Analysis study of the bearing capacity of pile foundations in the construction of Bogor SMA-SMAK educational buildings

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Abstract* — Foundation is the structure of the lower part of a building that is directly connected to the ground and functions to carry the load of other parts of the building above it. In planning pile foundations, several approaches are used to predict the bearing capacity of the foundation** [1]**. The approach can be based on soil conditions and existing loading using various methods. Soil data used to calculate the bearing capacity of piles is based on Standard Penetration Test (SPT) data. There are three types of piles analyzed in this research, namely with diameter variations of 0.4 m, 0.5 m, and 0.6 m. The results of the analysis show that the carrying capacity of a single pile based on the Luciano Decourt method is smaller with a result of 4430.1 kN than the result of the Meyerhof method with a result of 19138.9 kN calculated at a depth of 25 m with a pile variation of 0.4 and Schmertman with a result of 1868.9 kN calculation at a depth of 25 m, pile variation is 0.4.

Keywords— Meyerhof, Pile, Luciano Decourt, Schmertmann and Nottingham, Foundation, SPT

I. INTRODUCTION

One of the jobs that cannot be let go or forgotten in the process of building a building is foundation work. In multilevel buildings, deep foundations are usually used. Pile foundations are used to support buildings that withstand upward lifting forces, especially in high-rise buildings which are affected by overturning forces due to wind loads. [2]In addition, the masts are also used to support water structures, where these buildings and the pillars are affected by the forces of ship collision and water waves.[3]

This use is adjusted to the amount of load, site/environmental conditions, and soil layers. The various types of foundations depend on the individual who defines them [4]. One _ good foundation _ used for building multi-story is a pile foundation.
The many types of pile foundations that can be used, will greatly facilitate in determining the foundation plan to be used. However, in this research the author will discuss the bearing capacity of spun piles or often known as *Strauss piles* . After working on the foundation, tests are carried out to check its bearing capacity[5]

Soil bearing capacity is the ability of the soil to withstand the maximum pressure or load acting on the foundation. The bearing capacity of the pile foundation can be determined using *Mayerkhof* , *Schmertman -Nottingham* and *L. Decourt* based on the results of the N-SPT. This research uses a case study on the construction of the BOGOR Vocational High School Education [2]Building .

II. LITERATURE REVIEW

This literature study was carried out to study in more depth the SPT (Standard Penetration Test) method based on references relevant to the research carried out. These references can be in the form of books, scientific journals and articles.

A. Pile

Piles are construction parts made of wood, concrete and steel that are used to transmit surface loads to a lower surface level in the soil mass. The use of piles is used [7]for the foundation of a building if the subgrade under the building does not have sufficient bearing capacity. to carry the weight of the building and its load, or if the soil is hard enough to have sufficient bearing capacity to carry the load. buildings and their loads are very deep. [8][9]Horvitz et al conducted research on several tested pile foundations so that they reached failure and stated that there was a good correlation between the results of analytical calculations and the pile foundation collapse loads . The analytical calculation in question is the method proposed by Schmertmann and Nottingham (1975).) research was conducted using the method to compare the calculation results of pile analysis.[10]

B. N-SPT data

The Standard Penetration Test (SPT) was initially used to determine the relative density of coarse granular

U. S. Saputri and M. A. S. Yudono (eds.), *Proceedings of the International Conference on Consumer Technology and Engineering Innovation (ICONTENTION 2023)*, Advances in Engineering Research 233,
https://doi.org/10.2991/978-94-6463-406-8_19

soil, which eventually developed as a method that is also applicable to determine the consistency of fine grained soil. [11]By testing, we can determine the depth of the pile to be planted and its bearing capacity, including both tip resistance and shear resistance. The physical and mechanical properties of the soil are known by laboratory tests. Sampling can be done for any soil depth. Because it can be known the value of N-SPT simultaneously with the physical and mechanical properties of the soil.[12], [13]

C. *Meyerhoff Method (1976)*

Analysis of pile bearing capacity with the Meyerhoff method

Calculate the end bearing capacity of the pile using the following equation:

$Qp = 40 \cdot N_{60} \cdot Li/D \cdot Ap \leqslant 400 \cdot Ap \cdot N_{60}$ (1)

Where :

Qp = ultimate end resistance (kN)

N_{60} = average N-SPT value of pile tips (between 4D - 10D)

Li = pole length (m)

Ap = cross-sectional area of the pole (m2)

D = pole diameter (m)

Calculate the frictional resistance of the pile using the following equation:

$Qs = 2 \cdot N60 \cdot P \cdot L$ (2)

Where :

Qs = ultimate friction resistance (kN)

N60 = average N-SPT value of pile tip (between 4D - 10D)

L = pole length (m)

P = pole circumference (m

According to Harry, this method is used to calculate the bearing capacity of piles in sandy soil. M e yerhof (1976; 1983) in Fellenius (1990) proposed an equation for determining the bearing capacity of piles in sand by taking into account the effect of scale and pile penetration as follows.[14]

Meyerhoff (19 7 6) recommends the following bearing capacity formula for piles

$Qu = 0.4\ N_{60} (L/d) \cdot \sigma_r \leq 3\ N\ \sigma_r (kN/m^2)$ (3)

with:

Qu = power support ultimate pile foundation (tons)

Nb = N-SPT value at the base elevation of the pole

Ap = area cross section pole base (m2)

As = area blanket pole (m2)

N = average N-SPT price .

D. *Schmertmann Method - Nottingham (1975)*

Analysis of pile bearing capacity with the Schmertmann method

The Schmertmann-Nottingham method is used to obtain the bearing capacity of pile foundations based on the results of the Cone Penetration Test. In this method, the bearing capacity of the pile tip is influenced by the top and bottom soil layers at the pile tip. Meanwhile, the bearing capacity of the pile cover is calculated separately based on the type of soil layer[15], [16]

E. *Luciano Decourt Method (1987)*

Analysis of the bearing capacity of piles using the Luciano Decourt method

The Luciano Decourt method is a method for determining the bearing capacity of pile foundations based on. Standard Penetration Test Results. The end bearing capacity of a pile foundation is influenced by the coefficient value based on the type of soil layer. approached based on the following relationship:[8]

Pole End Resistance

$Qp = qp \cdot A$ (4)

with :

qp : is the end resistance per unit area (ton/m2)
A : is the cross-sectional area of the pole (m2)
qp : Np . K, with Np the average number of hits from the three prices obtained above the pile tip and below the pile tip, while K is a coefficient depending on the type of soil.

Table 1. K coefficient according to Luciano Decourt

Type of soil	Coefficient K (kPa)
Clay	117.7
Clay silt	196.0
Sand silt	245.0
Sand	395.0

Ultimate Bearing Capacity of Poles

$Qu = Qp + Qs$ (5)

with :

Qu: is the ultimate bearing capacity of the pile (tons)
Qp: is the ultimate bearing capacity of the pile end (tons)
Qs: is the ultimate bearing capacity of the pile blanket (tons)

III. RESEARCH METHODOLOGY

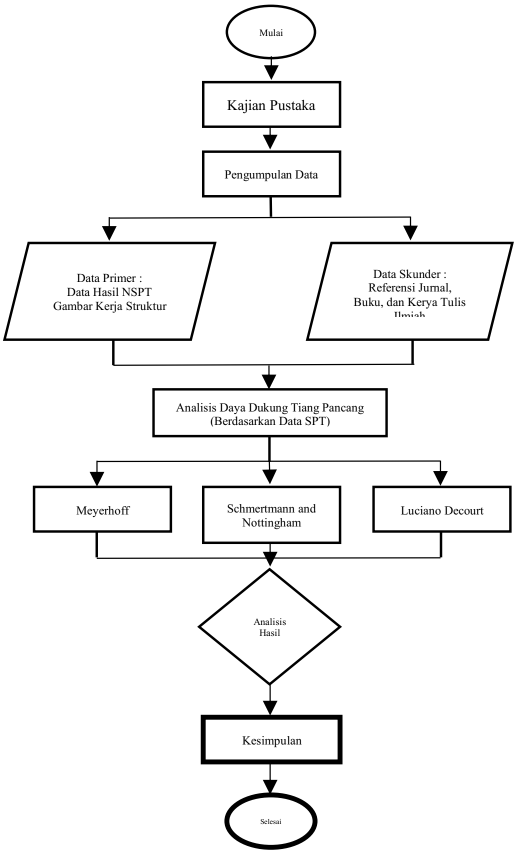
A. *Secondary data collector*

The data source used for this research comes from documents of soil investigation work (deep boring) with Standard Penetration Tests (SPT) carried out by
PT. PP Urban – NPS KSO.

B. *Data analysis*

Data analysis begins with soil data analysis to find the N-SPT correlation value on soil consistency and structural data analysis to obtain the pile bearing capacity value using the Luciano Decourt method, the Meyerhof method and the

Schmertmann - Nottingham method which is adjusted to the planned diameter variations.



IV. RESULTS AND DISCUSSION

From the data collected, 1 boring point has been taken which is close to the maximum column load, namely point BH-4. Data recording is grouped based on the diameter planning to be used. Then calculations were carried out using 3 methods, namely Meyerhoff. Luciano Decourt, and Schmertman and Nottingham.

Initial analysis by searching for the correlation of each NSPT based on depth with soil parameters is required according to the method used, namely the Meyerhoff, Luisiano Decourt and Schmertman – Nottingham methods.

Table 2. Carrying Capacity of a Single Pole Based on the Meyerhof Method with a diameter of 0.4m

H	N1	N2	N3	NM	CN	CE	CB	CR	CS	C60	D	Ap	P	Qp	Qs	Berat Tiang	Qult	Qult Ijin
(m)											(m)	(m2)	(m)	(ton)	(ton)	(kN)	(ton)	(ton)
5	2	3	3	6	1,7	0,7	1,15	1	1	5	0,4	0,126	1,256	294	58,61	3,0	351,4	140,5
10	7	12	18	30	1,6	0,7	1,15	1	1	15	0,4	0,126	1,256	1890	376,80	3,0	2265,5	906,2
15	5	16	20	22	1,5	0,7	1,15	1	1	26	0,4	0,126	1,256	4851	967,12	3,0	5816,9	2326,7
25	36	60	60	60	1,4	0,7	1,15	1	1	51	0,4	0,126	1,256	15960	3181,87	3,0	19140,6	7656,2

Table 3. Carrying Capacity of a Single Pole Based on the Meyerhof Method with a diameter of 0.5m

H	N1	N2	N3	NM	CN	CE	CB	CR	CS	C60	D	Ap	P	Qp	Qs	Berat Tiang	Qult	Qult Ijin
(m)											(m)	(m2)	(m)	(ton)	(ton)	(kN)	(ton)	(ton)
5	2	3	3	6	1,7	0,7	1,15	1	1	5	0,5	0,196	0,1963	366	9,16	4,7	374,8	149,9
10	7	12	18	30	1,6	0,7	1,15	1	1	15	0,5	0,196	1,57	2352	471,00	4,7	2821,4	1128,6
15	5	16	20	22	1,5	0,7	1,15	1	1	26	0,5	0,196	1,57	6037	1208,90	4,7	7244,1	2897,7
25	36	60	60	60	1,4	0,7	1,15	1	1	51	0,5	0,196	1,57	19861	3977,33	4,7	23837,1	9534,8

Table 4. Carrying Capacity of a Single Pole Based on the Meyerhof Method with a diameter of 0.6m

H	N1	N2	N3	NM	CN	CE	CB	CR	CS	C60	D	Ap	P	Qp	Qs	Berat Tiang	Qult	Qult Ijin
(m)											(m)	(m2)	(m)	(ton)	(ton)	(kN)	(ton)	(ton)
5	2	3	3	6	1,7	0,7	1,15	1	1	5	0,6	0,283	1,884	440	87,92	6,8	526,3	210,5
10	7	12	18	30	1,6	0,7	1,15	1	1	15	0,6	0,283	1,884	2830	565,20	6,8	3393,3	1357,3
15	5	16	20	22	1,5	0,7	1,15	1	1	26	0,6	0,283	1,884	7264	1450,68	6,8	8712,5	3485,0
25	36	60	60	60	1,4	0,7	1,15	1	1	51	0,6	0,283	1,884	23898	4772,80	6,8	28668,7	11467,5

Table 5. Carrying Capacity of a Single Pole Based on the Luisiano Decourt Method with a diameter of 0.4m

H	AS	NS+1	K	NS	β	α	NP	D	Ap	P	Qp	Qs	Berat Tiang	Qult	Qult Ijin
(m)			(kpa)					(m)	(m2)	(m)	(ton)	(ton)	(kN)	(ton)	(ton)
5	0,63	2,7	196	1,7	1	1	5	0,4	0,126	1,256	115	58,61	3,0	173,9	69,5
10	1,26	3,5	196	2,5	1	1	15	0,4	0,126	1,256	370	376,80	3,0	747,2	298,9
15	1,89	4,3	196	3,3	1	1	26	0,4	0,126	1,256	634	967,12	3,0	1601,0	640,4
25	3,15	5,6	196	4,6	1	1	51	0,4	0,126	1,256	1251	3181,87	3,0	4433,1	1773,3

Table 6. Carrying Capacity of a Single Pole Based on the Luisiano Decourt Method with a diameter of 0.5m

H	AS	NS+1	K	NS	β	α	NP	D	Ap	P	Qp	Qs	Berat Tiang	Qult	Qult Ijin
(m)			(kpa)					(m)	(m2)	(m)	(ton)	(ton)	(kN)	(ton)	(ton)
5	0,98	2,7	196	1,7	1	1	5	0,5	0,196	1,57	179	73,27	4,7	251,0	100,4
10	1,96	3,5	196	2,5	1	1	15	0,5	0,196	1,57	576	471,00	4,7	1045,7	418,3
15	2,94	4,3	196	3,3	1	1	26	0,5	0,196	1,57	986	1208,90	4,7	2193,3	877,3
25	4,9	5,6	196	4,6	1	1	51	0,5	0,196	1,57	1946	3977,33	4,7	5922,2	2368,9

Table 7. Carrying Capacity of a Single Pole Based on the Luisiano Decourt Method with a diameter of 0.6m

H	AS	NS+1	K	NS	β	α	NP	D	Ap	P	Qp	Qs	Berat Tiang	Qult	Qult Ijin
(m)			(kpa)					(m)	(m2)	(m)	(ton)	(ton)	(kN)	(ton)	(ton)
5	1,415	2,7	196	1,7	1	1	5	0,6	0,283	1,884	259	87,92	6,8	344,9	138,0
10	2,83	3,5	196	2,5	1	1	15	0,6	0,283	1,884	832	565,20	6,8	1395,3	558,1
15	4,245	4,3	196	3,3	1	1	26	0,6	0,283	1,884	1424	1450,68	6,8	2872,5	1149,0
25	7,075	5,6	196	4,6	1	1	51	0,6	0,283	1,884	2810	4772,80	6,8	7581,3	3032,5

Table 8. Carrying Capacity of a Single Pole Based on the Schmertman Method with a diameter of 0.4m

H	qc1	qc2	Kc	Ks	z	Fs	D	As	Ab	Qp	Qs	Berat Tiang	Qult	Qult Netto	Qult Ijin
(m)							(m)	(m2)	(m)	(ton)	(ton)	(kN)	(ton)	(ton)	(ton)
5	180	180	2,16	0,4	5	10	0,4	1,256	1,256	339	89,53	3,0	428,6	425,6	170,3
10	180	180	2,16	0,4	10	10	0,4	1,256	2,512	678	111,23	3,0	789,5	786,5	314,6
15	177,5	177,5	2,16	0,4	15	10	0,4	1,256	3,768	1003	132,94	3,0	1136,2	1133,2	453,3
25	180	180	2,16	0,4	25	10	0,4	1,256	6,28	1696	176,34	3,0	1871,9	1868,9	747,6

Table 9. Carrying Capacity of a Single Pole Based on the Schmertman Method with a diameter of 0.4m

H	qc1	qc2	Kc	Ks	z	As	D	As	Ab	Qp	Qs	Berat Tiang	Qult	Qult Netto	Qult Ijin
(m)							(m)	(m2)	(m)	(ton)	(ton)	(kN)	(ton)	(ton)	(ton)
5	180	180	2,16	0,4	5	10	0,5	1,57	1,9625	530	118,69	4,7	648,6	643,9	257,5
10	180	180	2,16	0,4	10	10	0,5	1,57	3,925	1060	152,60	4,7	1212,4	1207,6	483,1
15	177,5	177,5	2,16	0,4	15	10	0,5	1,57	5,8875	1568	186,52	4,7	1754,1	1749,4	699,7
25	180	180	2,16	0,4	25	10	0,5	1,57	9,8125	2649	254,34	4,7	2903,7	2899,0	1159,6

Table 10. Carrying Capacity of a Single Pole Based on the Schmertman Method with a diameter of 0.4m

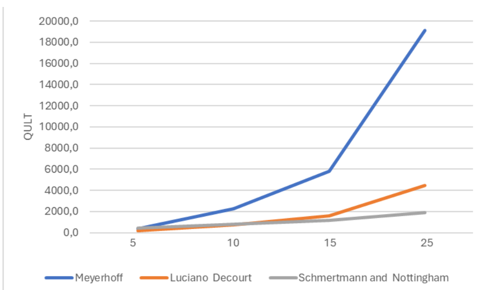
H	qc1	qc2	Kc	Ks	z	As	D	As	Ab	Qp	Qs	Berat Tiang	Qult	Qult Netto	Qult Ijin
(m)							(m)	(m2)	(m)	(ton)	(ton)	(kN)	(ton)	(ton)	(ton)
5	180	180	2,16	0,4	5	10	0,6	1,884	2,826	763	150,57	6,8	913,6	906,8	362,7
10	180	180	2,16	0,4	10	10	0,6	1,884	5,652	1526	199,40	6,8	1725,4	1718,7	687,5
15	177,5	177,5	2,16	0,4	15	10	0,6	1,884	8,478	2257	248,24	6,8	2505,5	2498,7	999,5
25	180	180	2,16	0,4	25	10	0,6	1,884	14,13	3815	345,90	6,8	4161,0	4154,2	1661,7

Based on calculation capacity Power support pole single with variations in diameter of 0.4 m , 0.5 m, and 0.6 m as presented in Table 2. Up to Table 11. so can done analysis comparison as following

Table 11. Comparison of the Carrying Capacity of a Single Pole Based on the Meyerhoff, Luiciano Decourt and Schmertman Method with a diameter of 0.4m

D	H	Qult (ton)		
(m)	(m)	Meyerhoff	Luciano Decourt	Schmertmann and Nottingham
0,4	5	349,6	170,8	425,6
	10	2263,8	744,2	786,5
	15	5815,1	1598,0	1133,2
	25	19138,9	4430,1	1868,9

Graph 1. Comparison of the Carrying Capacity of a Single Pole Based on the Meyerhoff, Luiciano Decourt and Schmertman Method with a diameter of 0.4m

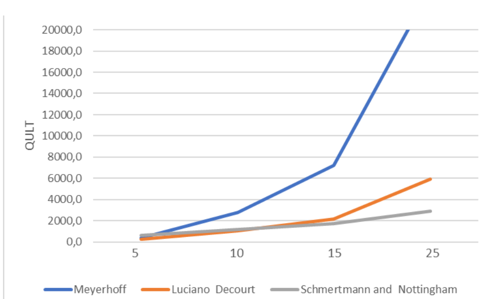


A comparison of the carrying capacity of a single pile pile based on Table 11 and Graph 1 with a pile diameter of 0.4 m shows that even though at a depth of 5 m the carrying capacity is greater than that produced by the Schmertman - Nottingham method, namely with a value of 425.6 kN, but At a depth of 25 meters the Meyerhoff method produces higher calculation results with a value of 19138.9 kN.

Table 12. Comparison of the Carrying Capacity of a Single Pole Based on the Meyerhoff, Luiciano Decourt and Schmertman Method with a diameter of 0.5m

D	H	Qult (ton)		
(m)	(m)	Meyerhoff	Luciano Decourt	Schmertmann and Nottingham
0,5	5	370,3	247,8	643,9
	10	2818,3	1042,5	1207,6
	15	7241,0	2190,2	1749,4
	25	23834,0	5919,0	2899,0

Graph 2. Comparison of the Carrying Capacity of a Single Pole Based on the Meyerhoff, Luiciano Decourt and Schmertman Method with a diameter of 0.5m

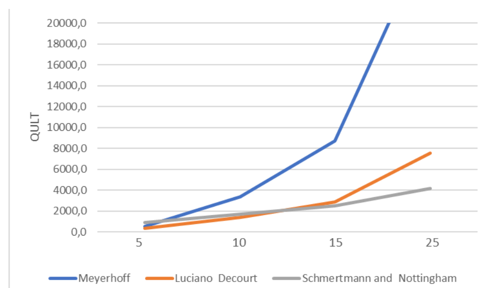


A comparison of the carrying capacity of a single pile pile based on Table 12 and Graph 2 with a pile diameter of 0.4m shows that even though at a depth of 5m the carrying capacity is greater than that produced by the Schmertman - Nottingham method, namely with a value of 634.9 kN, but At a depth of 25 meters the Meyerhoff method produces higher calculation results with a value of 23834.0 kN.

Table 13. Comparison of the Carrying Capacity of a Single Pole Based on the Meyerhoff, Luiciano Decourt and Schmertman Method with a diameter of 0.6m

D	H	Qult (ton)		
(m)	(m)	Meyerhoff	Luciano Decourt	Schmertmann and Nottingham
0,6	5	521,4	340,0	906,8
	10	3388,4	1390,4	1718,7
	15	8707,6	2867,6	2498,7
	25	28663,8	7576,4	4154,2

Graph 3. Comparison of the Carrying Capacity of a Single Pole Based on the Meyerhoff, Luiciano Decourt and Schmertman Method with a diameter of 0.6m



Comparison of the carrying capacity of a single pile based on Table 11. and Graph 1. with a pile diameter of 0.4m, states that even at a depth of 5m, a greater bearing capacity is produced by the Schmertman - Nottingham method, namely with a value of 906.8 kN, but At a depth of 25 meters the Meyerhoff method produces higher calculation results with a value of 28663.8 kN.

V. CONCLUSION

Based on the results of the analysis that has been carried out, the following conclusions can be drawn:

1. In a comparison of the single pile carrying capacity between the Meyerhoff method, Luciano Decourt and Schmertman – Nottingham tend to show that the Meyerhof method produces a greater bearing capacity at a pile depth of 25 m than the other two methods.
2. The results of calculating the carrying capacity of a single pile with a variation of 0.4 m in diameter and 25 m in length using SPT data with the Meyerhof method is 19138.9 kN, for calculations using the Luciano Decourt method is 4430.1 kN. Meanwhile, for Schmertman – Nottingham calculations using sondir data with a depth of 25 m produces a value of 1868.9 kN.
3. The results of calculating the carrying capacity of a single pile with a variation of 0.5 m in diameter and 25 m in length using SPT data with the Meyerhof

method is 23834.0 kN, for calculations using the Luciano Decourt method is 5919.0 kN. Meanwhile, for Schmertman – Nottingham calculations using sondir data with a depth of 25 m produces a value of 2889.0 kN.

4. The results of calculating the carrying capacity of a single pile with a variation of 0.6 m in diameter and 25 m in length using SPT data with the Meyerhof method is 28663.0 kN, for calculations using the Luciano Decourt method is 7576.4 kN. Meanwhile, for Schmertman – Nottingham calculations using sondir data with a depth of 25 m produces a value of 4154.2 kN.
5. Based on the results of the data analysis, it can be stated that the calculation using the Meyerhof method is an efficient calculation to find the value of the pile bearing capacity.

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