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ANALYSIS OF SOIL INVESTIGATION USING CONE PENETRATION TEST (CPT) IN THE CONSTRUCTION BUILDING OF THE MADRASAH ALIYAH NEGERI SURABAYA

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ABSTRACT

In a construction project, soil investigation is crucial. Soil investigation is the initial step in a project activity related to planning substructures or underground structures. This activity is expected to provide information about soil conditions, soil types, groundwater levels, soil structure layers, and soil properties for foundation planning. The problem formulation related to soil investigation in the construction project of the Madrasah Aliyah Negeri building in Surabaya City is to review the characteristics of soil layers, the total friction value based on Cone Penetration Test (CPT), and recommendations for bearing capacity and depth of pile foundations.

The research uses a quantitative method with direct data collection in the field through manometer readings on CPT/sondir at three sample points. The results obtained indicate that the soil characteristics at the research location are layers of Peat/Clay/Silt/Silty Clay/Silty Sand/Sand. The CPT test results at a depth of 8.6 - 9.6 meters have varying total friction values, namely S-01 = 435.60 kg/cm, S-02 = 365.40 kg/cm, S-03 = 372.60 kg/cm. As for the recommendation for pile depth = 9.6 m and the largest pile bearing capacity is found in pile size with Ø 50, with pile allowable compression capacity at each point being S-01 = 114,704 tons; S-02 = 110,897 tons; S-03 = 111,457 tons and pile allowable tension capacity at each point being S-01 = 39,562 tons; S-02 = 35,613 tons; S-03 = 35,805 tons.

Keywords: Soil investigation, sondir, CPT

Introduction

Madrasah Aliyah Negeri (MAN) Surabaya City is currently expanding its area by carrying out the construction of additional classroom buildings. The classroom building in question is a building that will be used to support learning activities with the aim of ensuring that they can be facilitated well and effectively.

Class building construction activities at MAN Surabaya City are divided into 3 (three) work stages which include: pre-construction stage, construction stage and operational stage. In a construction project, soil investigation has a very important role. Soil investigation is the initial stage in the project process related to planning buildings or underground structures. This step aims to provide information regarding soil conditions, soil type, groundwater levels, soil structure layers, and soil properties needed for foundation planning.

In planning a building foundation, a soil investigation is needed to understand the soil parameters that will be used in calculating the soil's bearing capacity. The bearing capacity of the soil greatly influences the shape and dimensions of the foundation so that optimal foundation planning can be achieved. The foundation is part of the lower construction (substructure) which functions to carry the load from the upper construction (superstructure) strongly and safely, as well as supporting the weight of the foundation itself. To meet these needs, a soil investigation was carried out.

Soil investigation is one of the activities in the geotechnical field which aims to obtain the properties and characteristics of soil for engineering design purposes. According to SNI 8460-2017, there are two types of soil investigations, namely field in situ tests and laboratory tests.

Cone Penetration Test (CPT), or more commonly referred to as sondir, is a soil investigation method in the field that is useful for estimating the location of hard soil layers. This test produces a value of cone penetration resistance, which is the resistance of the soil to the tip of the cone and is expressed in force per unit area. Apart from that, this test also measures adhesive resistance, namely the shear resistance of the soil against the biconus sheath in a force per unit length. The cone penetration resistance (qc) value obtained from the test can be directly correlated with the soil bearing capacity. The purpose of this test is to determine the bearing capacity of the soil and the type of foundation that is most suitable for the building to be erected at that location.

Research Methods

This type of research is field research or in situ test. Field research is a type of research that studies phenomena in their natural environment. Primary data is data obtained directly from the field, so that the information obtained

truly reflects the reality of the phenomena that occur at the research location. Therefore, researchers used field research methods to collect detailed and detailed data. In this way, researchers can observe the smallest phenomena that become a reference for problems to the largest phenomena, and try to find solutions to these problems.

This research uses quantitative data, namely data that can be expressed in numbers and can be measured. Quantitative data allows precise statistical analysis to understand and interpret the phenomenon under study. Apart from that, this research also uses primary data and secondary data. Primary data was obtained through direct test sampling in the field, while secondary data was collected from various relevant literature.

The samples in this research were soil samples which were taken directly using a cone penetration test (CPT). Sampling was carried out at 3 (three) points, namely point S-01, point S-02 and point S-03.

Table 1. Test Point Coordinates

No	Point	Coordinates
1	S-01	7°18'32.242"S,112°47'54.396"E
2	S-02	7°18'31.757"S,112°47'54.081"E
3	S-03	7°18'31.875"S,112°47'53.814"E

From investigating soil samples at these three points, researchers can then analyze the soil characteristics, bearing capacity and selecting the right type of foundation. The sampling locations can be seen in the following image:

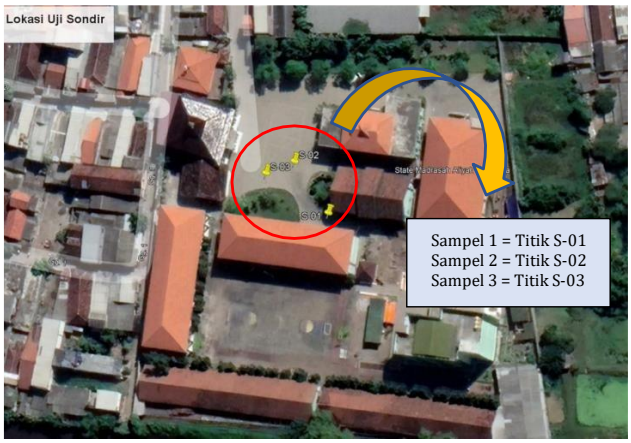

Figure 1. Sampling Location

The data collection techniques and methods used in this research were sondir data collection, which was carried out directly by reading a manometer in the field. Manometer readings are taken every 20 cm drop and stopped at the desired maximum depth or until the maximum reading limit is 150 kg/cm^2 or qc > 150 kg/cm^2.

Data analysis was carried out to determine the soil coefficient value at the research location, so the following steps were carried out:

1. Carry out soil inspection tests at predetermined points using a sondir tool in order to obtain data/values of cone resistance (Cw) and cone resistance and shear values (Tw) resulting from manometer readings on the tool.
2. Each point that has obtained the cone resistance value (Cw) and the cone and shear resistance values (Tw) is then analyzed.
3. The method used to analyze the sondir data uses 2 methods, namely graphics and analysis.

Results and Discussion

From the results of CPT testing on the MAN project, located in Surabaya, East Java. It is known that the layer reaches a depth of 8.6 – 9.6 meters. The test results can be seen as in the following table:

Table 2. Cone Penetration Test (S-01)

Depth (m)	Cw (kg/cm^2)	Tw (kg/cm^2)	Kw (Tw - Cw)	qc (kg/cm^2)	LF (kg/cm^2)	LF x 20 cm (kg/cm)	JHP (kg/cm)	Fr (%)
0.00	0	0	0	0.00	0.00	0.00	0.00	0.00
0.20	0	0	0	0.00	0.00	0.00	0.00	0.00
0.40	0	0	0	0.00	0.00	0.00	0.00	0.00
0.60	0	0	0	0.00	0.00	0.00	0.00	0.00
0.80	0	0	0	0.00	0.00	0.00	0.00	0.00
1.00	4	8	4	4.00	0.36	7.20	7.20	9.00
1.20	6	10	4	6.00	0.36	7.20	14.40	6.00
1.40	5	9	4	5.00	0.36	7.20	21.60	7.20
1.60	4	7	3	4.00	0.27	5.40	27.00	6.75
1.80	4	6	2	4.00	0.18	3.60	30.60	4.50
2.00	3	5	2	3.00	0.18	3.60	34.20	6.00
2.20	3	6	3	3.00	0.27	5.40	39.60	9.00
2.40	2	5	3	2.00	0.27	5.40	45.00	13.50
2.60	4	7	3	4.00	0.27	5.40	50.40	6.75
2.80	3	6	3	3.00	0.27	5.40	55.80	9.00
3.00	4	7	3	4.00	0.27	5.40	61.20	6.75
3.20	3	6	3	3.00	0.27	5.40	66.60	9.00
3.40	2	5	3	2.00	0.27	5.40	72.00	13.50

3.60	4	8	4	4.00	0.36	7.20	79.20	9.00
3.80	3	6	3	3.00	0.27	5.40	84.60	9.00
4.00	4	8	4	4.00	0.36	7.20	91.80	9.00
4.20	3	7	4	3.00	0.36	7.20	99.00	12.00
4.40	3	6	3	3.00	0.27	5.40	104.40	9.00
4.60	4	8	4	4.00	0.36	7.20	111.60	9.00
4.80	3	7	4	3.00	0.36	7.20	118.80	12.00
5.00	9	12	3	9.00	0.27	5.40	124.20	3.00
5.20	7	11	4	7.00	0.36	7.20	131.40	5.14
5.40	6	10	4	6.00	0.36	7.20	138.60	6.00
5.60	5	9	4	5.00	0.36	7.20	145.80	7.20
5.80	6	10	4	6.00	0.36	7.20	153.00	6.00
6.00	4	8	4	4.00	0.36	7.20	160.20	9.00
6.20	3	7	4	3.00	0.36	7.20	167.40	12.00
6.40	4	8	4	4.00	0.36	7.20	174.60	9.00
6.60	5	9	4	5.00	0.36	7.20	181.80	7.20
6.80	6	11	5	6.00	0.45	9.00	190.80	7.50
7.00	18	21	3	18.00	0.27	5.40	196.20	1.50
7.20	21	25	4	21.00	0.36	7.20	203.40	1.71
7.40	20	24	4	20.00	0.36	7.20	210.60	1.80
7.60	21	26	5	21.00	0.45	9.00	219.60	2.14
7.80	27	32	5	27.00	0.45	9.00	228.60	1.67
8.00	23	28	5	23.00	0.45	9.00	237.60	1.96
8.20	26	30	4	26.00	0.36	7.20	244.80	1.38
8.40	24	29	5	24.00	0.45	9.00	253.80	1.88
8.60	27	31	4	27.00	0.36	7.20	261.00	1.33
8.80	31	42	11	31.00	0.99	19.80	280.80	3.19
9.00	72	93	21	72.00	1.89	37.80	318.60	2.63
9.20	130	155	25	130.00	2.25	45.00	363.60	1.73
9.40	165	180	15	165.00	1.35	27.00	390.60	0.82
9.60	250	275	25	250.00	2.25	45.00	435.60	0.90

Table 3. Cone Penetration Test (S-02)

Depth (m)	Cw (kg/cm^2)	Tw (kg/cm^2)	Kw (Tw - Cw)	qc (kg/cm^2)	LF (kg/cm^2)	LF x 20 cm (kg/cm)	JHP (kg/cm)	Fr (%)
0.00	0	0	0	0.00	0.00	0.00	0.00	0.00
0.20	0	0	0	0.00	0.00	0.00	0.00	0.00
0.40	0	0	0	0.00	0.00	0.00	0.00	0.00
0.60	0	0	0	0.00	0.00	0.00	0.00	0.00
0.80	0	0	0	0.00	0.00	0.00	0.00	0.00
1.00	3	5	2	3.00	0.18	3.60	3.60	6.00
1.20	4	6	2	4.00	0.18	3.60	7.20	4.50
1.40	3	5	2	3.00	0.18	3.60	10.80	6.00
1.60	3	5	2	3.00	0.18	3.60	14.40	6.00
1.80	4	7	3	4.00	0.27	5.40	19.80	6.75
2.00	2	5	3	2.00	0.27	5.40	25.20	13.50
2.20	4	7	3	4.00	0.27	5.40	30.60	6.75
2.40	3	6	3	3.00	0.27	5.40	36.00	9.00
2.60	2	5	3	2.00	0.27	5.40	41.40	13.50

2.80	3	6	3	3.00	0.27	5.40	46.80	9.00
3.00	2	5	3	2.00	0.27	5.40	52.20	13.50
3.20	3	6	3	3.00	0.27	5.40	57.60	9.00
3.40	2	5	3	2.00	0.27	5.40	63.00	13.50
3.60	2	5	3	2.00	0.27	5.40	68.40	13.50
3.80	3	6	3	3.00	0.27	5.40	73.80	9.00
4.00	5	9	4	5.00	0.36	7.20	81.00	7.20
4.20	5	7	2	5.00	0.18	3.60	84.60	3.60
4.40	4	7	3	4.00	0.27	5.40	90.00	6.75
4.60	2	6	4	2.00	0.36	7.20	97.20	18.00
4.80	4	7	3	4.00	0.27	5.40	102.60	6.75
5.00	9	13	4	9.00	0.36	7.20	109.80	4.00
5.20	7	11	4	7.00	0.36	7.20	117.00	5.14
5.40	5	9	4	5.00	0.36	7.20	124.20	7.20
5.60	4	7	3	4.00	0.27	5.40	129.60	6.75
5.80	3	6	3	3.00	0.27	5.40	135.00	9.00
6.00	6	9	3	6.00	0.27	5.40	140.40	4.50
6.20	4	7	3	4.00	0.27	5.40	145.80	6.75
6.40	3	8	5	3.00	0.45	9.00	154.80	15.00
6.60	5	9	4	5.00	0.36	7.20	162.00	7.20
6.80	4	9	5	4.00	0.45	9.00	171.00	11.25
7.00	3	8	5	3.00	0.45	9.00	180.00	15.00
7.20	3	7	4	3.00	0.36	7.20	187.20	12.00
7.40	4	8	4	4.00	0.36	7.20	194.40	9.00
7.60	18	21	3	18.00	0.27	5.40	199.80	1.50
7.80	21	25	4	21.00	0.36	7.20	207.00	1.71
8.00	87	110	23	87.00	2.07	41.40	248.40	2.38
8.20	145	165	20	145.00	1.80	36.00	284.40	1.24
8.40	170	190	20	170.00	1.80	36.00	320.40	1.06
8.60	250	275	25	250.00	2.25	45.00	365.40	0.90

Table 4. Cone Penetration Test (S-03)

Depth (m)	Cw (kg/cm^2)	Tw (kg/cm^2)	Kw (Tw - Cw)	qc (kg/cm^2)	LF (kg/cm^2)	LF x 20 cm (kg/cm)	JHP (kg/cm)	Fr (%)
0.00	0	0	0	0.00	0.00	0.00	0.00	0.00
0.20	0	0	0	0.00	0.00	0.00	0.00	0.00
0.40	0	0	0	0.00	0.00	0.00	0.00	0.00
0.60	0	0	0	0.00	0.00	0.00	0.00	0.00
0.80	0	0	0	0.00	0.00	0.00	0.00	0.00
1.00	3	6	3	3.00	0.27	5.40	5.40	9.00
1.20	4	8	4	4.00	0.36	7.20	12.60	9.00
1.40	3	7	4	3.00	0.36	7.20	19.80	12.00
1.60	2	5	3	2.00	0.27	5.40	25.20	13.50
1.80	3	6	3	3.00	0.27	5.40	30.60	9.00
2.00	3	6	3	3.00	0.27	5.40	36.00	9.00
2.20	4	7	3	4.00	0.27	5.40	41.40	6.75
2.40	4	7	3	4.00	0.27	5.40	46.80	6.75

2.60	2	5	3	2.00	0.27	5.40	52.20	13.50
2.80	3	6	3	3.00	0.27	5.40	57.60	9.00
3.00	3	7	4	3.00	0.36	7.20	64.80	12.00
3.20	2	5	3	2.00	0.27	5.40	70.20	13.50
3.40	3	6	3	3.00	0.27	5.40	75.60	9.00
3.60	4	5	1	4.00	0.09	1.80	77.40	2.25
3.80	2	7	5	2.00	0.45	9.00	86.40	22.50
4.00	4	9	5	4.00	0.45	9.00	95.40	11.25
4.20	5	10	5	5.00	0.45	9.00	104.40	9.00
4.40	3	8	5	3.00	0.45	9.00	113.40	15.00
4.60	12	16	4	12.00	0.36	7.20	120.60	3.00
4.80	10	14	4	10.00	0.36	7.20	127.80	3.60
5.00	8	12	4	8.00	0.36	7.20	135.00	4.50
5.20	6	10	4	6.00	0.36	7.20	142.20	6.00
5.40	4	8	4	4.00	0.36	7.20	149.40	9.00
5.60	5	9	4	5.00	0.36	7.20	156.60	7.20
5.80	2	3	1	2.00	0.09	1.80	158.40	4.50
6.00	3	6	3	3.00	0.27	5.40	163.80	9.00
6.20	4	8	4	4.00	0.36	7.20	171.00	9.00
6.40	5	9	4	5.00	0.36	7.20	178.20	7.20
6.60	3	7	4	3.00	0.36	7.20	185.40	12.00
6.80	4	8	4	4.00	0.36	7.20	192.60	9.00
7.00	5	9	4	5.00	0.36	7.20	199.80	7.20
7.20	4	8	4	4.00	0.36	7.20	207.00	9.00
7.40	5	10	5	5.00	0.45	9.00	216.00	9.00
7.60	22	27	5	22.00	0.45	9.00	225.00	2.05
7.80	23	28	5	23.00	0.45	9.00	234.00	1.96
8.00	85	100	15	85.00	1.35	27.00	261.00	1.59
8.20	153	170	17	153.00	1.53	30.60	291.60	1.00
8.40	165	185	20	165.00	1.80	36.00	327.60	1.09
8.60	250	275	25	250.00	2.25	45.00	372.60	0.90

From the cone penetration test produced by the CPT sondir tool, the cone resistance value kg/cm² (CW) and the cone resistance and shear values kg/cm² (TW) were obtained from the tool's manometer readings. The value (KW) is the difference between the values (TW) and (CW).

KW = TW - CW

$$\text{Cone resistance value (qc)} = \frac{\text{CW x Api}}{\text{AC}}$$

Api = Piston cross-sectional area 20 cm²
AC = Piston cross-sectional area 10 cm²

$$\text{Local shear resistance value (LF)} = \frac{(\text{TW}-\text{CW})\text{x Api}}{\text{AS}}$$

As = Sliding blanket area 150 cm²

$$\text{Total shift value (JHP)} = \frac{\text{cumulative LF x 20}}{\text{Addition LF x 20 per depth}}$$

Sliding appeal number value % (Fr) = LF x 100

The results of the calculation of the values above can be seen in full in the following table:

Table 5. Interpretation of Soil Types/Characteristics

Point	Depth	Qc (kg/cm^2)	Fr (%)	Type of soil
S-01	0,2 – 0,8	0	0	Embankment
	0,8 – 7,0	2 -18	1,5 – 13,5	Silt/Silty Clay/Clay/Peat
	7,0 – 9,6	20 - 250	0,82 – 2,63	Silty Sand/Sand
S-02	0,2 – 0,8	0	0	Embankment
	0,8 – 7,6	2 -18	1,5 – 18,0	Silt/Silty Clay/Clay/Peat
	7,6 – 8,6	21 - 250	0,90 – 2,38	Silty Sand/Sand
S-03	0,2 – 0,8	0	0	Embankment
	0,8 – 7,4	2 -12	3,0 – 13,5	Silt/Silty Clay/Clay/Peat
	7,4 – 8,6	22 - 250	0,90 – 2,05	Silty Sand/Sand

For graphs of QC and Fr values against depth, you can see the following graphs:

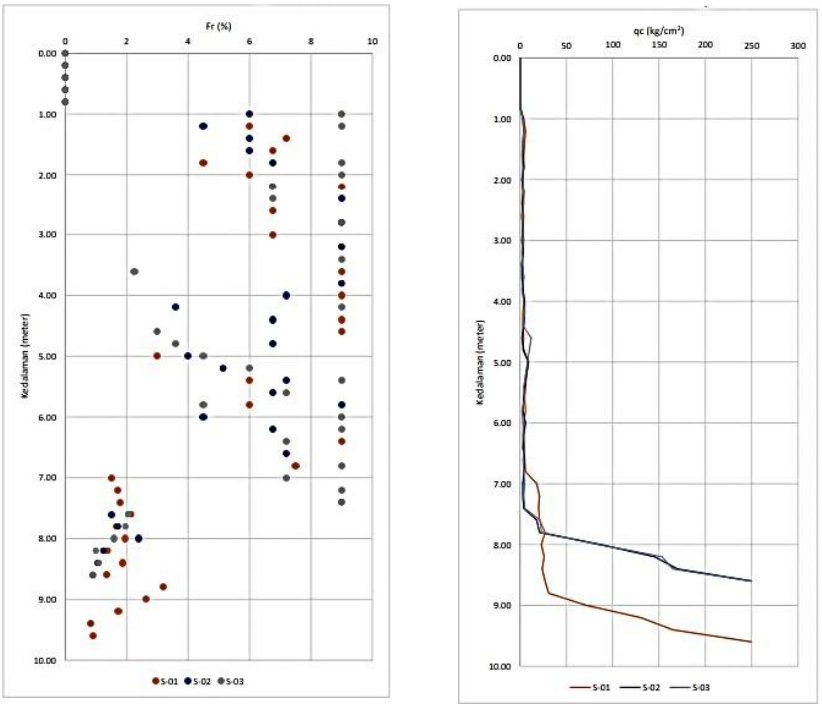

Figure 2. Graph of Qc against Depth and Graph of Friction Ratio (Fr) against Depth

Looking at the physical properties of the soil and the engineering properties of the soil, at points S-01, S-02, and S-03, at a depth of 0.2 – 0.8, the soil type is Embankment. At a depth of 0.8 – 7.0 is the Silt/ Silty Clay/ Clay/ Peat soil type. And at a depth of 7.0 – 9.6 meters the soil type is estimated to be Silty Sand.

In general, the soil conditions in the project area, which is located in Surabaya, East Java, are estimated. Consists of Peat/ Clay/ Silt/ Silty Clay/ Silty Sand/ Sand layer types.

The calculation of the bearing capacity of piles uses CPT/Sondir data using the Schmertmann and Notingham methods, as with other calculations in this calculation the bearing capacity consists of the bearing capacity of the pile tip and pile cover. Determination of the depth of the foundation is based on the results of the test depth. At a depth of between 8.6 – 9.6 meters the layer is hard/very stiff layer with a qc value ≥ 250.00 Kg/cm^2. This layer can be used as a bearing layer. The table below describes the bearing capacity of compression and tension piles to a depth of 8.6 – 9.6 meters.

To calculate the ultimate compression on bearing capacity (QU) or the static bearing capacity of the pile, it is calculated using soil mechanics theory.

$Qu = Qp + Qs$

Qu = Net ultimate carrying capacity
Qp = Ultimate bottom end resistance
Qs = Ultimate friction resistance

For example, for pile size ф 30, find Qs = 30,310 tons and Qp = 110,992 tons.

Qu = 30.310 + 110.922
Qu = 141.232 ton

According to Tomlinson, the permit carrying capacity is obtained from the ultimate carrying capacity divided by the safety factor. The following is the equation for permit carrying capacity.

$Qa = Qu / SF$

SF = 3,0

Qa = 141.232 / 3,0

Qa = 47.077 ton

Further data can be seen in the following tables:

Table 6. Recommendations for the bearing capacity of a single pile in compression and tension based on S-01

Pile Size	Pile Length	Pile Allowable Compression Capacity				Pile Allowable Tension Capacity		
		Ultimate Friction Resistence	Ultimate Base Resistence	Ultimate Compression Bearing Capacity	Allowable Compression Bearing Capacity	Ultimate Friction Resistence	Pile Effective Weight	Allowable Tension Bearing Capacity
(cm)	(m)	Qs (ton)	Qp (ton)	Qu (ton)	Qa (ton)	Qs (ton)	Wp (ton)	Qa (ton)
□ 30 x 30	9.6	39.651	141.231	180.882	60.294	31.721	12.096	21.159
□ 40 x 40	9.6	52.768	240.612	293.380	97.793	42.215	21.504	33.565
ϕ 30	9.6	30.310	110.922	141.232	47.077	24.248	9.500	16.428
ϕ 35	9.6	35.672	147.652	183.324	61.108	28.537	12.931	21.084
ϕ 40	9.6	41.444	188.976	230.420	76.807	33.155	16.889	26.362
ϕ 50	9.6	57.629	286.483	344.113	114.704	46.104	26.389	39.562

Table 7. Recommendations for the bearing capacity of a single pile in compression and tension based on S-02

Pile Size	Pile Length	Pile Allowable Compression Capacity				Pile Allowable Tension Capacity		
		Ultimate Friction Resistence	Ultimate Base Resistence	Ultimate Compression Bearing Capacity	Allowable Compression Bearing Capacity	Ultimate Friction Resistence	Pile Effective Weight	Allowable Tension Bearing Capacity
(cm)	(m)	Qs (ton)	Qp (ton)	Qu (ton)	Qa (ton)	Qs (ton)	Wp (ton)	Qa (ton)
□ 30 x 30	8.6	37.120	137.215	174.335	58.112	29.696	10.836	19.320
□ 40 x 40	8.6	47.570	234.259	281.829	93.943	38.056	19.264	30.137
ϕ 30	8.6	28.321	107.769	136.090	45.363	22.657	8.511	14.984
ϕ 35	8.6	33.361	143.387	176.748	58.916	26.689	11.584	19.209
ϕ 40	8.6	37.362	183.986	221.348	73.783	29.889	15.130	23.670
ϕ 50	8.6	52.378	280.312	332.690	110.897	41.902	23.640	35.613

Pile Size	Pile Length	Pile Allowable Compression Capacity				Pile Allowable Tension Capacity		
		Ultimate Friction Resistence	Ultimate Base Resistence	Ultimate Compression Bearing Capacity	Allowable Compression Bearing Capacity	Ultimate Friction Resistence	Pile Effective Weight	Allowable Tension Bearing Capacity
(cm)	(m)	Qs (ton)	Qp (ton)	Qu (ton)	Qa (ton)	Qs (ton)	Wp (ton)	Qa (ton)
□ 30 x 30	8.6	38.352	137.596	175.948	58.649	30.681	10.836	19.602
□ 40 x 40	8.6	50.695	234.635	285.330	95.110	40.556	19.264	30.851
ϕ 30	8.6	29.253	108.068	137.321	45.774	23.403	8.511	15.197
ϕ 35	8.6	34.641	143.676	178.317	59.439	27.713	11.584	19.502
ϕ 40	8.6	39.815	184.282	224.098	74.699	31.852	15.130	24.231
ϕ 50	8.6	53.218	281.154	334.372	111.457	42.574	23.640	35.805

Table 8. Recommendations for the bearing capacity of a single pile in compression and tension based on S-03

Conclusion

1. The general characteristics of the estimated soil conditions in the project area, which is located in Surabaya, East Java, consist of Peat/Clay/Silt/Silty Clay/Silty Sand/Sand layers.

2. CPT test results at a depth of 8.6 – 9.6 meters QC values vary

CPT	Depth (meter)	Cone Resistance (kg/cm^2)	Total Friction (kg/cm)
S-01	9,60	250	435,60
S-02	8,60	250	365,40
S-03	8.60	250	372,60

3. It is recommended that the structure be supported by a foundation that can refer to the results of sondir, until it reaches the hard soil layer/bearing layer. Recommendations for pile depth and recommendations for single pile bearing capacity relative to depth can be seen in the following table:

Pile Size	Pile Length	Pile Allowable Compression Capacity			Pile Allowable Tension Capacity		
		AllowableCompression Bearing Capacity			Allowable Tension Bearing Capacity		
(cm)	(m)	Qa (ton) S-01	Qa (ton) S-02	Qa (ton) S-03	Qa (ton) S-01	Qa (ton) S-02	Qa (ton) S-03
□ 30 x30	9.6	60.294	58.112	58.649	21.159	19.320	19.602
□ 40 x40	9.6	97.793	93.943	95.110	33.565	30.137	30.851
ϕ 30	9.6	47.077	45.363	45.774	16.428	14.984	15.197
ϕ 35	9.6	61.108	58.916	59.439	21.084	19.209	19.502
ϕ 40	9.6	76.807	73.783	74.699	26.362	23.670	24.231
ϕ 50	9.6	114.704	110.897	111.457	39.562	35.613	35.805

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