Comparative analysis of soft soil consolidation time due to improvement using Prefabricated Vertical Drain

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Abstract. Construction built on soft soils will cause several geotechnical problems, one of which is a consolidation settlement that lasts for a long time due to the low permeability of soft soils. This study aims to compare the time of soft soil consolidation settlement before and after soil improvement using Prefabricated Vertical Drain (PVD). PVD is a plastic sheet made from a composite, consisting of a drain core and filter jacket with a function to accelerate the process of pore water discharge to the ground surface by shortening the horizontal waterway. The method used using analysis, where the time of consolidation settlement reaches a degree of consolidation of 90%. The PVD pattern used is a triangle pattern and a rectangular pattern with a distance variation of 0.6 m; 0.7 m; 0.8 m; 0.9 m; 1.0 m; 1.1 m; and 1.2 m. The results obtained, based on the PVD pattern, the time of consolidation settlement is faster if using a triangle pattern compared to the rectangular pattern. Whereas, based on distance, the smaller the distance between PVDs, the faster the time of consolidation will decrease.

1. Introduction

The use of Prefabricated Vertical Drain (PVD) as an effort to improve soft soils can influence the time of consolidation settlement. The use of Prefabricated Vertical Drain (PVD) can increase soil permeability so that water can come out in a shorter time [1]. PVD has used extensively to accelerate the rate of water flowing from the soil and to accelerate the dissipation of excess pore pressure [2,3]. PVD is also a soil improvement technique that has proven to be economical and practical [4]. PVD is a sheet that is inserted into soft soil, consisting of a filter and a core, the filter functions to prevent soil grains from entering the core while the core functions to flow water to the ground surface.

Kayu Agung – Palembang – Betung Toll Road (KAPB) section 1A built on soft soil, which has unfavorable characteristics for the construction, high water absorption, high compressibility, and low permeability [4–7]. These soft soils generally categorized as soil with problems in geotechnical engineering [8,9]. High water absorption and high compressibility cause the soil to contain a lot of pore water; this is an essential parameter for analyzing soil settlement. While permeability is a vital soil parameter in predicting the flow rate of water [10], low permeability causes the rate of drainage to be prolonged [11]. Based on this, soft soils will undergo a very long process of consolidation settlement, and a difference in the settlement can occur that will later cause severe damage to the construction structure above and will occur significantly throughout the life of the structure [12,13].
Therefore, soil improvement must be made before construction begins. Soft soil improvement techniques have become the most practical and popular method for increasing soil strength, soil stiffness, and reducing soil compressibility [14]. Efforts that can be made to improve soil are to reduce the length of the pore drainage path because the time of consolidation is inversely proportional to the square of the drainage length [15–17].

In this study, an analysis was carried out to solve the problem of long-term consolidation settlement using PVD. The results of the analysis show that consolidation settlement that could not be improved and which could be improved could use related to using PVD could reduce the relatively long consolidation settlement time.

2. Method

The method used in this study is an analysis based on data obtained. The location of this research is in the area of South Sumatra Province, the construction of the Kayu Agung-Palembang-Betung toll road section 1. Based on the results of the cone penetration test, the type of soft clay soil is up to a depth of 12 m. The next layer is sand, then the direction of water flow into two directions.

Soil parameter data used in this study can be seen in Table 1.

| Parameter | Value |
|-----------|-------|
| C_v       | 0.810 m^2/year |
| C_h       | 1.620 m^2/year |
| H         | 12 M |
| H_dr      | 6 M |

The PVD configuration used in this analysis is a triangle and quadrilateral pattern with a variation distance 0.6 m; 0.7 m; 0.8 m; 0.9 m; 1.0 m; 1.1 m; and 1.2 m. The dimensions of the PVD used are 100 mm wide by 4 mm thick and installed as thick as soft clay soil, which is 12 m.

The time of consolidation settlement with PVD calculated using Equation 1, while the time of consolidation settlement without PVD uses Equation 2.

\[
t = \frac{D^2}{8C_h} F_n \ln \left( \frac{1}{1-U_h} \right)
\]

\[
t = \frac{T_v H_{dr}^2}{C_v}
\]

where:
- \( t \): time (year)
- \( D \): diameter of the circle of an area of influence of PVD (m)
- \( C_h \): horizontal consolidation coefficient
- \( F_n \): barrier function due to PVD distance
- \( U_h \): the degree of horizontal consolidation
- \( T_v \): time factor
- \( H_{dr} \): drainage length (m)
- \( C_v \): vertical consolidation coefficient

The diameter of the influence area distinguishes consolidation settlement time PVD triangular and rectangular patterns. The triangular pattern PVD will produce a faster time compared to the rectangular pattern because the multiplier factor at the diameter of the area of influence is smaller than the rectangular’s.

Analysis of the time of consolidation settlement carried out with a degree of consolidation of 90%. The degree of consolidation is the ratio of consolidation settlement at a specific time with a total settlement. Soil without PVD undergoes a process of consolidation only in a vertical direction, whereas
soil with PVD consolidation takes place in the horizontal and vertical directions. So the degree of consolidation used is the average degree of consolidation.

3. Results and discussion

Analysis of the time of settlement carried out on soft soil before improvement and after improvement. The time of settlement calculated when the degree of consolidation reaches 90%. The time of settlement in soil consolidation without PVD using Equation 2 is 37.69 years. It means that to build a construction, and it takes 37.69 years for the land to experience a settle; otherwise, there will be damage to construction due to soil settlement. Whereas the time of settlement in soil consolidation with PVD made in the form of a graph between the degree of consolidation and time. The graph for the triangular pattern PVD can be seen in Figure 1, while the rectangular pattern PVD graph in Figure 2.

![Figure 1. PVD triangular pattern.](image1)

Based on Figure 1, the consolidation settlement for PVD triangular pattern a distance of 0.6 m takes 3.8 weeks; a distance of 0.7 m takes 6 weeks; a distance of 0.8 m takes 8.6 weeks; a distance of 0.9 m takes 11.6 weeks; a distance of 1.0 m takes 15 weeks; 1.1 m distance takes 19.4 weeks; and a distance of 1.2 m takes 24 weeks.

![Figure 2. PVD rectangular pattern.](image2)
Based on Figure 2, the consolidation settlement for PVD rectangular pattern a distance of 0.6 m takes 4.8 weeks; a distance of 0.7 m takes 7.4 weeks; a distance of 0.8 m takes 10.4 weeks; a distance of 0.9 m takes 14 weeks; a distance of 1.0 m takes 18.4 weeks; 1.1 m distance takes 23 weeks; and a distance of 1.2 m takes 28.6 weeks.

Based on the results of the analysis of the time of consolidation settlement with triangular and rectangular PVD patterns, the closer the PVD distance, the faster the time of consolidation settlement. That is because the closer PVD distance can further reduce the length of the pore drainage path. Whereas, based on the pattern, the PVD of the triangle pattern takes a faster consolidation settlement compared to the rectangular pattern. That is because the diameter of the area of influence of the triangle pattern is smaller than that of the rectangular pattern.

4. Conclusion

PVD is a soil improvement technique that has proven to be economical and practical. PVD has been widely used to accelerate the rate of drainage of water from the soil and to accelerate the dissipation of excess pore pressure. It is following the results of the analysis in this study. PVD can reduce the time of soft soil settlement. Also, the PVD distance can affect, the closer the PVD distance, the faster the time of consolidation settlement. Whereas based on the pattern, the PVD of the triangle pattern takes a faster consolidation time compared to the rectangular pattern.

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