Geological Engineering Characteristics of the Residual Soil: Implementation for Soil Bearing Capacity at Gayungan, Surabaya, East Java

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Abstract. This paper presents the results of soil investigation on the residual soil at Gayungan Surabaya. The methodology of the research consists of Drilling + Standard Penetration Test (ASTM D1586-99), sampling and laboratory test for index properties & mechanical of soil, then analyzed for Soil Bearing Capacity (Meyerhoff, 1976). Field test analysis data showed that Bore Hole.01 (BH.01) and Bore Hole.03 (BH.03) were dominated by Sand / Sandy clay layer with Standard Penetration Test (SPT) values: 6-68, whereas in BH.02 was dominated by Clayey sand layer with Standard Penetration Test (SPT) values: 32-68. Based on Soil classification according to Unified Soil Classification System (USCS), the soil type at the research area consisted of ML (Silt with Low plasticity), CL (Clay with low plasticity), MH (Silt with High plasticity), and SP (Sand with Poor gradation). Based on the borlog data and soil bearing capacity analysis of the research area is recommended: for The Deep foundation to reaches at least 16 meters depth with $Q_a = 1160.40 - 2032.80$ kN / m², and Shallow foundation reaches at least 1-2 meters deep with $Q_a = 718.25$ kN / M².

1. Introduction
Research area is one of the busy towns in Indonesia. Therefore Bearing capacity of a soil is very important for pra construction when the building was erected. The Analysis of soil bearing capacity can be from field testing (SPT, CPT, DCP) and soil sample data test in laboratory [1].

Standard Penetration Test (SPT) is one of the geotechnical investigations performed to coincide with geotechnical drilling process to obtain a standard penetration value (N). Through the relationship between the N value with the relative density of the soil, we can know where are hard layers of soil are [2].

Surabaya is one of the fastest growing cities in Indonesia, where many construction projects exist in this area. The availability of soil bearing capacity data as a specific geotechnical support data in Surabaya is very important as one of the references in the process of preconstruction. Therefore this research can illustrate how the profile of hard soil layer in Surabaya by using the data of geotechnical drilling+SPT.

2. Standard Penetration Test (SPT)
This test is performed coincide with a geotechnical drilling process. This method describes the standard penetration test using the split-barrel sampler to obtain the resistance of the soil to penetration
The blow counts of hammer in penetrating the split barrel into soil are recorded. The first 150 mm penetration is regarded as seating drive and the number of blows to achieve this penetration is not included in the SPT N-value. The cumulative numbers of blow counts required for the last 300 mm penetration is recorded as the N-value. The recorded soil sample from the split barrel are then kept in a plastic jar for soil identification in office.

The recording of blow counts depends on the standard or code of practice. In British Standard (BS 1377), the blow counts are recorded for every 75 mm penetration. In ASTM Standard (ASTM D1586-99), the blow counts are recorded for every 150 mm penetration some Japanese practices, the blow counts are taken at the first 150 mm seating drive and then at every 100 mm penetration for the remaining 300 mm drive.

The method is applicable to all soil types. It is most often used in granular materials but also in other materials when simple in-place bearing strengths are required. It is also used when samples cannot easily be recovered by other means. The purpose of performing Standard Penetration Test (SPT) is to determine relative density or consistency of subsoil. The soil sample obtained from the test may be used for soil identification and laboratory index property tests. On Foundation planning, N value of the SPT results is used as an indication of the collapse model [4].

3. Bearing capacity of deep foundation (Meyerhof, 1976)

The calculation of soil bearing capacity in this research refers to equation:

3.1. Single pile ultimate compression bearing capacity (compression)

\[ Q_{ult} (kN) = m \cdot N_a \cdot A_s + n \cdot N_b \cdot A_p \] (1)

\#m = 2 (for sand), 5 (for clay), 1 (for bored pile).
\#n = 400 (for sand), 300 (for clay), 100 (for bored pile)

\[ Q_s = m \cdot N_a \cdot A_s \] (2)

\[ Q_b = n \cdot N_b \cdot A_p \] (3)

\[ Q_{ult} (kN) = Q_s + Q_b \] (4)

\[ Q_{ult} (kN) = m \cdot N_a \cdot A_s + n \cdot N_b \cdot A_p \] (5)

3.2. Allowable bearing capacity

\[ Q_{ult} (kN) = m \cdot N_a \cdot A_s / (F_s) + n \cdot N_b \cdot A_p / (F_b) \] (5)

\#Skin, \( F_s = 2.5 \)

\#Base, \( F_b = 2.5 \)

3.3. Single pile ultimate compression bearing capacity (tension)

\[ Q_{st} = 0.8 \cdot Q_s \] (6)

\[ \text{All Tension, } Q_{all} = Q_{st} / F_s + W_p \] (7)

4. Methods

4.1. Field test

This Research uses primary data, taken directly from the area of research. Field test consists of three point drilling (BH.01, BH.02, and BH.3). SPT data is taken together with soil sampling for basic properties and mechanical test in the laboratory.
4.2. Analysis data

Based on field data (N value), an analysis and calculation of soil bearing capacity are performed. Some N values are stable and are considered to be hard layers in numbers >30 with depths that are considered to be quite representative.

Calculation of soil bearing capacity refers to Meyerhoff, 1979 with Safety Factor (SF) used is 2.5. The uplift or tension capacity of the pile was obtained from the skin friction resistance estimated in the same manner as the compressive load capacity. A safety factor 3.0 was applied in estimating the allowable axial uplift load and the self-weight of the pile was not included to increase the safety margin. The bearing capacity of soil being recommended includes of deep and shallow foundations.

5. Results and discussion

Distribution of three test points can be seen in (Figure 1). Based on the drilling and Nspt values obtained, the prediction of soil layer as shown in (Figure 2 and Figure 3). BH.01 and BH.03 it is dominated by Sandy soil, and Sandy clay with Nspt value: 6-68, while in Bh.02 it is dominated by Sandy clay with Nspt: 32-68.

![Figure 1. Research area](image-url)
Generally, the soil type in the research area refers to USCS classification as ML (Silt with Low plasticity), CL (Clay with low plasticity), and SP (Sand with Poor gradation).

5.1. Deep foundation

5.1.1. BH.01. Determining of deep foundations at this point based on dense / very dense layer obtained at 16.00 - 18.00 meter with Nspt value: 33 - 38. This layer can be used as end bearing layer if a load of
structures or buildings not over than recommended bearing capacity, it can be seen in (Table 1 and Figure 4).

Table 1. The Result of Deep Foundation analysis based on data: BH.01

| Pile Size | Effective Pile Lenght | Ultimate Friction Resistance (Qs) | Ultimate Base Resistance (Qb) | Ultimate Compression Capacity | Allowable Compression Bearing Capacity | Ultimate Tension Capacity | Allowable Tension Bearing Capacity | Estimate Settlement |
|-----------|------------------------|-------------------------------|-------------------------------|-------------------------------|----------------------------------------|-----------------------------|----------------------------------|-------------------|
| 30 x 30   | 16                     | 2010.00                       | 891.00                        | 2901.00                       | 1160.40                               | 1608.00                     | 340.50                          | 22.99             |
| 18         | 2443.50                | 1026.00                       | 3469.50                       | 1387.80                       | 1945.80                               | 412.38                      | 399.58                          | 25.82             |
| 35 x 35   | 16                     | 2336.60                       | 1212.75                       | 3549.35                       | 1419.74                               | 1869.28                     | 483.93                          | 28.53             |
| 30 x 30   | 18                     | 2842.35                       | 1396.50                       | 4238.85                       | 1695.54                               | 2273.88                     | 462.40                          | 28.36             |
| 35 x 35   | 16                     | 2680.00                       | 1584.00                       | 4264.00                       | 1705.60                               | 2144.00                     | 462.40                          | 28.36             |
| Ø30       | 16                     | 3549.35                       | 1824.00                       | 5082.00                       | 2032.80                               | 2606.40                     | 559.36                          | 31.37             |
| Ø35       | 16                     | 1576.47                       | 816.42                        | 2101.73                       | 865.90                                | 1261.18                     | 377.16                          | 1981              |
| Ø40       | 16                     | 1499.52                       | 1111.24                       | 2610.76                       | 1174.41                               | 1471.37                     | 443.29                          | 22.18             |
| Ø30       | 18                     | 1839.22                       | 1096.81                       | 2936.02                       | 1266.06                               | 1370.99                     | 481.10                          | 25.59             |
| Ø35       | 18                     | 1713.74                       | 1451.42                       | 3165.15                       | 1413.81                               | 1681.57                     | 510.36                          | 24.59             |

Figure 4. Deep Foundation allowable capacity (kN): BH.01

5.1.2. BH.02. Determining of deep foundations at this point based on dense / very dense layer obtained at 16.00 - 18.00 meter with Nspt value: 36. This layer can be used as end bearing layer if the load of structures or buildings not over than recommended bearing capacity, it can be seen in (Table 2 and Figure 5).
Table 2. The Result of Deep Foundation analysis based on data: BH.02

| Pile Size (cm) | Effective Pile Length (m) | Ultimate Friction Resistance (kN) | Ultimate Base Resistance (kN) | Ultimate Compression Bearing Capacity (kN) | Allowable Compression Bearing Capacity (kN) | Ultimate Friction Resistance (kN) | Allowable Tension Bearing Capacity (kN) | Estimate Settlement (mm) |
|---------------|---------------------------|----------------------------------|-------------------------------|-------------------------------------------|------------------------------------------|-----------------------------------|----------------------------------------|--------------------------|
| 30 x 30       | 16                        | 2110.50                          | 1134.00                       | 3244.50                                   | 1297.80                                  | 1688.40                          | 356.58                                 | 26.57                    |
|               | 18                        | 2412.90                          | 1134.00                       | 3546.90                                   | 1418.76                                  | 1930.32                          | 407.48                                 | 26.80                    |
| 35 x 35       | 16                        | 2462.25                          | 1543.50                       | 4005.75                                   | 1602.30                                  | 1969.80                          | 419.69                                 | 29.70                    |
|               | 18                        | 2815.05                          | 1543.50                       | 4358.55                                   | 1743.42                                  | 2252.04                          | 479.56                                 | 29.67                    |
| 40 x 40       | 16                        | 2814.00                          | 2016.00                       | 4830.00                                   | 1932.00                                  | 2251.20                          | 483.84                                 | 32.92                    |
|               | 18                        | 3217.20                          | 2016.00                       | 5233.20                                   | 2093.28                                  | 2573.76                          | 552.83                                 | 32.66                    |
| Ø30           | 16                        | 1657.58                          | 890.64                        | 2548.22                                   | 865.90                                   | 1326.07                          | 393.72                                 | 21.16                    |
|               | 18                        | 1895.09                          | 890.64                        | 2785.73                                   | 865.90                                   | 1516.07                          | 449.99                                 | 21.17                    |
| Ø35           | 16                        | 1933.85                          | 1212.26                       | 3146.11                                   | 1178.59                                  | 1547.08                          | 462.23                                 | 23.81                    |
|               | 18                        | 2210.94                          | 1212.26                       | 3423.20                                   | 1178.59                                  | 1768.75                          | 528.25                                 | 23.66                    |
| Ø40           | 16                        | 2210.11                          | 1583.36                       | 3793.47                                   | 1517.39                                  | 1768.09                          | 531.56                                 | 26.50                    |
|               | 18                        | 2526.78                          | 1583.36                       | 4110.15                                   | 1539.38                                  | 2021.43                          | 607.46                                 | 26.19                    |

Figure 5. Deep Foundation allowable capacity (kN): BH.02

5.1.3. BH.03. Determining of deep foundations at this point based on dense / very dense layer obtained at 12.00 - 14.00 meter with Nspt value: 41-42. This layer can be used as end bearing layer if the load of structures or buildings not over than recommended bearing capacity, it can be seen in (Table 3 and Figure 6).
### Table 3. The Result of Deep Foundation analysis based on data: BH.03

| Pile Size | Effective Pile Length (cm) | Effective Pile Length (m) | Pile Compression Capacity | Pile Tension Capacity | Estimate Settlement (mm) |
|-----------|----------------------------|---------------------------|--------------------------|-----------------------|--------------------------|
|           |                            |                           | Ultimate Friction Resistance (Qs) (kN) | Ultimate Base Resistance (Qb) (kN) | Ultimate Compression Bearing Capacity (kN) | Allowable Compression Bearing Capacity (kN) | Ultimate Friction Resistance (kN) | Allowable Tension Bearing Capacity (kN) |
| Ø30       | 30 x 30                    | 12                        | 583.80                   | 1323.00               | 1906.80                  | 762.72                  | 467.04                  | 107.27                  | 24.18                  |
|           | 35 x 35                    | 14                        | 681.10                   | 1800.75               | 2481.85                  | 992.74                  | 544.88                  | 127.84                  | 27.62                  |
|           | 40 x 40                    | 14                        | 1086.58                  | 1757.88               | 2844.45                  | 1137.78                 | 896.26                  | 196.15                  | 29.79                  |
| Ø30       | 45 x 45                    | 12                        | 778.40                   | 2352.00               | 3130.40                  | 1252.16                 | 622.72                  | 149.18                  | 31.06                  |
| Ø35       | 50 x 50                    | 14                        | 1241.80                  | 2296.00               | 3537.80                  | 1415.12                 | 993.44                  | 227.81                  | 33.39                  |
| Ø40       | 55 x 55                    | 14                        | 458.52                   | 1039.08               | 1497.60                  | 599.04                  | 366.81                  | 115.09                  | 19.83                  |

**Figure 6.** Deep Foundation allowable capacity (kN): BH.03

5.2. **Shallow foundation**

Shallow foundations can be reliable at BH.2 if the loading from the upper structure is not exceeding than the allowable bearing capacity. The value of allowable bearing capacity for shallow foundation is more defined by the settlement that happens. Shallow foundation calculation is doing by using empiric formula based on SPT result. Empiric formulas that used are Meyerhof, 1956 (N_SPT data) and The limitation for settlement is 2.5 cm, it can be seen in (Table 4).
6. Conclusion
Sub soil stratification of the research area is dominated with sandy/sandy clay with USCS classification is ML (Silt with Low plasticity), and SP (Sand with Poor gradation).

The Deep Foundation is recommended until the hard / bearing layer at 16.00 - 18.00 meters at (BH.01 and BH.02) and 12.00-14.00 meters at (BH.03) with \( Q_a = 1160.40 - 2032.80 \) kN/m².

The shallow foundation can be considered and recommended until the hard / bearing layer at 1-2 meters at (BH.02), with \( Q_a = 718.25 \) kN/m²

References
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