Comparison of bearing capacity pile foundation base on pile dynamic analyzer test and conventional analysis (Case on foundation bridge in Cikampek)

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Abstract. The foundation as the base of construction work must be able to bear the structural load from above and carry it down. Thus, the foundation analysis needs to be done for designed and build to determine the stability value of the foundation due to load and deformation. This research will be carried out in two different ways: analyzing PDA test results and calculating the bearing capacity of the foundation using Mayerhoff, Poulos Davis and Tomlinson's method. Those two different ways will have resulted in a comparison of dynamic analysis. So it can be concluded through the regression results that will be determined in a linear and logarithmically. Based on the Mayerhoff method, bearing capacity regression values linearly ranged from 0.77 to 0.86 while logarithmically is 0.8. For the Poulos Davis method, the linear and logarithmic regression values range between 0.7 to 0.88. The Tomlinson method produces regression values ranging from 0.65 to 0.88 in a linear and logarithmic. This study shows differences in the value of regression from various conventional analyzes that have been carried out.

1. Introduction
All construction planned to rest on the soil must be supported by a foundation. The foundation is part of an engineering system that transmits the loads supported by the foundation and its weight to and into the soil and rock that lies below it [1]. In foundation planning, it is necessary to calculate the bearing capacity of the foundation. If the planned foundation cannot support the loads above it, it can result in dangerous collapse and subsidence. Bearing capacity refers to the soil's capacity to support loads applied to the ground [2]. To determine the foundation's bearing capacity, it can be done by using the calculation of soil data and pile load test (PDA Test). In foundation planning, sometimes the calculation results of the bearing capacity of the foundation between method one and the field analysis show different results. This is influenced by several factors, namely different types of soil, calculation methods, and soil sampling. Therefore, it is necessary to conduct a comprehensive study to evaluate the results of the calculation of the bearing capacity of the pile foundation [3].

Pile foundations are used when the foundation soil at a normal depth cannot support the load and the hard soil lies at a very deep depth. The pile foundation is divided into a driving pile foundation and a bored pile foundation. Pile foundations are generally smaller in diameter and longer than the other foundations [4]. The pile foundation's axial capacity is determined by the pile material's ability to withstand the load (structural capacity) or soil bearing capacity, with the smallest bearing capacity, which is more decisive. The soil's bearing capacity on the pile foundation can be calculated by static means, based on direct correlation with field tests (in-situ test), with dynamic formulas (from piling records), wave propagation analysis, based on hydraulic jacking results, and by field testing. Bearing
capacity is distinguished by the end bearing capacity and the shear bearing capacity [5]. Pile driving formulas, which directly relate the pile set resulting from a hammer blow to the pile's static load capacity are often used to decide whether a pile will have the required design capacity [6].

This study aims to obtain the regression value from a conventional analysis with the results of the Pile Dynamic Analyzer. The calculation of the pile's bearing capacity using a dynamic formula is carried out by analyzing the ultimate capacity of the pile and comparing it with laboratory test results and field test results. The results of pile capacity testing in the field sometimes need to be double-checked to ensure the results. Some formulas may give results that exceed the estimated bearing capacity; there may even be formulas that give results that are much smaller than the estimates. This is considered important for research to provide a real, economic, and efficient picture at the time of the design [3].

2. Methodology of Research

In the process of comparing the results of the bearing capacity of the foundation with the results of the Pile Dynamic Analyzer, soil data and PDA results were collected from several foundation points on the bridge in Cikampek. The research work process can be seen in the following flow chart (Figure 1):

![Flow Chart of Research](image)

**Figure 1.** Flow Chart of Research

For the calculation of conventional pile bearing capacity, it is carried out using the method of the formulation of Mayerhoff, Poulos Davis, and Tomlinson, where the results of the three formulas are regressed with PDA values linearly and logarithmically. The following is the formulation of the bearing capacity of the pile [7]:

\[
Qu = Qp + Qs \tag{1}
\]
• **Mayerhoff:**
  \[
  Q_p = 40 \cdot \text{NSPT} \cdot \text{Ap} \\
  Q_s = A_k \cdot \text{ftotal}
  \]
  (2) (3)

• **Poulos Davis:**
  \[
  Q_p = A_b \cdot p_b \cdot N_q \\
  Q_s = A_s \cdot K_d \cdot t_g \cdot \delta \cdot p'_o
  \]
  (4) (5)

• **Tomlinson:**
  \[
  Q_p = A_b \cdot c_u \cdot N_c \\
  Q_s = \alpha \cdot c_u \cdot A_s
  \]
  (6) (7)

3. **Result and Discussions**

The following are the results of the PDA Test and the results of calculations obtained conventionally with the three formulation methods for the end, friction, and ultimate bearing capacity (Table 1, Table 2, Table 3):

| Table 1 End Bearing Capacity |
|-----------------------------|
| Qp (kN)                     |
| PDA                        |
| Mayerhoff                  |
| Poulos Davis               |
| Tomlinson                  |
| 1909.70                    |
| 1838.96                    |
| 1006.00                    |
| 1191.71                    |
| 5636.40                    |
| 2216.71                    |
| 2213.20                    |
| 3638.91                    |
| 2927.70                    |
| 2216.71                    |
| 2213.20                    |
| 3638.91                    |
| 3762.50                    |
| 2216.71                    |
| 2213.20                    |
| 3638.91                    |
| 3637.00                    |
| 2100.00                    |
| 1881.03                    |
| 2900.00                    |
| 2422.70                    |
| 2126.23                    |
| 1800.00                    |
| 2844.96                    |
| 167.00                     |
| 150.12                     |
| 181.19                     |
| 141.04                     |
| 870.83                     |
| 622.04                     |
| 558.89                     |
| 735.13                     |

| Table 2 Friction Bearing Capacity |
|-----------------------------------|
| Qs (kN)                           |
| PDA                              |
| Mayerhoff                        |
| Poulos Davis                     |
| Tomlinson                        |
| 9218.20                          |
| 12935.85                        |
| 14186.75                        |
| 1888.03                         |
| 10982.90                        |
| 21307.59                        |
| 22810.87                        |
| 4678.33                         |
| 10152.50                        |
| 21307.59                        |
| 22810.87                        |
| 4678.33                         |
| 10220.20                        |
| 21307.59                        |
| 22810.87                        |
| 4678.33                         |
| 9987.50                         |
| 9627.36                         |
| 8912.87                         |
| 4204.15                         |
| 10717.80                        |
| 15000.00                        |
| 29187.69                        |
| 2366.64                         |
| 774.44                          |
| 1126.31                         |
| 1915.42                         |
| 393.09                          |
| 6830.33                         |
| 4613.01                         |
| 22121.59                        |
| 4677.08                         |
Table 3 Ultimate Bearing Capacity

| Qult (kN) | PDA       | Mayerhoff | Poulos Davis | Tomlinson |
|----------|-----------|-----------|--------------|-----------|
| 11127.90 | 14774.81  | 15192.75  | 3079.73      |
| 16619.30 | 23524.30  | 25024.07  | 8317.24      |
| 13080.20 | 23524.30  | 25024.07  | 8317.24      |
| 13982.70 | 23524.30  | 25024.07  | 8317.24      |
| 13624.50 | 11727.36  | 10793.90  | 4204.15      |
| 13140.50 | 17000.00  | 30987.69  | 5211.60      |
| 941.44   | 1276.43   | 2096.60   | 534.13       |
| 7701.16  | 5235.04   | 22680.48  | 5412.21      |

From the three tables, it can be noted that not all conventional calculations have the same value. The difference is also visible when compared with the PDA test scores that have been conducted. The Tomlinson method gives the smallest results on the ultimate bearing capacity. Based on the carrying capacity in the table, linear and logarithmic regression values were taken which can be seen in (Figure 2, Figure 3, Figure 4, Figure 5, Figure 6, Figure 7).

![Figure 2. End Bearing Capacity (Linear)](image1)

![Figure 3. End Bearing Capacity (Logarithmic)](image2)

The regression results of the end resistance on this foundation's bearing capacity for the three conventional analyzes compared to the PDA results linearly were 0.77, 0.74, 0.74, and logarithmically were 0.82, 0.88, 0.88.
The regression results of the foundation pile friction on the bearing capacity of this foundation for the three conventional analyzes compared to the PDA results linearly were 0.82, 0.71, 0.66, and logarithmically were 0.82, 0.71, 0.66.

For the foundation's ultimate bearing capacity, the linear regression values were 0.86, 0.83, and 0.87. The logarithmic value of the regression in the ultimate bearing capacity was 0.84, 0.70, 0.79. The regression value of each of these conventional methods varies either linearly or logarithmically. However, this regression value can be said to be good.

4. Conclusion
As for what can be concluded from the results of this study are as follows:

1. The value of bearing capacity in conventional analysis of the three methods results in different values. Based on the foundation bearing capacity's total capacity, the conventional Tomlinson
method produces the smallest value. The difference in these values occurs due to the multiplying factors which also differ in each formula.

2. Based on the calculation results of several points, the value of bearing capacity is conventionally greater than the value of the PDA Test.

3. The regression results obtained from this study can be said to be good. This is because the regression value obtained is almost close to 1. A good regression value is 1. This means that the confidence level in the foundation data can be equated with the results of field tests using the PDA Test.

4. To get a better regression value, it is advisable to perform more data analysis.

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