Action for Reaction (equation 10), as used for calculating the conus resistance value and the shear resistance value below.

1. **Perlawanan Konus ($q_c$)**

   \[
   P_{konus} = P_{piston} \quad \text{(1)} \\
   q_c \times A_c = C_w \times A_{pi} \quad \text{(2)} \\
   q_c = C_w \times A_{pi} / A_c \quad \text{(3)} \\
   A_{pi} = \frac{D_{pi}^2}{4} \quad \text{(4)} \\
   A_c = \frac{(D_{c})^2}{4} \quad \text{(5)}
   \]

   Where:
   - $P_{konus}$: force on the piston (kN)
   - $P_{piston}$: force at the conical end (kN)
   - $A_c$: conical cross-sectional area (cm$^2$)
   - $A_{pi}$: piston cross section area (cm$^2$)
   - $C_w$: piston cross section area (kPa)
   - $D_{pi}$: piston diameter (cm)
   - $D_c = D_s$: the diameter of conus is the same as the diameter of the sliding blanket (cm)

2. **Perlawanan Geser ($f_s$)**

   \[
   P_{konus} + P_{geser} = P_{piston} \quad \text{(5)} \\
   (q_c \times A_c) + (f_s \times A_{s}) = T_w \times A_{pi} \quad \text{(6)} \\
   (C_w \times A_{pi}) + (f_s \times A_{s}) = T_w \times A_{pi} \quad \text{(7)} \\
   F_s = K_w \times A_{pi} / A_{s} \quad \text{(8)} \\
   A_{s} = D_s \times L_s \quad \text{(9)} \\
   K_w = (T_w - C_w) \quad \text{(10)}
   \]

   Where:
   - $C_w$: manometer readings for cone resistance values (kPa)
   - $T_w$: Manometer readings for cone and sliding resistance values (kPa)
   - $K_w$: difference with (kPa)
Fs: local shear resistance (kPa)
Ds: diameter of the sliding blanket (cm)
Ls: long sliding blanket (cm)

3. Slide Comparison Number (Rf)
\[ R_f = \left( \frac{f_s}{q_c} \right) \times 100(\%) \] .................. (9)

4. Slide Total (Tf)
\[ T_f = (f_s \times \text{reading interval}) \] .................. (10)

The carrying capacity of the mast is the ability or capacity of the mast to support the load. If in the carrying capacity the shallow foundation is the unit of pressure (kPa), then the carrying capacity of the unit is the unit of force (kN). Calculation of bearing capacity of the pile foundation there are several methods used including:

5. Method Schmertmann -Nottingham (1975)
6. Method Philipponant
7. Method Andina

Hydraulic Jacking System (HJS) is a piling foundation method using a tool called a Hydraulic Static Pile Driver (HSPD) with a Hydraulic Jacking Foundation System mechanism, which operates using a pinning system then presses the pile continuously into the ground, without noise, and without noise. This system has obtained patents from the United States, United Kingdom, China and New Zealand.

Hydraulic Jacking System (HJS) is used because it has advantages including:
1. With the Hydraulic Jacking System (HJS), the actual carrying capacity of the pile penetration is known and monitored directly from a manometer mounted on the Hydraulic Jacking System (HJS) equipment during the designing process. As we know that the condition of the original soil under the foundation to be built generally consists of layers of different thickness, type of soil and carrying capacity.
2. Generate better soil friction carrying capacity because by using the Hydraulic Jacking System (HJS) which was pushed to the side laterally due to penetration of the pile, within a few hours the pushed ground will re-clamp the pole and provide additional carrying capacity.
3. Does not produce noise like in hammer and generally uses Silent Genset as main power for the activities of the Hydraulic Static Pile Driver (HSPD) so it does not produce significant smoke pollution. Hydraulic Static Pile Driver (HSPD) is suitable for use in residential areas because there is almost no noise and vibration.
4. Job output or work productivity is better than hammer, for piling work where maximum penetration is flat ground.
5. Does not cause vibrations around so it is safe for nearby buildings so as to minimize structural cracks in neighboring buildings.

No cracking occurs at the head of the pole and no necking (indentation on the foundation).

The conversion of Psi for a 120-ton pile load with a piston cylinder diameter = 20 cm with two cylinders is as follows:
- Formula \( A = 2 \times \frac{1}{4} \pi x 20^2 \)
  \[ = 628 \text{ cm}^2 \]
- Formula \( \sigma = \frac{P}{A} \rightarrow P = \sigma x A \)
- For Pressure Gauge readings are as follows:
  10 kg/cm\(^2\) = 10,00 \times 628
  = 6,280,00 kg = 6,28 ton
  50 kg/cm\(^2\) = 50,00 \times 628
  = 31,400,00 kg = 31,4 ton

Pile Dynamic Analyzer (PDA) Test which is a test to dynamically measure the capacity of a compressed pile on a deep foundation, be it a pile or bore, the integrity of the pile, and the energy of the hammer. Pile Driving Analyzer (PDA) Test itself is a special computer that has been made for testing with digital computer data obtained from the Strain Transducer and Accelerometer to obtain force and speed curves when the pole is hit using a hammer with a certain weight after piling. He can assess the capacity of the pile, hammer energy,
decrease of the pile, evaluate the integrity of the pile, etc. according to ASTM D-4945.

After the Pile Driving Analyzer (PDA) test is carried out, further analysis is carried out with the Case Pile Wave Analysis Program (CAPWAP) to obtain the load transfer of the pile and soil behavior around the pile, the friction capacity and end of the pile, the compressive and tensile stress along the pile and the pile drop.

RESULT AND DISCUSSION

The following are the results of the author's research

1. Ond Sondir Results Data

The sondir data contained in the field were 3 points, namely Sondir S1, Sondir S2, and Sondir S3. In this study, the author uses Sondir S2 data because it is located close to the point of the Pile Driving Analyzer (PDA) Test conducted. This is done because the author assumes Sondir S2 point with Pile Driving Analyzer (PDA) Test has validity of data due to the close distance (sondir data table as attached).

2. Hydraulic Jacking System Data (HJS)

Data Hydraulic Jacking System berasal dari hasil pemancangan pada As F9 dengan jumlah 7 titik tiang pancang tiap penetrasi 2 meter. Penulis menggunakan data Hydraulic Jacking System (HJS) pada As F9 karena ada salah satu titiknya yang dilakukan Pile Driving Analyzer (PDA) Test yaitu pada titik P418. Data Hydraulic Jacking System (HJS) pada As F9:

| Kedalaman (Meter) | Pressure Gauge Rata-rata (Ton) |
|-------------------|-------------------------------|
| 2.00              | 16.46                         |
| 4.00              | 20.12                         |
| 6.00              | 29.26                         |
| 8.00              | 44.81                         |
| 10.00             | 78.65                         |

3. Pile Driving Analyzer Data (PDA) Test

Pile Driving Analyzer (PDA) Building Test of DPRD Building Kab. Bangkalan on 19 July 2019 was carried out at pole number P 418 on Pile Cap As F9 with 11.2 meters penetration. Pile Driving Analyzer (PDA) Test Pole Data Test:

| No Tiang | Daya Dukung Total (Ton) | Daya Dukung Friksi (Ton) | Daya Dukung Ujung (Ton) |
|----------|-------------------------|--------------------------|-------------------------|
| P 418    | 84.4                    | 63.0                     | 21.4                    |

Calculation of bearing capacity of pile foundation based on Sondir data as follows:

4. Metode Schmertmann -Nottingham (1975)

\[ Q_u = Q_p + Q_s \] ……………………… (11)

\[ Q_p = C_n \text{ rata-rata} \times A_p \] ………………… (12)

\[ C_n \text{ rata-rata} = \frac{q_{c1} + q_{c2}}{2} \] ……………………… (13)

\[ Q_s = K_c, K_s \left[ \sum_{i=0}^{2} \frac{z^2}{8d} f_s x A_s + \sum_{i=0}^{8d} f_s x A_s \right] \] … (14)

(calculation results as in the attached table).

5. Metode Philipphonant

\[ Q_p = \frac{q_p - A}{2} \] …………………………… (15)

\[ q_p = \alpha P \cdot q_c \rightarrow \text{with } q_c = \frac{1}{6d} \int_{-3d}^{3d} q_c(z)dz \] … (16)

\[ Q_s = \frac{P}{2} x J\beta P \] …………………………… (17)

\[ Q_u = Q_p + Q_s \] …………………………… (18)

(calculation results as in the attached table).

6. Metode Andina

\[ Q_u = \frac{Q_p + Q_s}{F} \] …………………………… (19)

\[ F = \text{ safety number 2} \]
where:
\[ P = \text{around the cross section of the pole} = 4 \times 25 = 100 \text{ cm} \]

\[ Q_u = \frac{Q_p + Q_s}{F} \]  

(23)

(calculation results as in the attached table).

7. Calculation of Difference in Third Result Method with Hydraulic Jacking System (HJS) and Pile Driving Analyzer (PDA) Test

For the calculation of carrying capacity based on the Hydraulic Jacking System (HJS) and Pile Driving Analyzer (PDA) Test shown in the table as attached.

And for the difference between the three methods of calculating the carrying capacity above with the HJS and PDA tests are as follows:

1. At a depth of 2 meters
   The value of the\( Q_{ult} \) calculation using the Schmertmann-Nottingham method is 4,932 tons, while the value of the Hydraulic Jacking System (HJS) is 16.46 tons. The percentage difference between these values is 70.04%. At a depth of 2 meters the Schmertmann-Nottingham method has the smallest percentage compared to the other two methods.

2. At a depth of 4 meters
   The value of the\( Q_{ult} \) calculation using the Schmertmann-Nottingham method is 14,330 tons, while the Hydraulic Jacking System (HJS) has a value of 20.12 tons. The percentage difference of this value is 28.78%. At a depth of 4 meters the Schmertmann-Nottingham method still has the smallest percentage compared to the other two methods.

3. At a depth of 6 meters
   The value of the\( Q_{ult} \) calculation by the Andina method is 31,626 tons, while from the Hydraulic Jacking System (HJS) a value of 29.26 tons is obtained. The percentage difference between these values is 8.07%. At a depth of 6 meters the Andina method has the smallest percentage compared to the other two methods.

4. At a depth of 8 meters
   The value of the\( Q_{ult} \) calculation using the Philipphonant method is 39,241 tons, while the Hydraulic Jacking System (HJS) obtained a value of 44.81 tons. The percentage difference between these values is 12.43%. At a depth of 8 meters the Philipphonant method has the smallest percentage compared to the other two methods.

5. At a depth of 10 meters
   The value of the\( Q_{ult} \) calculation by the Andina method is 82,856 tons, while from the Hydraulic Jacking System (HJS) a value of 78.65 tons is obtained. The percentage difference between these values is 5.35%. At a depth of 10 meters, the Andina method again has the smallest percentage compared to the other two methods.

From the calculation results it can also be seen that for the percentage value of the average difference at each depth of 2 meters, for the method with the smallest value is the Andina method, with a difference of 28.64%.

As for the difference in the calculation of the three methods with the Pile Driving Analyzer (PDA) Test, as in table 4.17, it was found that at a depth of 10 meters pile penetration, the results of carrying capacity calculations using the Andina method amounted to 82.86 tons. While the results of PDA tests in the field amounted to 84.4 tons. The percentage difference between the two values is 1.83%. This difference value is the smallest value when compared to the two other methods of bearing carrying capacity of the foundation.

CONCLUSION
After considering and considering the value of the result of the calculation of the average difference of all depths of each method to the Hydraulic Jacking System and the results of the calculation of the difference from each method to the Pile Driving Analyzer (PDA) Test at a depth of 10 meters, it can be concluded that the Andina Method is the most approach with data in the field.

Appendix 1: Sondir S2 Data Results

| Kedalaman cm | Cn Kg/cm² | Cn + CL Kg/cm² | CL Kg/cm² | Local Friction Hp Kg/cm | HP Kg/cm | JHP Kg/cm |
|--------------|-----------|----------------|---------|-------------------------|---------|---------|
| 0            | 0         | 0              | 0       | 0.00                    | 0       | 0       |
| 20           | 2         | 4              | 2       | 0.20                    | 4       | 4       |
| 40           | 6         | 8              | 2       | 0.20                    | 4       | 8       |
| 60           | 16        | 19             | 3       | 0.30                    | 6       | 14      |
| 80           | 7         | 9              | 2       | 0.20                    | 4       | 18      |
| 100          | 6         | 8              | 2       | 0.20                    | 4       | 22      |
| 120          | 5         | 7              | 2       | 0.20                    | 4       | 26      |
| 140          | 5         | 7              | 2       | 0.20                    | 4       | 30      |
| 160          | 6         | 9              | 3       | 0.30                    | 6       | 36      |
| 180          | 11        | 14             | 3       | 0.30                    | 6       | 42      |
| 200          | 12        | 16             | 4       | 0.40                    | 8       | 50      |
| 220          | 14        | 18             | 4       | 0.40                    | 8       | 58      |
| 240          | 6         | 9              | 3       | 0.30                    | 6       | 64      |
| 260          | 5         | 7              | 2       | 0.20                    | 4       | 68      |
| 280          | 5         | 7              | 2       | 0.20                    | 4       | 72      |
| 300          | 5         | 7              | 2       | 0.20                    | 4       | 76      |
| 320          | 5         | 7              | 2       | 0.20                    | 4       | 80      |
| 340          | 5         | 7              | 2       | 0.20                    | 4       | 84      |
| 360          | 4         | 6              | 2       | 0.20                    | 4       | 88      |
| 380          | 6         | 8              | 2       | 0.20                    | 4       | 92      |
| 400          | 15        | 18             | 3       | 0.30                    | 6       | 98      |
| 420          | 30        | 35             | 5       | 0.50                    | 10      | 108     |
| 440          | 45        | 50             | 5       | 0.50                    | 10      | 118     |
| 460          | 50        | 55             | 5       | 0.50                    | 10      | 128     |
| 480          | 40        | 52             | 12      | 1.20                    | 24      | 152     |
| 500          | 45        | 55             | 10      | 1.00                    | 20      | 172     |
| 520          | 47        | 58             | 11      | 1.10                    | 22      | 194     |
| 540          | 45        | 55             | 10      | 1.00                    | 20      | 214     |
| 560          | 60        | 70             | 10      | 1.00                    | 20      | 234     |
| 580          | 72        | 80             | 8       | 0.80                    | 16      | 250     |
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|--------------------------------|
| 600 75 85 10 1.00 20 270 |
| 620 70 80 10 1.00 20 290 |
| 640 65 75 10 1.00 20 310 |
| 660 75 85 10 1.00 20 330 |
| 680 72 85 13 1.30 26 356 |
| 700 70 85 15 1.50 30 386 |
| 720 87 95 8 0.80 16 402 |
| 740 85 100 15 1.50 30 432 |
| 760 95 110 15 1.50 30 462 |
| 780 77 87 10 1.00 20 482 |
| 800 76 88 12 1.20 24 506 |
| 820 87 95 8 0.80 16 522 |
| 840 98 105 7 0.70 14 536 |
| 860 93 102 9 0.90 18 554 |
| 880 105 112 7 0.70 14 568 |
| 900 112 122 10 1.00 20 588 |
| 920 120 125 5 0.50 10 598 |
| 940 122 127 5 0.50 10 608 |
| 960 127 132 5 0.50 10 618 |
| 980 136 144 8 0.80 16 634 |
| 1000 205 215 10 1.00 20 654 |

(Source: Mek. UWKS Civil Engineering Laboratory)
Appendix 2: Calculation of the Pole End (Qp) of the Schmartmann - Nottingham Method (1975)

| Depth (Cm) | Cn | qc1 Cn Rata2 4D ke bawah (Kg/cm²) | qc2 Cn Rata2 8D ke atas (Kg/cm²) | qc rata-rata (Kg/cm²) | Qp Q Ujung (Kg) |
|-----------|----|-----------------------------------|-----------------------------------|----------------------|----------------|
| 0         | 0  | 6.17                              | -                                 | 3.08                 | 1,927.08       |
| 20        | 2  | 7.00                              | 1.00                              | 4.00                 | 2,500.00       |
| 40        | 6  | 7.50                              | 2.67                              | 5.08                 | 3,177.08       |
| 60        | 16 | 7.50                              | 6.00                              | 6.75                 | 4,218.75       |
| 80        | 7  | 6.67                              | 6.20                              | 6.43                 | 4,020.83       |
| 100       | 6  | 7.50                              | 6.17                              | 6.83                 | 4,270.83       |
| 120       | 5  | 8.83                              | 6.00                              | 7.42                 | 4,635.42       |
| 140       | 5  | 9.00                              | 5.88                              | 7.44                 | 4,648.44       |
| 160       | 6  | 9.00                              | 5.89                              | 7.44                 | 4,652.78       |
| 180       | 11 | 8.83                              | 6.40                              | 7.62                 | 4,760.42       |
| 200       | 12 | 7.83                              | 6.91                              | 7.37                 | 4,607.01       |
| 220       | 14 | 6.67                              | 8.18                              | 7.42                 | 4,640.15       |
| 240       | 6  | 5.17                              | 8.55                              | 6.86                 | 4,285.04       |
| 260       | 5  | 4.83                              | 8.45                              | 6.64                 | 4,152.46       |
| 280       | 5  | 5.00                              | 7.45                              | 6.23                 | 3,892.05       |
| 300       | 5  | 6.67                              | 7.27                              | 6.97                 | 4,356.06       |
| 320       | 5  | 10.83                             | 7.18                              | 9.01                 | 5,629.73       |
| 340       | 5  | 17.50                             | 7.18                              | 12.34                | 7,713.07       |
| 360       | 4  | 25.00                             | 7.09                              | 16.05                | 10,028.41      |
| 380       | 6  | 31.00                             | 7.09                              | 19.05                | 11,903.41      |
| 400       | 15 | 37.50                             | 7.45                              | 22.48                | 14,048.30      |
| 420       | 30 | 42.83                             | 9.09                              | 25.96                | 16,226.33      |
| 440       | 45 | 45.33                             | 11.91                             | 28.62                | 17,888.26      |
| 460       | 50 | 47.83                             | 15.91                             | 31.87                | 19,919.51      |
| 480       | 40 | 51.50                             | 19.09                             | 35.30                | 22,059.66      |
| 500       | 45 | 57.33                             | 22.73                             | 40.03                | 25,018.94      |
| 520       | 47 | 61.50                             | 26.55                             | 44.02                | 27,514.20      |
| 540       | 45 | 64.50                             | 30.18                             | 47.34                | 29,588.07      |
| 560       | 60 | 69.50                             | 35.18                             | 52.34                | 32,713.07      |
| 580       | 72 | 71.50                             | 41.36                             | 56.43                | 35,269.89      |
| 600       | 75 | 71.17                             | 47.64                             | 59.40                | 37,125.95      |
| 620       | 70 | 73.17                             | 52.64                             | 62.90                | 39,313.45      |
| 640       | 65 | 75.67                             | 55.82                             | 65.74                | 41,089.02      |
| 660       | 75 | 80.67                             | 58.55                             | 69.61                | 43,503.79      |
| 680       | 72 | 81.00                             | 60.55                             | 70.77                | 44,232.95      |
| 700       | 70 | 81.67                             | 63.27                             | 72.47                | 45,293.56      |
| 720       | 87 | 84.50                             | 67.09                             | 75.80                | 47,372.16      |
| 740       | 85 | 86.33                             | 70.55                             | 78.44                | 49,024.62      |
| 760       | 95 | 87.67                             | 75.09                             | 81.38                | 50,861.74      |
| 780       | 77 | 89.33                             | 76.64                             | 82.98                | 51,865.53      |
Appendix 3: Calculation of Pole Blanket (Qs) for the Schmartmann-Nottingham Method (1975)

| Depth cm | Cn Kg/cm² | Local Friction Kg/cm² | Ks ; Kc Kg/cm² | Li / 8D Kg | Qs1 (0 - 8D) Kg | Qs2 (8D - L) Kg | Qs Qs1 + Qs2 Kg |
|----------|-----------|-----------------------|----------------|-----------|----------------|----------------|----------------|
| 0        | 0         | 0.00                  | 1.22           | -         | -              | -              | -              |
| 20       | 2         | 0.20                  | 0.75           | 0.10      | 9.38           | 93.75          | 103.13         |
| 40       | 6         | 0.20                  | 0.49           | 0.20      | 12.25          | 61.25          | 73.50          |
| 60       | 16        | 0.30                  | 0.67           | 0.30      | 37.69          | 125.63         | 163.31         |
| 80       | 7         | 0.20                  | 0.75           | 0.40      | 37.50          | 93.75          | 131.25         |
| 100      | 6         | 0.20                  | 0.67           | 0.50      | 41.88          | 83.75          | 125.63         |
| 120      | 5         | 0.20                  | 0.51           | 0.60      | 38.25          | 63.75          | 102.00         |
| 140      | 5         | 0.20                  | 0.51           | 0.70      | 44.63          | 63.75          | 108.38         |
| 160      | 6         | 0.30                  | 0.51           | 0.80      | 76.50          | 95.63          | 172.13         |
| 180      | 11        | 0.30                  | 0.46           | 0.90      | 77.63          | 86.25          | 163.88         |
| 200      | 12        | 0.40                  | 0.65           | 1.00      | 162.50         | 162.50         | 325.00         |
| 220      | 14        | 0.40                  | 0.6            | 1.10      | 165.00         | 150.00         | 315.00         |
| 240      | 6         | 0.30                  | 0.5            | 1.20      | 112.50         | 93.75          | 206.25         |
| 260      | 5         | 0.20                  | 0.52           | 1.30      | 84.50          | 65.00          | 149.50         |
| 280      | 5         | 0.20                  | 0.5            | 1.40      | 87.50          | 62.50          | 150.00         |
| 300      | 5         | 0.20                  | 0.5            | 1.50      | 93.75          | 62.50          | 156.25         |
| 320      | 5         | 0.20                  | 0.46           | 1.60      | 92.00          | 57.50          | 149.50         |
| 340      | 5         | 0.20                  | 0.5            | 1.70      | 106.25         | 62.50          | 168.75         |
| 360      | 4         | 0.20                  | 0.5            | 1.80      | 112.50         | 62.50          | 175.00         |
| 380      | 6         | 0.20                  | 0.5            | 1.90      | 118.75         | 62.50          | 181.25         |
| 400      | 5         | 0.30                  | 0.5            | 2.00      | 187.50         | 93.75          | 281.25         |
| 420      | 30        | 0.50                  | 0.5            | 2.10      | 328.13         | 156.25         | 484.38         |
| 440      | 45        | 0.50                  | 0.5            | 2.20      | 343.75         | 156.25         | 500.00         |
| 460      | 50        | 0.50                  | 0.5            | 2.30      | 359.38         | 156.25         | 515.63         |
| 480      | 40        | 1.20                  | 0.5            | 2.40      | 900.00         | 375.00         | 1,275.00       |
| 500      | 45        | 1.00                  | 0.5            | 2.50      | 781.25         | 312.50         | 1,093.75       |
| 520      | 47        | 1.10                  | 0.5            | 2.60      | 893.75         | 343.75         | 1,237.50       |
| 540      | 45        | 1.00                  | 0.5            | 2.70      | 843.75         | 312.50         | 1,156.25       |
| 560      | 60        | 1.00                  | 0.5            | 2.80      | 875.00         | 312.50         | 1,187.50       |
| Depth (cm) | Qp (Kg) | Qs (Kg) | Qult (Kg) | Qult (Ton) |
|-----------|---------|---------|-----------|------------|
| 0         | 1,927.08| -       | 1,927.08  | 1.927      |
| 20        | 2,500.00| 103.13  | 2,603.13  | 2.603      |
| 40        | 3,177.08| 73.50   | 3,250.58  | 3.251      |
| 60        | 4,218.75| 163.31  | 4,382.06  | 4.382      |
| 80        | 4,020.83| 131.25  | 4,152.08  | 4.152      |
| 100       | 4,270.83| 125.63  | 4,396.46  | 4.396      |
| 120       | 4,635.42| 102.00  | 4,737.42  | 4.737      |
| 140       | 4,648.44| 108.38  | 4,756.81  | 4.757      |
| 160       | 4,652.78| 172.13  | 4,824.90  | 4.825      |
| 180       | 4,760.42| 163.88  | 4,924.29  | 4.924      |
| 200       | 4,607.01| 325.00  | 4,932.01  | 4.932      |
| 220       | 4,640.15| 315.00  | 4,955.15  | 4.955      |
| 240       | 4,285.04| 206.25  | 4,491.29  | 4.491      |
| 260       | 4,152.46| 149.50  | 4,301.96  | 4.302      |
| 280       | 3,892.05| 150.00  | 4,042.05  | 4.042      |
| 300       | 4,356.06| 156.25  | 4,512.31  | 4.512      |
| 320       | 5,629.73| 149.50  | 5,779.23  | 5.779      |
| 340       | 7,713.07| 168.75  | 7,881.82  | 7.882      |

Appendix 4: Carrying capacity of the ultimate Q (Qult) Schmartmann-Nottingham Method (1975)
|   |   |   |   |
|---|---|---|---|
| 360 | 10,028.41 | 175.00 | 10,203.41 | 10.203 |
| 380 | 11,903.41 | 181.25 | 12,084.66 | 12.085 |
| 400 | 14,048.30 | 281.25 | 14,329.55 | 14.330 |
| 420 | 16,226.33 | 484.38 | 16,710.70 | 16.711 |
| 440 | 17,888.26 | 500.00 | 18,388.26 | 18.388 |
| 460 | 19,919.51 | 515.63 | 20,435.13 | 20.435 |
| 480 | 22,059.66 | 1,275.00 | 23,334.66 | 23.335 |
| 500 | 25,018.94 | 1,093.75 | 26,112.69 | 26.113 |
| 520 | 27,514.20 | 1,237.50 | 28,751.70 | 28.752 |
| 540 | 29,588.07 | 1,156.25 | 30,744.32 | 30.744 |
| 560 | 32,713.07 | 1,187.50 | 33,900.57 | 33.901 |
| 580 | 35,269.89 | 975.00 | 36,244.89 | 36.245 |
| 600 | 37,125.95 | 1,250.00 | 38,375.95 | 38.376 |
| 620 | 39,313.45 | 1,281.25 | 40,594.70 | 40.595 |
| 640 | 41,089.02 | 1,312.50 | 42,401.52 | 42.402 |
| 660 | 43,503.79 | 1,343.75 | 44,847.54 | 44.848 |
| 680 | 44,232.95 | 1,787.50 | 46,020.45 | 46.020 |
| 700 | 45,293.56 | 2,109.38 | 47,402.94 | 47.403 |
| 720 | 47,372.16 | 1,150.00 | 48,522.16 | 48.522 |
| 740 | 49,024.62 | 2,203.13 | 51,227.75 | 51.228 |
| 760 | 50,861.74 | 2,250.00 | 53,111.74 | 53.112 |
| 780 | 51,865.53 | 1,531.25 | 53,396.78 | 53.397 |
| 800 | 53,802.08 | 1,875.00 | 55,677.08 | 55.677 |
| 820 | 56,434.66 | 1,275.00 | 57,709.66 | 57.710 |
| 840 | 59,053.03 | 1,137.50 | 60,190.53 | 60.191 |
| 860 | 61,358.90 | 1,490.63 | 62,849.53 | 62.850 |
| 880 | 64,450.76 | 1,181.25 | 65,632.01 | 65.632 |
| 900 | 70,795.45 | 1,718.75 | 72,514.20 | 72.514 |
| 920 | 73,778.41 | 875.00 | 74,653.41 | 74.653 |
| 940 | 76,491.48 | 890.63 | 77,382.10 | 77.382 |
| 960 | 80,340.91 | 906.25 | 81,247.16 | 81.247 |
| 980 | 86,036.93 | 1,475.00 | 87,511.93 | 87.512 |
| 1000 | 100,454.55 | 1,875.00 | 102,329.55 | 102.330 |
### Appendix 5: Calculation of Bearing Capacity of the Pole (Qp) Philipponant Method

| Depth (cm) | Cn | q_c (Kg/cm²) | rata-rata (Kg/cm²) | qp (Kg/cm²) | Qp (Kg) |
|------------|----|--------------|---------------------|-------------|---------|
| 0          | 0  | 6.20         | 3.10                | 968.75      |
| 20         | 2  | 6.17         | 3.08                | 963.54      |
| 40         | 6  | 6.00         | 3.00                | 937.50      |
| 60         | 16 | 5.88         | 2.94                | 917.97      |
| 80         | 7  | 5.89         | 2.94                | 920.14      |
| 100        | 6  | 7.11         | 3.56                | 1,111.11    |
| 120        | 5  | 8.22         | 4.11                | 1,284.72    |
| 140        | 5  | 9.11         | 4.56                | 1,423.61    |
| 160        | 6  | 8.00         | 4.00                | 1,250.00    |
| 180        | 11 | 7.78         | 3.89                | 1,215.28    |
| 200        | 12 | 7.67         | 3.83                | 1,197.92    |
| 220        | 14 | 7.67         | 3.83                | 1,197.92    |
| 240        | 6  | 7.67         | 3.83                | 1,197.92    |
| 260        | 5  | 7.56         | 3.78                | 1,180.56    |
| 280        | 5  | 6.78         | 3.39                | 1,059.03    |
| 300        | 5  | 6.11         | 3.06                | 954.86      |
| 320        | 5  | 6.22         | 3.11                | 972.22      |
| 340        | 5  | 8.89         | 4.44                | 1,388.89    |
| 360        | 4  | 13.33        | 6.67                | 2,083.33    |
| 380        | 6  | 18.33        | 9.17                | 2,864.58    |
| 400        | 15 | 22.22        | 11.11               | 3,472.22    |
| 420        | 30 | 26.67        | 13.33               | 4,166.67    |
| 440        | 45 | 31.33        | 15.67               | 4,895.83    |
| 460        | 50 | 35.89        | 17.94               | 5,607.64    |
| 480        | 40 | 41.89        | 20.94               | 6,545.14    |
| 500        | 45 | 48.22        | 24.11               | 7,534.72    |
| 520        | 47 | 53.22        | 26.61               | 8,315.97    |
| 540        | 45 | 56.00        | 28.00               | 8,750.00    |
| 560        | 60 | 57.67        | 28.83               | 9,010.42    |
| 580        | 72 | 61.56        | 30.78               | 9,618.06    |
| 600        | 75 | 64.56        | 32.28               | 10,086.81   |
| 620        | 70 | 67.11        | 33.56               | 10,486.11   |
| 640        | 65 | 71.78        | 35.89               | 11,215.28   |
| 660        | 75 | 74.56        | 37.28               | 11,649.31   |
| 680        | 72 | 77.11        | 38.56               | 12,048.61   |
| 700        | 70 | 77.33        | 38.67               | 12,083.33   |
| 720        | 87 | 78.00        | 39.00               | 12,187.50   |
| 740        | 85 | 80.44        | 40.22               | 12,569.44   |
| 760        | 95 | 83.00        | 41.50               | 12,968.75   |
| 780        | 77 | 85.33        | 42.67               | 13,333.33   |
### Appendix 6: Calculation of Pole Blanket (Qs) Philipponant Method

| Depth (cm) | Cn | JHP (Kg/cm²) | Qs (Kg) |
|------------|----|--------------|---------|
| 0          | 0  | -            | -       |
| 20         | 2  | 4.00         | 200.00  |
| 40         | 6  | 8.00         | 400.00  |
| 60         | 16 | 14.00        | 700.00  |
| 80         | 7  | 18.00        | 900.00  |
| 100        | 6  | 22.00        | 1,100.00|
| 120        | 5  | 26.00        | 1,300.00|
| 140        | 5  | 30.00        | 1,500.00|
| 160        | 6  | 36.00        | 1,800.00|
| 180        | 11 | 42.00        | 2,100.00|
| 200        | 12 | 50.00        | 2,500.00|
| 220        | 14 | 58.00        | 2,900.00|
| 240        | 6  | 64.00        | 3,200.00|
| 260        | 5  | 68.00        | 3,400.00|
| 280        | 5  | 72.00        | 3,600.00|
| 300        | 5  | 76.00        | 3,800.00|
| 320        | 5  | 80.00        | 4,000.00|
| 340        | 5  | 84.00        | 4,200.00|
| 360        | 4  | 88.00        | 4,400.00|
| 380        | 6  | 92.00        | 4,600.00|
| 400        | 15 | 98.00        | 4,900.00|
| 420        | 30 | 108.00       | 5,400.00|
| 440        | 45 | 118.00       | 5,900.00|
| 460        | 50 | 128.00       | 6,400.00|
| 480        | 40 | 152.00       | 7,600.00|
| 500        | 45 | 172.00       | 8,600.00|
| 520        | 47 | 194.00       | 9,700.00|
| 540        | 45 | 214.00       | 10,700.00|
| 560        | 60 | 234.00       | 11,700.00|
### Appendix 7: Carrying capacity of the ultimate Q Philipponant Method

| Depth (cm) | Qp (Kg) | Qs (Kg) | Qult (Kg) | Ton |
|------------|---------|---------|-----------|------|
| 0          | 968.75  | -       | 968.75    | 0.969|
| 20         | 963.54  | 200.00  | 1,163.54  | 1.164|
| 40         | 937.50  | 400.00  | 1,337.50  | 1.338|
| 60         | 917.97  | 700.00  | 1,617.97  | 1.618|
| 80         | 920.14  | 900.00  | 1,820.14  | 1.820|
| 100        | 1,111.11| 1,100.00| 2,211.11  | 2.211|
| 120        | 1,284.72| 1,300.00| 2,584.72  | 2.585|
| 140        | 1,423.61| 1,500.00| 2,923.61  | 2.924|
| 160        | 1,250.00| 1,800.00| 3,050.00  | 3.050|
| 180        | 1,215.28| 2,100.00| 3,315.28  | 3.315|
| 200        | 1,197.92| 2,500.00| 3,697.92  | 3.698|
| 220        | 1,197.92| 2,900.00| 4,097.92  | 4.098|
| 240        | 1,197.92| 3,200.00| 4,397.92  | 4.398|
| 260        | 1,180.56| 3,400.00| 4,580.56  | 4.581|
| 280        | 1,059.03| 3,600.00| 4,659.03  | 4.659|
| 300        | 954.86  | 3,800.00| 4,754.86  | 4.755|
| 320        | 972.22  | 4,000.00| 4,972.22  | 4.972|
| 340        | 1,388.89| 4,200.00| 5,588.89  | 5.589|
| 360 | 2,083.33 | 4,400.00 | 6,483.33 | 6.483 |
| 380 | 2,864.58 | 4,600.00 | 7,464.58 | 7.465 |
| 400 | 3,472.22 | 4,900.00 | 8,372.22 | 8.372 |
| 420 | 4,166.67 | 5,400.00 | 9,566.67 | 9.567 |
| 440 | 4,895.83 | 5,900.00 | 10,795.83 | 10.796 |
| 460 | 5,607.64 | 6,400.00 | 12,007.64 | 12.008 |
| 480 | 6,545.14 | 7,600.00 | 14,145.14 | 14.145 |
| 500 | 7,534.72 | 8,600.00 | 16,134.72 | 16.135 |
| 520 | 8,315.97 | 9,700.00 | 18,015.97 | 18.016 |
| 540 | 8,750.00 | 10,700.00 | 19,450.00 | 19.450 |
| 560 | 9,010.42 | 11,700.00 | 20,710.42 | 20.710 |
| 580 | 9,618.06 | 12,500.00 | 22,118.06 | 22.118 |
| 600 | 10,086.81 | 13,500.00 | 23,586.81 | 23.587 |
| 620 | 10,486.11 | 14,500.00 | 24,986.11 | 24.986 |
| 640 | 11,215.28 | 15,500.00 | 26,715.28 | 26.715 |
| 660 | 11,649.31 | 16,500.00 | 28,149.31 | 28.149 |
| 680 | 12,048.61 | 17,800.00 | 29,848.61 | 29.849 |
| 700 | 12,083.33 | 19,300.00 | 31,383.33 | 31.383 |
| 720 | 12,187.50 | 20,100.00 | 32,287.50 | 32.288 |
| 740 | 12,569.44 | 21,600.00 | 34,169.44 | 34.169 |
| 760 | 12,968.75 | 23,100.00 | 36,068.75 | 36.069 |
| 780 | 13,333.33 | 24,100.00 | 37,433.33 | 37.433 |
| 800 | 13,940.97 | 25,300.00 | 39,240.97 | 39.241 |
| 820 | 14,375.00 | 26,100.00 | 40,475.00 | 40.475 |
| 840 | 14,982.64 | 26,800.00 | 41,782.64 | 41.783 |
| 860 | 15,451.39 | 27,700.00 | 43,151.39 | 43.151 |
| 880 | 16,319.44 | 28,400.00 | 44,719.44 | 44.719 |
| 900 | 17,361.11 | 29,400.00 | 46,761.11 | 46.761 |
| 920 | 19,409.72 | 29,900.00 | 49,309.72 | 49.310 |
| 940 | 19,921.88 | 30,400.00 | 50,321.88 | 50.322 |
| 960 | 20,691.96 | 30,900.00 | 51,591.96 | 51.592 |
| 980 | 21,406.25 | 31,700.00 | 53,106.25 | 53.106 |
| 1000 | 22,187.50 | 32,700.00 | 54,887.50 | 54.888 |
**Appendix 8**: Calculation of the Pole End (Qp) of the Andina Method

| Depth (cm) | Cn | Cn min | \(q_{c1} \) Cn Rata\(^2\) 4D ke bawah | \(q_{c2} \) Cn Min Rata\(^2\) 4D ke bawah | \(q_{c3} \) Cn Min Rata\(^2\) 8D ke atas | qc rata-rata | Qp |
|------------|----|--------|----------------------------------------|----------------------------------------|----------------------------------------|----------------|-----|
| 0          | 0  | 0      | 6.17                                   | 4.33                                   | -                                      | 2.63           | 1,640.63 |
| 20         | 2  | 2      | 7.00                                   | 5.17                                   | 1.00                                   | 3.54           | 2,213.54 |
| 40         | 6  | 6      | 7.50                                   | 5.67                                   | 2.67                                   | 4.63           | 2,890.63 |
| 60         | 16 | 7      | 7.50                                   | 5.67                                   | 3.75                                   | 5.17           | 3,229.17 |
| 80         | 7  | 6      | 6.67                                   | 6.33                                   | 4.20                                   | 5.35           | 3,343.75 |
| 100        | 6  | 5      | 7.50                                   | 7.33                                   | 4.33                                   | 5.88           | 3,671.88 |
| 120        | 5  | 5      | 8.83                                   | 7.50                                   | 4.43                                   | 6.30           | 3,936.01 |
| 140        | 5  | 5      | 9.00                                   | 7.50                                   | 4.50                                   | 6.38           | 3,984.38 |
| 160        | 6  | 6      | 9.00                                   | 7.50                                   | 4.67                                   | 6.46           | 4,036.46 |
| 180        | 11 | 11     | 8.83                                   | 7.33                                   | 5.30                                   | 6.69           | 4,182.29 |
| 200        | 12 | 12     | 7.83                                   | 6.33                                   | 5.91                                   | 6.50           | 4,060.13 |
| 220        | 14 | 6      | 6.67                                   | 5.17                                   | 6.45                                   | 6.19           | 3,866.00 |
| 240        | 6  | 5      | 5.17                                   | 4.83                                   | 6.73                                   | 5.86           | 3,664.77 |
| 260        | 5  | 5      | 4.83                                   | 4.67                                   | 6.64                                   | 5.69           | 3,558.24 |
| 280        | 5  | 5      | 5.00                                   | 4.83                                   | 6.45                                   | 5.69           | 3,553.50 |
| 300        | 5  | 5      | 6.67                                   | 6.50                                   | 6.36                                   | 6.47           | 4,045.93 |
| 320        | 5  | 5      | 10.83                                  | 10.67                                  | 6.36                                   | 8.56           | 5,348.01 |
| 340        | 5  | 4      | 17.50                                  | 17.33                                  | 6.27                                   | 11.84          | 7,402.94 |
| 360        | 4  | 4      | 25.00                                  | 23.33                                  | 6.18                                   | 15.17          | 9,483.90 |
| 380        | 6  | 6      | 31.00                                  | 29.33                                  | 6.18                                   | 18.17          | 11,358.90 |
| 400        | 15 | 15     | 37.50                                  | 35.83                                  | 6.55                                   | 21.61          | 13,503.79 |
| 420        | 30 | 30     | 42.83                                  | 40.83                                  | 8.18                                   | 25.01          | 15,629.73 |
| 440        | 45 | 45     | 45.33                                  | 43.33                                  | 11.73                                  | 28.03          | 17,518.94 |
| 460        | 50 | 40     | 47.83                                  | 45.83                                  | 14.91                                  | 30.87          | 19,294.51 |
| 480        | 40 | 40     | 51.50                                  | 51.17                                  | 18.09                                  | 34.71          | 21,695.08 |
| 500        | 45 | 45     | 57.33                                  | 56.17                                  | 21.73                                  | 39.24          | 24,524.15 |
| 520        | 47 | 45     | 61.50                                  | 59.50                                  | 25.36                                  | 42.93          | 26,832.39 |
| 540        | 45 | 45     | 64.50                                  | 62.83                                  | 29.00                                  | 46.33          | 28,958.33 |
| 560        | 60 | 60     | 69.50                                  | 67.33                                  | 34.09                                  | 51.25          | 32,033.62 |
| 580        | 72 | 72     | 71.50                                  | 69.00                                  | 40.27                                  | 55.26          | 34,538.35 |
| 600        | 75 | 70     | 71.17                                  | 68.67                                  | 46.09                                  | 58.00          | 36,252.37 |
| 620        | 70 | 65     | 73.17                                  | 71.17                                  | 50.64                                  | 61.40          | 38,375.95 |
| 640        | 65 | 65     | 75.67                                  | 74.50                                  | 53.82                                  | 64.45          | 40,281.72 |
| 660        | 75 | 72     | 80.67                                  | 76.50                                  | 56.27                                  | 67.43          | 42,142.52 |
| 680        | 72 | 70     | 81.00                                  | 77.17                                  | 59.00                                  | 69.04          | 43,151.04 |
| 700        | 70 | 70     | 81.67                                  | 78.17                                  | 61.73                                  | 70.82          | 44,263.73 |
| 720        | 87 | 85     | 84.50                                  | 81.00                                  | 65.36                                  | 74.06          | 46,285.51 |
| 740        | 85 | 85     | 86.33                                  | 82.33                                  | 69.00                                  | 76.67          | 47,916.67 |
| 760        | 95 | 77     | 87.67                                  | 83.67                                  | 71.91                                  | 78.79          | 49,242.42 |

**Note**: The values are calculated using the Andina method for pole end assessment.
Appendix 9: Calculation of Bearing Capacity (Qs) of Andina Method

| Depth (cm) | Cn  | JHP (Kg/cm²) | Qs (Kg)   |
|-----------|-----|--------------|-----------|
| 0         | 0   | -            | -         |
| 20        | 2   | 4.00         | 400.00    |
| 40        | 6   | 8.00         | 800.00    |
| 60        | 16  | 14.00        | 1,400.00  |
| 80        | 7   | 18.00        | 1,800.00  |
| 100       | 6   | 22.00        | 2,200.00  |
| 120       | 5   | 26.00        | 2,600.00  |
| 140       | 5   | 30.00        | 3,000.00  |
| 160       | 6   | 36.00        | 3,600.00  |
| 180       | 11  | 42.00        | 4,200.00  |
| 200       | 12  | 50.00        | 5,000.00  |
| 220       | 14  | 58.00        | 5,800.00  |
| 240       | 6   | 64.00        | 6,400.00  |
| 260       | 5   | 68.00        | 6,800.00  |
| 280       | 5   | 72.00        | 7,200.00  |
| 300       | 5   | 76.00        | 7,600.00  |
| 320       | 5   | 80.00        | 8,000.00  |
| 340       | 5   | 84.00        | 8,400.00  |
| 360       | 4   | 88.00        | 8,800.00  |
| 380       | 6   | 92.00        | 9,200.00  |
| 400       | 15  | 98.00        | 9,800.00  |
| 420       | 30  | 108.00       | 10,800.00 |
| 440       | 45  | 118.00       | 11,800.00 |
| 460       | 50  | 128.00       | 12,800.00 |
| 480       | 40  | 152.00       | 15,200.00 |
| 500       | 45  | 172.00       | 17,200.00 |
| 520       | 47  | 194.00       | 19,400.00 |
| 540       | 45  | 214.00       | 21,400.00 |
| Depth (cm) | Qp   | Qs   | Qult  |
|-----------|------|------|-------|
| 0         | 1,640.63 | -    | 820.31 | 0.820 |
| 20        | 2,213.54 | 400.00 | 1,306.77 | 1.307 |
| 40        | 2,890.63 | 800.00 | 1,845.31 | 1.845 |
| 60        | 3,229.17 | 1,400.00 | 2,314.58 | 2.315 |
| 80        | 3,343.75 | 1,800.00 | 2,571.88 | 2.572 |
| 100       | 3,671.88 | 2,200.00 | 2,935.94 | 2.936 |
| 120       | 3,936.01 | 2,600.00 | 3,268.01 | 3.268 |
| 140       | 3,984.38 | 3,000.00 | 3,492.19 | 3.492 |
| 160       | 4,036.46 | 3,600.00 | 3,818.23 | 3.818 |
| 180       | 4,182.29 | 4,200.00 | 4,191.15 | 4.191 |
| 200       | 4,060.13 | 5,000.00 | 4,530.07 | 4.530 |
| 220       | 3,866.00 | 5,800.00 | 4,833.00 | 4.833 |
| 240       | 3,664.77 | 6,400.00 | 5,032.39 | 5.032 |
| 260       | 3,558.24 | 6,800.00 | 5,179.12 | 5.179 |
| 280       | 3,553.50 | 7,200.00 | 5,376.75 | 5.377 |
| 300       | 4,045.93 | 7,600.00 | 5,822.96 | 5.823 |
| 320       | 5,348.01 | 8,000.00 | 6,674.01 | 6.674 |

**Appendix 10**: Carrying Capacity Qultimate (Qult) Andina Method
Appendix 11 : Carrying Capacity Hydraulic Jacking System (HJS) on As F9

| Depth (meter) | P413 (Ton) | P414 (Ton) | P415 (Ton) | P416 (Ton) | P417 (Ton) | P418 (Ton) | P419 (Ton) | Rata-rata (Ton) |
|---------------|------------|------------|------------|------------|------------|------------|------------|----------------|
| 2.00          | 12.80      | 19.20      | 12.80      | 25.61      | 12.80      | 19.20      | 12.80      | 16.46          |
| 4.00          | 12.80      | 25.61      | 19.20      | 25.61      | 19.20      | 25.61      | 12.80      | 20.12          |
| 6.00          | 25.61      | 25.61      | 25.61      | 25.61      | 38.41      | 32.01      | 25.61      | 29.26          |
| 8.00          | 38.41      | 51.21      | 44.81      | 51.21      | 44.81      | 44.81      | 38.41      | 44.81          |
Appendix 12: Carrying Capacity of the Pile Driving Analyzer (PDA) Test Pole Test

| No Tiang | Carrying capacity Total (Ton) | Carrying Capacity of Friction (Ton) | Endurance carrying capacity (Ton) | Decrease (mm) |
|----------|-------------------------------|-------------------------------------|-----------------------------------|--------------|
| P 418    | 84.4                          | 63.0                                | 21.4                              | 10.66        |

(Source: Pile Driving Analyzer (PDA) Report For Pile P 418 DPRD Building Construction Kab. Bangkalan)

Appendix 13: Difference in Calculation of Several Methods with a Hydraulic Jacking System

| Depth (meter) | Schmertmann | Philipphonant | Andina | HJS |
|---------------|-------------|---------------|--------|-----|
|               | Qult        | Selisih 70.04%| Qult 77.54%| Qult 72.48%| 16.46 |
| 2.00          | 4.932       | 3.698         | 4.530  | 11.652 | 20.12 |
| 4.00          | 14.330      | 8.372         | 11.652 | 31.626 | 29.26 |
| 6.00          | 38.376      | 23.587        | 31.626 | 8.07%  | 44.81 |
| 8.00          | 55.677      | 39.241        | 51.625 | 15.20% | 29.26 |
| 10.00         | 102.330     | 54.888        | 82.856 | 5.35%  | 78.65 |

Jumlah Selisih Rata-rata 184.31% 197.97% 143.19%
Selisih Rata-rata 36.86% 39.59% 28.64%

Appendix 14: Difference in Calculation of Several Methods with PDA Test

| Depth meter | Schmertmann | Philipphonant | Andina | PDA |
|-------------|-------------|---------------|--------|-----|
| 10.00       | 102.33      | 21.24%        | 54.89  | 84.4 |
|             | 34.97%      | 82.86         | 1.83%  |     |