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Effect of Bored Pile Foundation Implementation on Environment, Cost of Elevated Railway Construction Project Between Solo Balapan-Kadipiro KM 104 + 700 to KM 107 + 000 (Phase 1)

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Abstract - **The high volume of vehicles at Simpang Joglo, which caused traffic congestion, became a particular focus for the government. The construction of the bridge on this railway line of PT. Wijaya Karya (WIKA) is located at KM 105+499 to KM 105 +772, with a bridge stretch of 272.80 m and a width of 14.1 m. The problems raised in this study include the effect of the implementation of bored pile work on the environment, whether the solution to the problem affects cost and time, and how much the carrying capacity of the bored pile is at this stage, using qualitative research methods and quantitative research methods. After observations and interviews with the community, it can be known that the bored pile foundation work on the Railway Elevated Line Construction Project between Solo Balapan - Kadipiro at KM 104 + 700 to KM 107 + 000 (phase 1) has several impacts that affect the work environment and the community environment, including noise, road damage, air pollution, land collapse due to drilling damage to tools, etc. From this impact, there are several solutions, including repairing road facilities, changing tools, etc. From the results of the analysis of the calculation of the bearing capacity of the foundation at Pier 11, a value of 28135.397 kN was obtained. The benefits of this research are that it can find out problems and solutions for work, know the impact on time and cost, and know the carrying capacity of a bored pile.**

Keywords: bored pile, carrying capacity, cost, environment, impact.

I. INTRODUCTION

The high volume of vehicles on Simpang Joglo, which caused traffic congestion, became a particular highlight for the government. Railway construction is currently the primary choice as a solution to the problem and is an important aspect of improving the nation's economy. The bridge on this railway line of PT. Wijaya Karya (WIKA) has a stretch of 272.80 m and a bridge width of 14.1 m. The bridge consists of four pier points, namely, Piers 9, Piers 10, Piers 11, and Piers 12. Each distance between pier 9 and pier 10 is 71.4 m, the distance between pier 10 and pier 11 is 130 m, and the distance between pier 11 and pier 12 is 71,4 m.

In the implementation of bridgework, the lower structure is very influential on the strength of the structure above it. The foundation is part of the lowest and most basic building structure that serves to channel the load of the upper structure evenly to the hard soil layer. According to the book Soil Mechanics and Foundation Engineering (2017), the foundation is the lowest part of a structure to the supporting soil layer below. According to the book Soil Mechanics and Foundation Engineering (2000), things that need to be considered when determining the type of foundation are the state of the foundation soil, limitations due to construction on it (superstructure), limitations from the surroundings, time and cost of work.

The activities carried out first are by conducting soil investigation tests that aim to determine the carrying capacity of the soil and soil characteristics. Because the project area is located in the middle of an urban area, with densely populated environmental conditions, and by considering what impacts will occur, in planning the foundation for this project, a type of bored pile foundation is used. A bored pile foundation is a type of deep foundation whose manufacture is carried out directly on the ground surface by determining the bored pile point first, then drilling holes. After drilling, then inserting reinforcement and tremie pipes, then casting using ready-mix concrete.

Each project implementation has its impacts and problems, including those that can have an impact on time, cost, and the environment. Therefore, according to the Decree of the State Minister of Environment KEP 48 / MENLH / 11/1996, noise is unwanted noise from businesses or activities at a certain level and time that can cause human health problems and environmental comfort. Regarding work safety that needs to be considered, there is a law PP no 50 of 2012 concerning the Implementation of the Occupational Safety and

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Health Management System (SMK3) (Central Government, Government Regulation of the Republic of Indonesia, 2012). But this is not a big problem, and will be used as evaluation material for further work so that it continues to run well with good results as well. The problems raised in this study include the effect of the implementation of bored pile work on the environment, whether the solution to the problem affects cost and time, and how much the carrying capacity of the bored pile is.

The larger the project, the tighter the budget and the timeline, and the greater the likelihood of problems arising. Although the problems that arise can be predicted, there are certainly problems that still arise unexpectedly (Davidson, 2002).Things that affect construction costs are found in activities and activities such as labor productivity, availability of materials and equipment, weather, types of contracts, quality issues, ethics, and control systems (Muhammad Nur Sahid, et al. 2019). From a technical perspective, the measure of project success is associated with the number of costs allocated, the schedule of activities, and the quality that must be met (Soeharto, 1999). Meanwhile, according to (Muhammad Nur Sahid. et al, 2019) a project can be said to be successful, one of which is if it is right on cost according to the budget plan.

Previous research on the factors causing the problem of adding costs to the project has been carried out by Muhammad Nur Sahid, et al (2019) with the title Analysis of Important Factors Causing the Problem of Adding Costs in the Klaten Regency Road Project written in the UMM Journal Volume 17, Number 2, August 2019. In this study, factors that affect cost overruns were obtained, including labor factors, material factors, and implementation time.

The research was also conducted by Muhammad Nur Sahid, et al. (2020), with the title Factors Causing Cost Overruns by Solo City Road Project Contractors, published in the Sukowati R&D Journal, Volume 4, Number 1, November 2020, Pages 24-36.

In addition to cost, this study also takes references from previous research conducted by Agus Susant et al. (2020) entitled Kendeng River Bridge Abutment Drill Foundation Planning (Comparison of Meyerhof's Method and Reese and Wright's Method).

The purpose of this study is to determine the effect of the implementation of bored pile foundations on the environment and costs. So that the title raised in this study is "Analysis of the Carrying Capacity and Effect of Bored Pile Foundation Implementation on the Environment and Cost in the Elevated Railway Construction Project between Solo Balapan – Kadipiro KM 104 + 700 to KM 107 + 000 (phase 1)".

II. METHOD

The research method conducted by the author aims to determine the effect of bored pile foundation work on the environment and the costs of railway construction projects. In addition, this study aims to determine the carrying capacity or strength of the bored pile foundation.

At this stage, using qualitative research methods and quantitative methods is appropriate. Qualitative research methods are those that use narrative-shaped data obtained from in-depth interviews and observation activities. Quantitative methods, according to V. Wiratna Sujarweni (2014: 39), are types of research that produce findings that can be achieved (obtained) using statistical procedures or other means of quantification (measurement). The location of this research is in Simpang Joglo, Surakarta, Central Java.

Figure 1: Project Location of Elevated Railway Solo Balapan – Kadipiro
(Source: Google Earth)

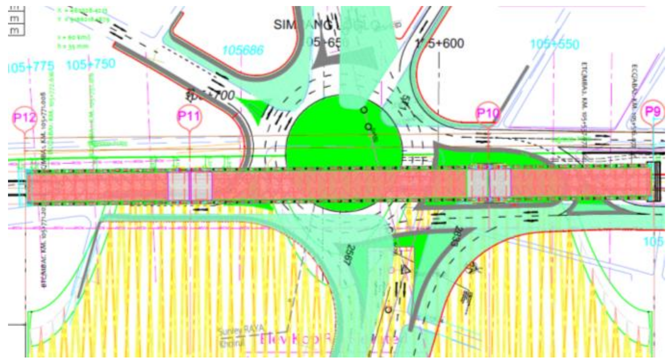

Figure 2: Project Layout of Elevated Railway Solo Balapan – Kadipiro
(Source: Data PT. Rayakonsult)

The stages carried out to obtain research results include. The initial stage carried out is the collection and understanding of several articles or journals as a support for data processing and as a complement to the theories used in research. This term is commonly referred to as study literature.

Then analyze the factors that influence bored pile work. Furthermore, conclusions are made from the results that have been obtained. Meanwhile, before carrying out bored pile work, a calculation plan is carried out first.

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Strong Capacity to Support Bored Pile from Standard Penetration Test (NSPT) Results (Hary Christady Hardiyatmo, 2015)

The O'Neil and Reese Method (1989)

1) Ultimate End Resistance

$Qb = Ab\ fb$ (1)

O'Neil and Reese (1989) of the drill pile end resistance recommend a 5% decrease of the pile base diameter in the sand, as follows:

$fb = 0{,}60\sigma r\ N_{60} \leq 4500 kPa$ (2)

Information :

Ab = Base area of drilled piles (m^2)

fb = Net end resistance per unit area (kPa)

60=Average N-SPT value between ends

bottom drilled pile up to 2db in underneath, no need to correct against overburden

d_b= Diameter of the lower end of the drill pile (m)

σr = Reference voltage = 100 kPa

If the base drill pile is more than 120 cm in diameter, then the size of fb can result in a drop greater than 25 mm (1 in). To qualify for a decrease in permissions, O'Neil and Reese (1989) suggest fb be reduced to fbr, by:

$fbr = 4{,}17(dr/db)\ fb$; bila db ≥1200 mm (3)

Information :

dr=Reference width = 300 mm

db = The width of the lower end of the bored pile.

The final resistance value of the unit used in the design is fbr. Alternatively, O'Neil and Reese (1989) suggest doing a decline analysis, then changing the design of the mast so that the decline is still within tolerance limits. If the tolerance drop is allowed to be greater or smaller than 25 mm, and the pole diameter is where the excessive drop is a problem, then adjustments in the fb count analysis need to be done.

2) Ultimate friction resistance

$fs = \beta p_o'$ (4)

$\beta = K \tan \delta$ (5)

Information :

Fs = Unit friction resistance

$\beta p_o'$ = Overbuden pressure in the middle Subsoil (kN/m2)

δ = Friction angle between ground and pole (degree)

This method is also called the β method. K/Ko values are shown in the table, and the δ/φ' ratio is shown in the table. The β coefficient can also be calculated using the equation suggested by O'Neil and Reese (1989):

$\beta = 1{,}5 - 0{,}135\ \sqrt{z/dr}$ with $0{,}25 \leq \beta \leq 1{,}2$ (6)

Information :

z = Depth in the middle of the soil layer (m)

dr = Reference width = 300 mm

When the reference width dr = 300 mm is substituted into the equation

$\beta = 1{,}5 - 0{,}245\ \sqrt{z}$ with $0{,}25 \leq \beta \leq 1{,}2$ (7)

If N60 ≤ 15, then the β in the equation is multiplied by N60 /15 or

$\beta = N60/15\ (1{,}5 - 0{,}245\sqrt{z})$ for $N60 \leq 15$ (8)

N60 is an N-SPT that is not corrected for overburden and is only corrected by the influence of procedures (tools) in the field. Some β values for non-cohesive soil suggested by Reese et al. (2006):

1. For sand:
$\beta = 0{,}25$, jika $z > 26{,}14$ m (9)

2. For sand that contains a lot of gravel:
$\beta = 2 - 0{,}15(z)^{0{,}75}$; $0{,}25 \leq \beta \leq 1{,}8$ (10)

3. For gravel sand or gravel:
$\beta = 0{,}25$, jika $z > 26{,}5$ m (11)

For sand and gravel sand, the β function reaches its limits at depths z = 1.5 m and 26 m; therefore, the creation of the boundaries of the subsoil should be in the zones between them. In addition, layer boundaries should also be created at the groundwater level. Additional boundaries should also be made at each interval of 6 m and where the boundaries of the sand layer end. After that, the analysis is based on the type of soil (loam or rock).

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III. RESULTS AND DISCUSSION

3.1 The Effects of Bored Pile Work on the Environment

After observations and interviews with the community, it is know that the impact of bored pile work affects the work environment and the community environment, this impact is still within a radius of 5 m to 10 m from bored pile drilling work. As for the impact of bored pile foundation work, this can be seen in the table below:

Table 1: Impact on Bored Pile Work of Pier 9, Pier 10, Pier 11, and Pier 12

No	Impact
1	Noise generated from material mobilization activities and heavy equipment (rotary drilling machines) during bored pile work
2	Road damage in the neighborhood surrounding the work
3	Air pollution caused during drilling
4	Soil collapse as a result of drilling
5	Disrupted road access

(Source: Results of Independent Observations in the Field and Interviews)

The obstacles or problems that occur during bored pile foundation work are explained in the table below:

Table 2: Problems in Bored Pile Foundation Work of Pier 9, Pier 10, Pier 11, and Pier 12

No	Problems That Occur
1	Kelly's tool in rotary drilling is porous so that it is detached from the rotary drilling tool
2	At the time of pouring ready mix concrete, tremi pipe cannot go down
3	The welded joint part of the casing is broken, so the casing cannot be completely unplugged
4	The ready mix comes late, and the batching plant has a limited number of mixer trucks, so casting is not done on time.

(Source: Results of Independent Observations in the Field)

Location	Date	No construction activity		Construction activities		Δ Leq dB(A)
		Range L dB(A)	Leq dB(A)	Range L dB(A)	Leq dB(A)	
P9	3/10/22	51.7 - 84.7	78.36	75.7 - 93.2	83.78	5.42
	4/10/22	51.2 - 84	76.37	75.4 - 89.5	79.71	3.34
	5/10/22	59,9- 82,3	69.24	65,5 - 89,3	75.96	6.72
	6/10/22	54,8 - 80,6	71.8	64,1- 90,2	77.45	5.65
	7/10/22	60,4 - 84,9	69,84	72,8 - 91,9	82,22	12.38
	11/10/22	62,5 - 83,9	68.44	70,8 - 89,9	88.69	20.25
	12/10/22	60,1 - 82,8	67.56	78,4 - 115,7	95.6	28.04
	14/10/22	63.1 - 86	69.89	78,4 - 115,7	95.6	25.71
P11	3/10/22	62 - 78,5	73.06	75,3 - 110,1	89.49	16.43
	4/10/22	59,2 - 76,8	69.33	73,5 - 124,4	100.64	31.31
	5/10/22	63,8 - 80,5	70.71	68,3 - 101,5	71.29	0.58
	6/10/22	62,9 - 82,6	71.5	76,8 - 94,5	81.76	10.26
	7/10/22	60,3 - 76,9	70,06	73,7 - 100,1	87,81	17.75
	11/10/22	59,9 - 77,7	70.03	69,3 - 95,7	84.61	14.58
	14/10/22	63.9 - 78.9	68.65	77 - 104.5	88.55	19.9
	24/10/22	62.5 - 87	73.32	81.2 - 97	88.05	14.73
	25/10/22	51.2 - 77	67.88	77.6 - 106.9	88.38	20.5
	26/10/22	62.8 - 74.6	68.56	70.1 - 99.9	86.18	17.62
P10	24/10/22	62.3 - 77.8	71.25	83.2 - 93.7	87.09	15.84
	25/10/22	62.7 - 75.2	65.86	75.7 - 99.6	85.65	19.79
	26/10/22	62.5 - 75.6	67.28	76.7 - 99.9	85.1	17.82

Figure 3: Noise Levels at Bored Pile Pier 9, Pier 10, and Pier 11 Locations

(Source: RKL-RPL Construction of Double Line Solo – Semarang Phase I)

Solution of Problem

In solving a problem that occurs in the work environment and community environment, each project has its own way to take action or find an alternative to solve the problem. The alternative used was chosen as the most effective. Of the problems that occur in the bored pile foundation work of the elevated railway construction project between Solo Balapan - Kadipiro at KM 104 + 700 and KM 107 + 000 (phase 1), there are several solutions or actions to deal with these problems. Among them:

Table 3: Solution of Problem Bored Pile Work of Pier 9, Pier 10, Pier 11, and Pier 12

No	Actions Performed
1	For residents who are worried about the noise from bored pile equipment, how to overcome it by asking for permission for drilling work to be carried out at certain hours / working hours
2	By repairing public facilities, we can utilize the remaining ready-mix concrete for road repairs.
3	On damaged asphalt roads, actions are carried out by repaving damaged roads
4	For air pollution due to dust, the action taken is by spraying using water.
5	Increasing the number of workers, increasing work time (held overtime hours), adding tools, and improving work methods.
6	Regulation and improvement of traffic order
7	Replacement of damaged kelly tools with new kelly.

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8	When pouring concrete and tremi pipes will not go down, pouring is assisted by excavators
9	On the part of the casing connection that cannot be removed, it remains embedded
10	In order to achieve the target bored pile casting time, ready mix concrete orders are placed in several batching plant places.

(Source: Results of Independent Observations in the Field)

3.2 Effect on time and cost

From the impacts and problems that occur in the implementation of bored pile work, it is found that bored pile work does not experience delays in its work. Of the several obstacles that occur, the solution that is carried out so that the work is still completed on time is by adding overtime hours, increasing the number of workers, and adding work tools. Regarding the impact on costs, the implementation of bored pile work does not experience cost overruns (it is still said to be safe).

3.3 Bored Pile Foundation Strength

Bored Pile Foundation Strength Planning

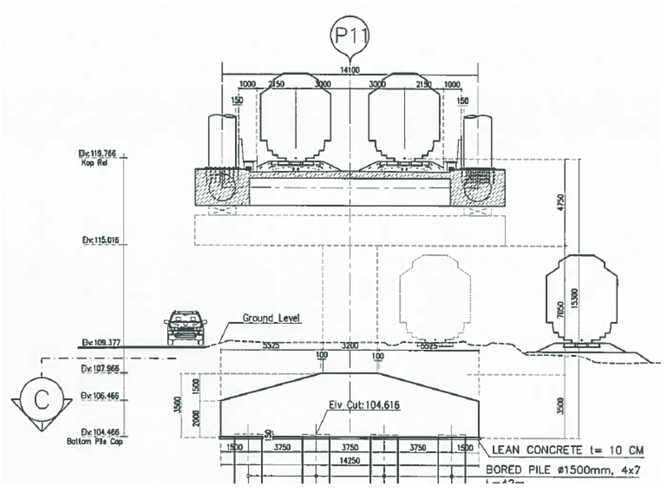

Figure 4: Bored Pile Pier 11 Pieces

(Source: Data Shop Drawing)

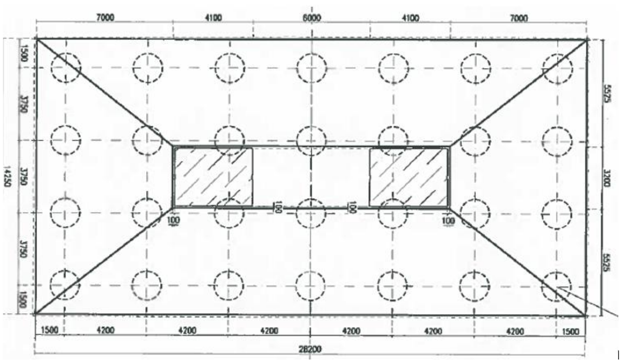

Figure 5: Top View of Bored Pile Pier 11

(Source: Data Shop Drawing)

Technical data of bored pile foundation P11

1. Diameter *bored pile* : 150 cm
2. Foundation depth : 42 m
3. Number of*bored piles* : 28 buah
4. Distance between *bored pile(s)* : 420 cm
5. m : 4 tiang
6. n : 7 tiang

Soil data on this project was obtained from Standard Penetration Test (SPT) testing, presented in the figure:

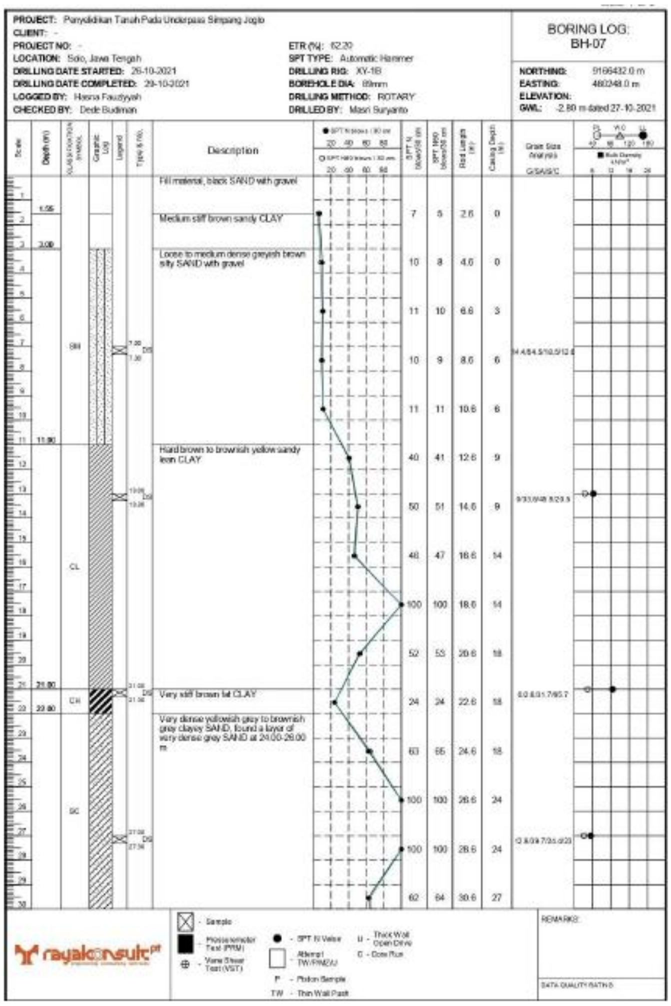

Figure 6: P11 Soil Data

(Source: Soil Test Data)

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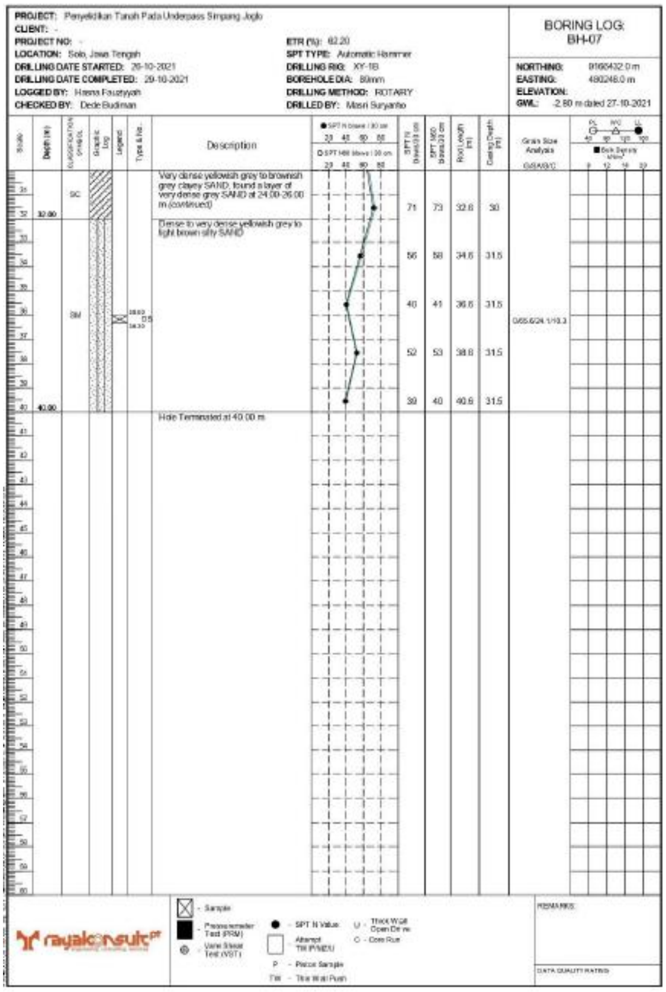

Figure 7: P11 Soil Data (Advanced)

(Source: Soil Test Data)

Table 4: Data N-SPT P11

No	Layer	Depth (m)	Soil Type	N SPT			Consistency
				N2	N3	N	
1	1	0-2	Sand with gravel, black, very loose	8	12	10	Soft
2	2	2-4	Sandy CLAY, brown, medium stiff	7	5	6	Medium
3	3	4-6	SAND with Gravel, grayish brown, Loose	10	8	9	Stiff
4		6-8		11	10	10,5	Stiff
5		8-10		10	9	9,5	Stiff
6		10-12		11	11	11	Stiff
7	4	12-14	Clayey SAND, brownish yellow, very dense	40	41	40,5	Hard
8		14-16		50	51	50,5	Hard
9		16-18		46	47	46,5	Hard
10		18-20		100	100	100	Very hard
11	5	20-22	Clay SAND, brown, medium dense	52	53	52,5	Hard
12	6	22-24	Clayey SAND yellowish grey, very dense	24	24	24	Very stiff
13		24-26		63	65	64	Hard
14		26-28		100	100	100	Very hard
15	7	28-30	Clayey SAND, brown, very dense	100	100	100	Very hard
16		30-32		62	64	63	Hard
17	8	32-34	Silty SAND, Light Brown, Very dense	71	73	72	Hard
18		34-36		56	58	57	Hard
19		36-38		40	41	40,5	Hard
20		38-40		52	53	52,5	Hard
21		40-42		39	40	39,5	Hard

(Source: Soil Test Data)

Strong Capacity to Support Bored Pile from Standard Penetration Test (NSPT) Results

The O'Neil and Reese Method (1989)

Ultimate End Resistance

$fb = 0{,}60\sigma r\ N_{60} \leq 4500 kPa$

$fb = 0{,}60.100.39{,}5$

$fb = 2370\ Kpa \leq 4500 kPa$

so fb value = 2370 Kpa

Because the drill pole is more than 120 cm in diameter, it is recommended that fb be reduced to fbr, by:

$fbr = 4{,}17(dr/db)\ fb$; $when db \geq 1200$ mm

$fbr = 4{,}17(300/1500)\ 2370$

$fbr = 1976{,}58$ Kpa

$Ab = ¼\ \pi\ d^2$

$Ab = ¼\ \pi\ 1{,}5^2$

$Ab = 1{,}767\ m^2$

$Qb = Ab.fb$

$Qb = 1{,}767.1976{,}58$

$Qb = 3492{,}616$ kN

Ultimate friction resistance

Table 5: Ultimate friction resistance count

Depth (m)	As (m2)	Effective overburden preassure ρo' (kN/m2)	ρo' Average (kN/m2)
2	9,424	2 x 18,4 = 36,8	½ (0 + 36,8) = 18,4
4	9,424	36,8 + 2 x 18,4 = 73,6	½ (36,8 + 73,6) = 55,2
6	9,424	73,6 + 2 x 18,4 = 110,4	½ (73,6 + 110,4) = 92
8	9,424	110,4 + 2 x 18,4 = 147,2	½ (110,4 + 147,2) = 128,8
10	9,424	147,2 + 2 x 18,4 = 184	½ (147,2 + 184) = 165,6
12	9,424	184 + 2 x 18,4 = 220,8	½ (184 + 220,8) = 202,4
14	9,424	220,8 + 2 x 18,4 = 257,6	½ (220,8 + 257,6) = 239,2
16	9,424	257,6 + 2 x 18,4 = 294,4	½ (257,6 + 294,4) = 276
18	9,424	294,4 + 2 x 18,4 = 331,2	½ (294,4 + 331,2) = 312,8
20	9,424	331,2 + 2 x 18,4 = 368	½ (331,2 + 368) = 349,6
22	9,424	368 + 2 x 18,4 = 404,8	½ (368 + 404,8) = 386,4
24	9,424	404,8 + 2 x 18,4 = 441,6	½ (404,8 + 441,6) = 423,2
26	9,424	441,6 + 2 x 18,4 = 478,4	½ (441,6 + 478,4) = 460
28	9,424	478,4 + 2 x 18,4 = 515,2	½ (478,4 +515,2) = 496,8
30	9,424	515,2 + 2 x 18,4 = 552	½ (515,2 + 552) = 533,6
32	9,424	552 + 2 x 18,4 = 588,8	½ (552 + 588,8) = 570,4
34	9,424	588,8 + 2 x 18,4 = 625,6	½ (588,8 + 625,6) = 607,2
36	9,424	625,6 + 2 x 18,4 = 662,4	½ (625,6 + 662,4) = 644
38	9,424	662,4 + 2 x 18,4 = 699,2	½ (662,4 + 699,2) = 680,8
40	9,424	699,2 + 2 x 18,4 = 736	½ (699,2 + 736) = 717,6
42	9,424	736 + 2 x 18,4 = 772,8	½ (736 + 772,8) = 754,4

(Source: N-SPT Data Count Analysis Results)

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Table 6: Ultimate friction resistance count (Advanced)

Depth Interval (m)	Z (m)	b	ΔQs = As b ro' Average (kN)
0 - 2	1	0,836	144,963
2 - 4	3	0,430	223,688
4 - 6	5	0,571	495,061
6 - 8	7	0,596	723,431
8 - 10	9	0,484	755,337
10 - 12	11	0,504	961,338
12 - 14	13	0,616	1388,600
14 - 16	15	0,551	1433,164
16 - 18	17	0,489	1441,487
18 - 20	19	0,432	1423,280
20 - 22	21	0,377	1372,820
22 - 24	23	0,325	1296,176
24 - 26	25	0,275	1192,136
26 - 28	27	0,25	1170,46
28 - 30	29	0,25	1257,161
30 - 32	31	0,25	1343,86
32 - 34	33	0,25	1430,56
34 - 36	35	0,25	1517,264
36 - 38	37	0,25	1603,964
38 - 40	39	0,25	1690,665
40 - 42	41	0,25	1777,366
Total			24642,781

(Source: N-SPT Data Count Analysis Results)

Ultimate carrying capacity:

$Qu = Qb + Qs$

$Qu = 3492,616 + 24642,781$

$Qu = 28135,397$ kN

Permit carrying capacity: (f = 2,5)

$Qa = Qu/f$

$Qa = 28135,397/2,5$

$Qa = 11254,158$ kN

Efficiency of bored pile group

$$Eg = 1 - \theta \frac{(n-1)m + (m-1)n}{90mn}$$

$\theta = \arctan (d/s)$

$\theta = \arctan (1,5/4,2)$

$\theta = 19,65382$

$$Eg = 1 - 19,65382 \frac{(7-1)4 + (4-1)7}{90.4.7}$$

$Eg = 0,649$

Bearing capacity of bored pile permit group

$Qg = Eg.m.n.Qu$

$Qg = 0,649 \times 4 \times 7 \times 28135,397$

$Qg = 511276,434$ kN

IV. CONCLUSION

Based on the research that has been done, it can be concluded that. In the implementation of bored pile foundation work, the resulting impact is not so harmful and does not cause a severe impact on the environment. So that in overcoming it, it is still quite safe.

In the impact and problems of bored pile foundation work, there are several actions taken by contractors to overcome these problems. One of them is by holding overtime hours and increasing the number of workers to catch up with time delays so that work is still completed at the planned time. In this problem, it also does not have more impact on the costs incurred. The value results of the bored pile planning calculation are:

Ultimate end resistance/ Qb : 3492,616 kN
Ultimate friction resistance/ Qs : 24642,781 kN
Ultimate carrying capacity/ Qu : 28135,397 kN
Permit carrying capacity/ Qa :11254,158kN
Bored pile group efficiency/ Eg : 0,649
Bearing capacity of *bored pile* permit group: 511276,434 kN

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