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)

Choirus Soleh Rozeli

Mahasiswa Jurusan Teknik Sipil
Universitas Narotama Surabaya
Herusckbkl723@gmail.com

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 a 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 a 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 Static 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)

$$P_{\text{konus}} = P_{\text{piston}} \dots\dots\dots (1)$$

$$q_c \times A_c = C_w \times A_{pi}$$

$$q_c = C_w \times A_{pi} / A_c \dots\dots\dots (2)$$

$$A_{pi} = \square (D_{pi})^2 / 4 \dots\dots\dots (3)$$

$$A_c = \square (D_c)^2 / 4 \dots\dots\dots (4)$$

Where:

P_{konus} : force on the piston (kN)

P_{piston} : force at the conical end (kN)

A_c : conical cross-sectional area (cm)

A_{pi} : piston cross section area (cm)

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)

$$P_{\text{konus}} + P_{\text{geser}} = P_{\text{piston}} \dots\dots\dots (5)$$

$$(q_c \times A_c) + (f_s \times A_s) = T_w \times A_{pi}$$

$$(C_w \times A_{pi}) + (f_s \times A_s) = T_w \times A_{pi}$$

$$f_s = K_w \times A_{pi} / A_s \dots\dots\dots (6)$$

$$A_s = \square D_s L_s \dots\dots\dots (7)$$

$$K_w = (T_w - C_w) \dots\dots\dots (8)$$

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 : ong sliding blanket (cm)

3. Slide Comparison Number (Rf)

Rf = (fs / qc) x 100(%) (9)

4. Slide Total (Tf)

Tf = (fs x 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 $A = 2 \times \frac{1}{4} \pi \times 20^2$
= 628 cm²
- Formula $\sigma = \frac{P}{A} \rightarrow P = \sigma \times A$
- For Pressure Gauge readings are as follows:
10 kg/cm² = 10,00 x 628
= 6.280,00 kg = 6,28 ton
50 kg/cm² = 50,00 x 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	Pressure Gauge
Meter	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)

$$Q_u = Q_p + Q_s \quad (11)$$

$$Q_p = C_n \text{ rata-rata} \times A_p \quad (12)$$

$$C_n \text{ rata-rata} = \frac{q_{c1} + q_{c2}}{2} \quad (13)$$

$$Q_s = K_c, K_s \left[\sum_{z=0}^{z=8d} \frac{z}{8d} f_s \times A_s + \sum_{li}^{z=8d} f_s \times A_s \right] \dots \quad (14)$$

(calculation results as in the attached table).

5. Metode Philipponant

$$Q_p = \frac{q_p \cdot A}{2} \quad (15)$$

$$q_p = q_p \cdot q_c \rightarrow \text{with } q_c = \frac{1}{6D} \int_{-3D}^{3D} q_c(z) dz \quad (16)$$

$$Q_s = \frac{P}{2} \times JHP \quad (17)$$

$$Q_u = Q_p + Q_s \quad (18)$$

(calculation results as in the attached table).

6. Metode Andina

$$Q_u = \frac{Q_p + Q_s}{F} \quad (19)$$

$$F = \text{safety number 2}$$

$$Q_p = q_c \text{ average} \times A_p \dots\dots\dots (20)$$

$$q_c \text{ rata} - \text{rata} = \frac{\frac{q_{c1} + q_{c2}}{2} + q_{c3}}{2} \dots\dots\dots (21)$$

$$Q_s = JHP \times P \dots\dots\dots (22)$$

Where :

P = around the cross section of the pole = $4 \times 25 = 100 \text{ cm}$

$$Q_u = \frac{Q_p + Q_s}{F} \dots\dots\dots (23)$$

(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 Qult 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 Qult 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 Qult 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 Qult 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 Qult 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	Cn	Cn + CL	CL	Local Friction	HP	JHP
cm	Kg/cm2	Kg/cm2	Kg/cm2	Kg/cm2	Kg/cm	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

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 Schmartzmann - Nottingham Method (1975)

Depth	Cn	qc1	qc2	qc rata-rata	Qp
		Cn Rata2 4D ke bawah	Cn Rata2 8D ke atas		Q Ujung
Cm	Kg/cm2	Kg/cm2	Kg/cm2	Kg/cm2	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

800	76	95.17	77.00	86.08	53,802.08
820	87	102.50	78.09	90.30	56,434.66
840	98	108.33	80.64	94.48	59,053.03
860	93	113.17	83.18	98.17	61,358.90
880	105	120.33	85.91	103.12	64,450.76
900	112	137.00	89.55	113.27	70,795.45
920	120	142.00	94.09	118.05	73,778.41
940	122	147.50	97.27	122.39	76,491.48
960	127	156.00	101.09	128.55	80,340.91
980	136	170.50	104.82	137.66	86,036.93
1000	205	205.00	116.45	160.73	100,454.55

Appendix 3: Calculation of Pole Blanket (Qs) for the Schmartzmann-Nottingham Method (1975)

Depth	Cn	Local Friction	Ks ; Kc	Li / 8D	Qs1 (0 - 8D)	Qs2 (8D - L)	Qs Qs1 + Qs2
cm	Kg/cm2	Kg/cm2	Kg/cm2		Kg	Kg	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	15	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

580	72	0.80	0.5	2.90	725.00	250.00	975.00
600	75	1.00	0.5	3.00	937.50	312.50	1,250.00
620	70	1.00	0.5	3.10	968.75	312.50	1,281.25
640	65	1.00	0.5	3.20	1,000.00	312.50	1,312.50
660	75	1.00	0.5	3.30	1,031.25	312.50	1,343.75
680	72	1.30	0.5	3.40	1,381.25	406.25	1,787.50
700	70	1.50	0.5	3.50	1,640.63	468.75	2,109.38
720	87	0.80	0.5	3.60	900.00	250.00	1,150.00
740	85	1.50	0.5	3.70	1,734.38	468.75	2,203.13
760	95	1.50	0.5	3.80	1,781.25	468.75	2,250.00
780	77	1.00	0.5	3.90	1,218.75	312.50	1,531.25
800	76	1.20	0.5	4.00	1,500.00	375.00	1,875.00
820	87	0.80	0.5	4.10	1,025.00	250.00	1,275.00
840	98	0.70	0.5	4.20	918.75	218.75	1,137.50
860	93	0.90	0.5	4.30	1,209.38	281.25	1,490.63
880	105	0.70	0.5	4.40	962.50	218.75	1,181.25
900	112	1.00	0.5	4.50	1,406.25	312.50	1,718.75
920	120	0.50	0.5	4.60	718.75	156.25	875.00
940	122	0.50	0.5	4.70	734.38	156.25	890.63
960	127	0.50	0.5	4.80	750.00	156.25	906.25
980	136	0.80	0.5	4.90	1,225.00	250.00	1,475.00
1000	205	1.00	0.5	5.00	1,562.50	312.50	1,875.00

Appendix 4: Carrying capacity of the ultimate Q (Qult) Schmartzmann-Nottingham Method (1975)

Depth	Qp	Qs	Qult	
cm	Kg	Kg	Kg	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

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	Cn	qc rata-rata	qp	Qp
cm	Kg/cm2	Kg/cm2	Kg/cm2	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

800	76	89.22	44.61	13,940.97
820	87	92.00	46.00	14,375.00
840	98	95.89	47.94	14,982.64
860	93	98.89	49.44	15,451.39
880	105	104.44	52.22	16,319.44
900	112	111.11	55.56	17,361.11
920	120	124.22	62.11	19,409.72
940	122	127.50	63.75	19,921.88
960	127	132.43	66.21	20,691.96
980	136	137.00	68.50	21,406.25
1000	205	142.00	71.00	22,187.50

Appendix 6 : Calculation of Pole Blanket (Qs) Philipponant Method

Depth	Cn	JHP	Qs
cm	Kg/cm2	Kg/cm2	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

580	72	250.00	12,500.00
600	75	270.00	13,500.00
620	70	290.00	14,500.00
640	65	310.00	15,500.00
660	75	330.00	16,500.00
680	72	356.00	17,800.00
700	70	386.00	19,300.00
720	87	402.00	20,100.00
740	85	432.00	21,600.00
760	95	462.00	23,100.00
780	77	482.00	24,100.00
800	76	506.00	25,300.00
820	87	522.00	26,100.00
840	98	536.00	26,800.00
860	93	554.00	27,700.00
880	105	568.00	28,400.00
900	112	588.00	29,400.00
920	120	598.00	29,900.00
940	122	608.00	30,400.00
960	127	618.00	30,900.00
980	136	634.00	31,700.00
1000	205	654.00	32,700.00

Appendix 7 : Carrying capacity of the ultimate Q Philipponant Method

Depth	Qp	Qs	Qult	
cm	Kg	Kg	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	Cn	Cn min	qc1 Cn Rata2 4D ke bawah	qc2 Cn Min Rata2 4D ke bawah	qc3 Cn Min Rata2 8D ke atas	qc rata- rata	Qp
cm	Kg/cm2	Kg/cm2	Kg/cm2	Kg/cm2	Kg/cm2	Kg/cm2	Kg
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

780	77	76	89.33	88.33	73.36	81.10	50,686.55
800	76	76	95.17	94.33	73.73	84.24	52,649.15
820	87	87	102.50	101.67	75.27	88.68	55,423.77
840	98	93	108.33	107.50	77.82	92.87	58,042.14
860	93	93	113.17	113.17	80.36	96.77	60,478.22
880	105	105	120.33	120.33	83.36	101.85	63,655.30
900	112	112	137.00	137.00	87.18	112.09	70,056.82
920	120	120	142.00	142.00	91.73	116.86	73,039.77
940	122	122	147.50	147.50	95.09	121.30	75,809.66
960	127	127	156.00	156.00	98.91	127.45	79,659.09
980	136	136	170.50	170.50	104.27	137.39	85,866.48
1000	205	205	205.00	205.00	116.00	160.50	100,312.50

Appendix 9 : Calculation of Bearing Capacity (Qs) of Andina Method

Depth	Cn	JHP	Qs
cm	Kg/cm2	Kg/cm2	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

560	60	234.00	23,400.00
580	72	250.00	25,000.00
600	75	270.00	27,000.00
620	70	290.00	29,000.00
640	65	310.00	31,000.00
660	75	330.00	33,000.00
680	72	356.00	35,600.00
700	70	386.00	38,600.00
720	87	402.00	40,200.00
740	85	432.00	43,200.00
760	95	462.00	46,200.00
780	77	482.00	48,200.00
800	76	506.00	50,600.00
820	87	522.00	52,200.00
840	98	536.00	53,600.00
860	93	554.00	55,400.00
880	105	568.00	56,800.00
900	112	588.00	58,800.00
920	120	598.00	59,800.00
940	122	608.00	60,800.00
960	127	618.00	61,800.00
980	136	634.00	63,400.00
1000	205	654.00	65,400.00

Appendix 10 : Carrying Capacity Qultimate (Qult) Andina Method

Depth	Qp	Qs	Qult	
cm	Kg	Kg	Kg	Ton
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

340	7,402.94	8,400.00	7,901.47	7.901
360	9,483.90	8,800.00	9,141.95	9.142
380	11,358.90	9,200.00	10,279.45	10.279
400	13,503.79	9,800.00	11,651.89	11.652
420	15,629.73	10,800.00	13,214.87	13.215
440	17,518.94	11,800.00	14,659.47	14.659
460	19,294.51	12,800.00	16,047.25	16.047
480	21,695.08	15,200.00	18,447.54	18.448
500	24,524.15	17,200.00	20,862.07	20.862
520	26,832.39	19,400.00	23,116.19	23.116
540	28,958.33	21,400.00	25,179.17	25.179
560	32,033.62	23,400.00	27,716.81	27.717
580	34,538.35	25,000.00	29,769.18	29.769
600	36,252.37	27,000.00	31,626.18	31.626
620	38,375.95	29,000.00	33,687.97	33.688
640	40,281.72	31,000.00	35,640.86	35.641
660	42,142.52	33,000.00	37,571.26	37.571
680	43,151.04	35,600.00	39,375.52	39.376
700	44,263.73	38,600.00	41,431.87	41.432
720	46,285.51	40,200.00	43,242.76	43.243
740	47,916.67	43,200.00	45,558.33	45.558
760	49,242.42	46,200.00	47,721.21	47.721
780	50,686.55	48,200.00	49,443.28	49.443
800	52,649.15	50,600.00	51,624.57	51.625
820	55,423.77	52,200.00	53,811.88	53.812
840	58,042.14	53,600.00	55,821.07	55.821
860	60,478.22	55,400.00	57,939.11	57.939
880	63,655.30	56,800.00	60,227.65	60.228
900	70,056.82	58,800.00	64,428.41	64.428
920	73,039.77	59,800.00	66,419.89	66.420
940	75,809.66	60,800.00	68,304.83	68.305
960	79,659.09	61,800.00	70,729.55	70.730
980	85,866.48	63,400.00	74,633.24	74.633
1000	100,312.50	65,400.00	82,856.25	82.856

Appendix 11 : Carrying Capacity Hydraulik Jacking System (HJS) on As F9

Depth meter	Pressure Gauge							Rata- rata Ton
	P413 Ton	P414 Ton	P415 Ton	P416 Ton	P417 Ton	P418 Ton	P419 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	38.41	32.01	25.61	32.01	29.26
8.00	38.41	51.21	44.81	51.21	44.81	44.81	38.41	44.81

10.00	76.82	76.82	76.82	76.82	76.82	89.62	76.82	78.65
-------	-------	-------	-------	-------	-------	-------	-------	-------

(Source: Supervision Report on the Construction of Piling Project for the Building of DPRD Building in Kab. Bangkalan)

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	Qult	Selisih	Qult	Selisih	(ton)
2.00	4.932	70.04%	3.698	77.54%	4.530	72.48%	16.46
4.00	14.330	28.78%	8.372	58.39%	11.652	42.09%	20.12
6.00	38.376	31.13%	23.587	19.40%	31.626	8.07%	29.26
8.00	55.677	24.25%	39.241	12.43%	51.625	15.20%	44.81
10.00	102.330	30.11%	54.888	30.21%	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
	Qult	Selisih	Qult	Selisih	Qult	Selisih	(ton)
10.00	102.33	21.24%	54.89	34.97%	82.86	1.83%	84.4