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Redesign of the Foundation for Development of Al Barokah Foundation Flat to Bore Pile Foundation

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Abstract: The purpose of redesigning the foundation of the Al Barokah Foundation Apartment into a Bore Pile Foundation is to increase the bearing capacity and ensure structural stability against applied loads. The foundation bearing capacity calculation is based on Standard Penetration Test (SPT) data using the Mayerhoff method on cohesive soil.The results of this research include studying the analysis of changes in deep foundations, soil characteristics, and the foundation's bearing capacity against building loads. The foundation redesign involves using a 60 cm bore pile. For pile cap PC 1, the dimensions are 120 x 120 cm and 60 cm thick. For PC 2, the dimensions are 120 x 120 cm and 60 cm thick, with a concrete quality of fc'=25 MPa. The bore pile reinforcement design for the BP 1 pile foundation is 10D19, with shear reinforcement of D10-52 mm. For the PC 1 pile cap design, the compression main reinforcement in the x- and y-axes is D13-530 mm. For the tension main reinforcement, a diameter of D13-150 mm is used, based on SNI 2847:2019. The foundation settlement value for each pile is the same, at 1.71 cm, which is still within the tolerance limit according to SNI 8460:2017.

Keywords: Deep foundation, foundation redesign, bore pile

INTRODUCTION

Foundations are the basic elements of a building that interact directly with the ground. Their function is to transfer the building's load from above to the ground. Foundations play a crucial role in the stability of a building's construction. Therefore, careful foundation planning is essential to ensure they can support the load according to applicable safety standards and withstand the maximum possible load. If the soil strength exceeds its capacity, it can experience excessive settlement or even collapse. Generally, foundations are divided into two categories: shallow foundations and deep foundations. Shallow foundations are generally chosen for buildings with light loads, such as residential buildings, and on stable soils, while deep foundations are more often used for buildings with heavy loads. Examples of deep foundations include bored piles and pile foundations.

The AL Barokah Matra Sarana Mulya three-story apartment building project requires planning for the superstructure and substructure. In principle, a building cannot be constructed on soil that is less able to support the load.

RESEARCH METHOD

A research method is a way to solve problems or develop knowledge using scientific methods. More broadly, a research method is defined as a scientific method for obtaining valid data, with the goal of discovering, developing, and proving specific knowledge that can, in turn, be used to understand, solve, and anticipate problems.

The design of the bored pile foundation for the Al Barokah Matra Sarana Mulya Foundation apartment complex involved several stages, including load calculations, foundation dimensions and depth calculations, pile bearing capacity calculations, number of piles, settlement calculations for single pile foundations, bearing capacity calculations due to lateral loads, pile deflection calculations due to lateral loads, foundation reinforcement, pile cap planning, and pile requirement calculations for static and dynamic foundation testing.

RESULT AND DISCUSSION

Primary Data

The primary data in this study are the SPT test results at the construction site of the AL-Barokah Matra Sarana Mulya Foundation apartment complex, which will be developed through soil parameter analysis.

Soil Parameter Analysis

Soil parameter analysis refers to boring log data from a depth of 0 to 30 meters.

Table 4.1 Soil Parameters

Depth (m)	Soil Type	N-SPT	e_0	γ (kN/m³)	Cu (kN/m²)	qu (kN/m²)
1 – 2	Clay	9	0,9	17,5	25	120
2 – 4	Clay	10	0,85	17,8	28	130
4 – 6	Clay	12	0,8	18	30	150
6 – 8	Clay	18	0,75	18,5	200	200
9 – 10	Clay	35	0,65	19	200	350
11 – 12	Clay	36	0,63	19,2	200	360
12 – 14	Clay	38	0,6	19,4	200	380
14 – 16	Clay	38	0,58	19,4	200	380
16 – 18	Clay	27	0,6	19	200	270
18 – 20	Clay	49	0,55	19,5	200	450
20 – 22	Clay	59	0,52	19,8	200	500
22 – 24	Clay	60	0,5	20	200	520
24 – 26	Clay	60	0,5	20	200	520
26 – 28	Clay	60	0,5	20	200	520
28 – 30	Clay	60	0,5	20	200	520

Secondary Data

Load Combinations

Referring to the specifications and SNI 1726:2019, the load combinations used are:

a. 1,4 DL

b. 1,2 DL +1,6 LL

c. 1,2 DL + 1 LL + 0,5 TLL + 1 WL(X) + 0,3 WL(Y)

d. 1,2 DL + 1 LL + 0,5 TLL + 0,3 WL(Y) + 1 WL (Y)

e. (1,2+0,2 Sds) DL + 1LL + 1 ρ Eq(X)+ 0,3ρ Eq(Y)

f. (1,2+0,2 Sds) DL + 1LL + 1 ρ Eq(X)- 0,3ρ Eq(Y)

g. (1,2+0,2 Sds) DL + 1LL - 1 ρ Eq(X)- 0,3ρ Eq(Y)

h. (1,2+0,2 Sds) DL + 1LL - 1 ρ Eq(X)+ 0,3ρ Eq(Y)

i. (1,2+0,2 Sds) DL + 1LL + 0,3 ρ Eq(X)+ 1ρ Eq(Y)

j. (1,2+0,2 Sds) DL + 1LL + 0,3 ρ Eq(X)- 1ρ Eq(Y)

k. (1,2+0,2 Sds) DL + 1LL - 0,3 ρ Eq(X)- 1ρ Eq(Y)

l. (1,2+0,2 Sds) DL + 1LL - 0,3 ρ Eq(X)+ 13ρ Eq(Y)

Table 4.2 Loading Data

Story	label	FX	FY	FZ	Pijin
		tonf	tonf	tonf	ton
Base	2	0.4	-0,82	37.76	40
Base	5	-0.11	-1.38	54.75	40
Base	8	-0.1	-1.39	42.07	40
Base	18	0.42	0.69	37.42	40
Base	19	1.63	0.38	26.21	40
Base	20	6.32	-1.16	45.00	40
Base	21	1.41	0.14	43.95	40
Base	23	1.43	-0.08	45.07	40
Base	24	1.45	-0.12	45.99	40
Base	25	1.44	-0.09	46.32	40
Base	26	1.22	-0.51	37.10	40
Base	27	0.9	1.14	61.90	40
Base	36	0.07	0.9	62.56	40
Base	37	-0.77	0.37	46.60	40
Base	38	-1.47	0.09	69.86	40
Base	39	-0.95	0.04	64.14	40
Base	41	-1.09	0.18	64.19	40
Base	42	-1.2	-.0.07	61.84	40
Base	43	-1.21	-0.04	62.29	40
Base	44	-1.01	-0.71	45.93	40
Base	49	0.000634	0.14	17.61	40
Base	50	0.43	0.72	47.08	40
Base	52	0.69	-1.01	42.11	40
Base	53	0.18	0.1	34.16	40
Base	54	-0.1	-0.07	36.15	40
Base	55	-0.11	-0.05	36.15	40
Base	56	0.13	-0.19	34.40	40
Base	57	-0.15	1.06	60.52	40
Base	59	-0.05	-1.39	41.55	40
Base	62	0.08	1.35	42.53	40
Base	64	0.04	-1.21	58.40	40

Base	65	0.05	-0.13	35.98	40
Base	68	-0.03	0.08	36.33	40
Base	69	-0.04	1.16	57.68	40
Base	71	-0.08	-1.4	42.13	40
Base	74	0.11	1.37	42.11	40
Base	76	0.06	-1.2	58.01	40
Base	77	0.06	-0.12	35.95	40
Base	80	-0.02	0.09	36.33	40
Base	81	-0.01	1.18	58.50	40
Base	83	-0.05	-1.39	42.52	40
Base	86	0.08	1.35	41.57	40
Base	88	0.17	-1.1	60.75	40
Base	89	-0.11	0.15	34.37	40
Base	90	0.12	0.01	36.57	40
Base	91	0.11	0.03	36.53	40
Base	92	-0.16	-0.14	34.57	40
Base	93	-0.67	0.97	41.99	40
Base	95	-0.41	-076	46.73	40
Base	96	0.01	-0.18	17.46	40
Base	101	1.01	0.67	45.52	40
Base	102	1.23	0.000779	61.90	40
Base	103	1.22	0.03	61.49	40
Base	104	1.11	0.13	64.01	40
Base	106	1.19	0.04	65.81	40
Base	107	1.42	-0.27	70.42	40
Base	108	0.61	-0.37	45.79	40
Base	110	0.11	1.35	41.8	40
Base	112	-0.06	-0.95	62.28	40
Base	122	0.13	1.41	42.68	40
Base	124	0,09	-1.21	57.02	40
Base	125	-0.77	0.43	46.03	40
Base	126	-1.43	0.04	46.46	40
Base	127	-1.44	0.07	45.98	40
Base	128	-1.42	0.03	45.03	40
Base	130	-1.63	0.24	45.65	40
Base	131	-7.89	-0.68	46.58	40
Base	132	-5.76	-2.25	25.97	40
Base	134	-0.39	0.82	25.34	40
Base	136	-0.59	-0.67	32.37	40
Base	137	-0.15	-0.02	13.41	40

Bore Pile Foundation Planning Stages

The bore pile foundation planning stage begins with collecting primary data in the form of superstructure data and N-SPT data as secondary data. The foundation planning calculation stage is then continued. The following are the calculation stages for bore pile foundation planning, Axial bearing capacity of a single pile, Permissible bearing capacity of a single pile, Determining the number and spacing of piles, Group pile arrangement, Pile foundation settlement, Pile bearing capacity due to lateral loads, Deflection due to lateral loads, Reinforcement of the bore pile foundation, Planning the dimensions and reinforcement of the pile cap

Calculation of the Bearing Capacity of a Single Pile

The calculation of the bearing capacity of a single pile uses the Mayerhoff method based on the following data:

Soil Data :N-SPT
Soil Type :Cohesive
Bore Pile Type :60 cm Bore Pile
Foundation Length :12 m

Pile Tip Bearing Capacity Calculation (Qp)

An example of calculating the pile tip bearing capacity (Qp) using the Mayerhoff method is as follows.

Bore pile Diameter 60 cm
Pile Bore Diameter :60 cm = 0.6 m
Bore Pile Area (Ap) : $\frac{1}{4} \times \pi \times d^2$

: $\frac{1}{4} \times 3{,}14 \times 0{,}6^2$

: 0,283 m^2

N1 = 8 D = 8 x 0.6 = 4.8 m (12 – 4.8 = 7.2m)
N2 = 4 D = 4 x 0.6 = 2.4 m (12 + 2.4 = 14.4 m)
So the average N-SPT of the zone 8D above and 4D below the tip of the pole is:

N1 $= \frac{18+35+36}{3} = 29{,}67$

N2 $= \frac{36+38+38}{3} = 37{,}33$

N60’ $= \frac{29{,}67+37{,}33}{2} = 33{,}5$

q_p = 0,4 x N60’ x (L/d) x σr’

= 0,4 x 33,5 x (2/0,6) x 100

= 4.422 kN/m^2

The bearing capacity at the end of the bored pile is:

Qp = Ap x qp
= 0.283 x 4,422
= 1,251.426 kN
= 127.61 tons

Calculation of the Bearing Capacity of a Pile Cover (Qs)

An example of calculating the bearing capacity of a single pile cover (Qs) using the Mayerhoff method for BP1 is as follows:

Qs = As x fs

As = π x d x L

= 3,14 x 0,6 x 12

= 22,61 m^2

fs = $\frac{1}{50} \times N_{60}' x \sigma r'$

= $\frac{1}{50} \times 33{,}5 x 100$

= 67 kN/m^2

s = As x fs

As = π x d x L

= 3.14 x 0.6 x 12

= 22.61 m2

fs = 1/50 x N_60' x σr'

= 1/50 x 33.5 x 100

= 67 kN/m2

Qs = As x fs

Qs = 22.61 x 67

= 1,514.87 kN

= 154.47 tons

Calculation of the Ultimate Bearing Capacity of a Pile (Qu)

An example of calculating the ultimate bearing capacity of a pile (Qu) using the Mayerhoff method for BP1 is as follows.

Qu = Qp + Qs

= 127.61 + 154.47

= 282.08 tons

= 2766.26 kN

Calculation of the Allowable Bearing Capacity of a Pile (Qijin)

According to Hadiyatmo, the working load or permissible bearing capacity of a pile (Qijin) is calculated taking into account safety against collapse. With a Safety Factor of 3,

Qijin = $\frac{Qu}{SF}$

= $\frac{282{,}08}{3}$

= 94,03 tons

Calculation of the Bearing Capacity of a Pile Group

The calculation of the bearing capacity of a pile group begins with determining the number of piles in a group, the spacing between them, the pile arrangement, and the efficiency of the pile group using the Converse-Labarre equation.

a. Number of Piles (n)

The number of piles is determined based on the bearing capacity of a single pile and the load acting on a single foundation point. An example of calculating the number of foundation piles using type BP1 is as follows:

$$n_{tiang} = \frac{Pu}{Q_{ijin}}$$

Where:

Pu = 70.42 tons

Qijin = 94.03 tons

Therefore, the calculation can be made:

$$n_{tiang} = \frac{70,42}{94,03}$$

= 0,75 = 1 Tiang

Requirements for calculating the permissible bearing capacity of a single pile

Q_{ijin} > Pu

94,03 > 70,42 Ton **(OK)**

A summary of the calculation of the number of foundation piles at all points is attached in the following table.

Story	label	FZ	Qijin	Number of Poles	
		tonf	ton		
Base	2	37,76	94,03	0,40	1,00
Base	5	54,75	94,03	0,58	1,00
Base	8	42,07	94,03	0,45	1,00
Base	18	37,42	94,03	0,40	1,00
Base	19	26,21	94,03	0,28	1,00
Base	20	45,00	94,03	0,48	1,00
Base	21	43,95	94,03	0,47	1,00
Base	23	45,07	94,03	0,48	1,00
Base	24	45,99	94,03	0,49	1,00
Base	25	46,32	94,03	0,49	1,00
Base	26	37,10	94,03	0,39	1,00
Base	27	61,90	94,03	0,66	1,00
Base	36	62,56	94,03	0,67	1,00
Base	37	46,60	94,03	0,50	1,00
Base	38	69,86	94,03	0,74	1,00
Base	39	64,14	94,03	0,68	1,00
Base	41	64,19	94,03	0,68	1,00
Base	42	61,84	94,03	0,66	1,00
Base	43	62,29	94,03	0,66	1,00

Base	44	45,93	94,03	0,49	1,00
Base	49	17,61	94,03	0,19	1,00
Base	50	47,08	94,03	0,50	1,00
Base	52	42,11	94,03	0,45	1,00
Base	53	34,16	94,03	0,36	1,00
Base	54	36,15	94,03	0,38	1,00
Base	55	36,15	94,03	0,38	1,00
Base	56	34,40	94,03	0,37	1,00
Base	57	60,52	94,03	0,64	1,00
Base	59	41,55	94,03	0,44	1,00
Base	62	42,53	94,03	0,45	1,00
Base	64	58,40	94,03	0,62	1,00
Base	65	35,98	94,03	0,38	1,00
Base	68	36,33	94,03	0,39	1,00
Base	69	57,68	94,03	0,61	1,00
Base	71	42,13	94,03	0,45	1,00
Base	74	42,11	94,03	0,45	1,00
Base	76	58,01	94,03	0,62	1,00
Base	77	35,95	94,03	0,38	1,00
Base	80	36,33	94,03	0,39	1,00
Base	81	58,50	94,03	0,62	1,00
Base	83	42,52	94,03	0,45	1,00
Base	86	41,57	94,03	0,44	1,00
Base	88	60,75	94,03	0,65	1,00
Base	89	34,37	94,03	0,37	1,00
Base	90	36,57	94,03	0,39	1,00
Base	91	36,53	94,03	0,39	1,00
Base	92	34,57	94,03	0,37	1,00
Base	93	41,99	94,03	0,45	1,00
Base	95	46,73	94,03	0,50	1,00
Base	96	17,46	94,03	0,19	1,00
Base	101	45,52	94,03	0,48	1,00
Base	102	61,90	94,03	0,66	1,00
Base	103	61,49	94,03	0,65	1,00
Base	104	64,01	94,03	0,68	1,00
Base	106	65,81	94,03	0,70	1,00
Base	107	70,42	94,03	0,75	1,00
Base	108	45,79	94,03	0,49	1,00

Base	110	41,80	94,03	0,44	1,00
Base	112	62,28	94,03	0,66	1,00
Base	122	42,68	94,03	0,45	1,00
Base	124	57,02	94,03	0,61	1,00
Base	125	46,03	94,03	0,49	1,00
Base	126	46,46	94,03	0,49	1,00
Base	127	45,98	94,03	0,49	1,00
Base	128	45,03	94,03	0,48	1,00
Base	130	45,65	94,03	0,49	1,00
Base	131	46,58	94,03	0,50	1,00
Base	132	25,97	94,03	0,28	1,00
Base	134	25,34	94,03	0,27	1,00
Base	136	32,37	94,03	0,34	1,00
Base	137	13,41	94,03	0,14	1,00

b. Pole-to-Edge Distanc

According to Fellinius (2006), the recommended pole-to-edge distance in a pole group is determined as follows:

Pole-to-Edge Distance = 1 x D

= 1 x 0.6 m = 0.6 m

Pile Group Arrangement

The pile arrangement in a pile group for PC1, with one pile, is shown in the following figure.

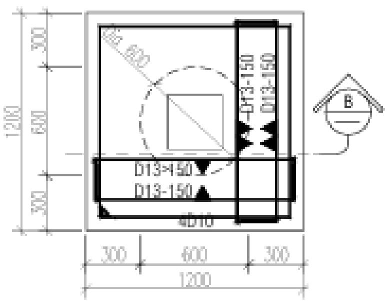

Figure 1. Pile Cap Arrangement

Single Pile Settlement (S)

The calculation of single pile settlement at BP1 using the empirical method can be seen in the following equation:

• Bore pile foundation data:

Panjanng *Bore pile* (L) = 12 m

Diameter *Bore pile* (D) = 0,6 m

Beban Uji = 70,42 ton

Ap = $0{,}283 \text{ m}^2$

Ep = $4.700 \times \sqrt{fc'} = 4.700 \times \sqrt{25}$

= $4.700 \times 5 = 23.500$ MPa = $23.500.000 \text{ kN/m}^2$

Berat Tiang = Ap x y x n x L

= 0,283 x 19,2 x 33,5 x 12 = 2.184,31 kN

Q = P + Berat Tiang

= 686,47 + 2.184,31 = 2.870,78 kN

S $= \frac{D}{100} + \frac{Q \times L}{Ap \times Ep}$

$= \frac{0{,}6}{100} + \frac{2.870{,}78 \times 12}{0{,}283 \times 23.500.000}$

= 0,0121 m

= 1,21 cm

Sg (Penurunan Tiang Kelompok) $= S \sqrt{\frac{Bg}{D}}$

$= 1{,}21 \sqrt{\frac{120}{60}}$

= 1,71 cm

Check the conditions for reducing the single pole permit:

Sg	<	15 + b/600 cm (Pasal 9.2.4.3 SNI 8460-2017)
1,71	<	15 + 60/600 cm
1,71	<	15,1 cm **(safe)**

CONCLUSIONS AND RECOMMENDATIONS

Based on the calculations and analysis in the previous chapter, it can be concluded that the bearing capacity of the bored pile foundation is greater than the load it supports. The bored pile diameter is 60 cm and the depth is 12 m. The bearing capacity of the single pile foundation (Qijin) is 94.03 tons. The pile dimensions for all foundations are the same, 60 cm in diameter, with one pile in each PC1. The bore pile reinforcement design for the BP 1 pile foundation is 10D19, with shear reinforcement of D10-52 mm. For the PC I pile cap design, the compression reinforcement in the x- and y-axes is D13-530 mm. The tension reinforcement is D13-150 mm. The foundation settlement for each pile is the same, at 1.71 cm. From the results of the calculations and conclusions, it is recommended to carry out further analysis by considering other methods. Before conducting research, it is best to look for literature that has similarities with the research being carried out. Investigations must be carried out carefully, in order to obtain data that is in accordance with the objectives.

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