Study of PVD effect on modulus of subgrade reaction

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Abstract. The basic strength parameter that is important for use in designing pavement is the modulus of subgrade reaction (k). Increase in k-value can be obtained by soil improvement using preloading and PVD (Prefabricated Vertical Drain). The method that can be used to get the k-value is the plate load test using plates with a diameter of 304.8 mm in soil conditions without PVD and with PVD with a distance of 100 mm and 150 mm. The results obtained from the plate load test are settlement and pressure and then graphed. The k value is based on a pressure of 69 kN/m\textsuperscript{2} which determines a certain settlement. The most significant increase in the modulus of the subgrade reaction is that the soil mounted by PVD is 100 mm apart, an increase of 80.73%. Whereas for the soil installed PVD 150 mm increases by 56.24%. Based on this, soil with PVD with a closer distance gives a more significant increase in modulus of subgrade reaction.

1. Introduction
Rigid pavements are widely used in low soil bearing capacity. The modulus of subgrade reaction (k) describes the soil bearing capacity. The soil bearing capacity is very important to know before the construction period begins \cite{1}. The higher the modulus of subgrade reaction, the smaller the deflection that occurs for the given load \cite{2}. Based on this, one of the important parameters in the design of rigid pavement is the modulus of subgrade reaction.

The subgrade must have a possess strength so that large permanent deformations do not accumulate over a long period of time and affect the performance of the pavement \cite{3}. The modulus of subgrade reaction can obtain by conducting a plate load test in the field. Plate load test has been commonly used to determine the modulus reaction of subgrade in the highway design on soft soils \cite{4,5}. An increase in the modulus of subgrade reaction value is needed for soft soil. Soft soil has characteristics of high compressibility, low permeability, and heterogeneous soil material. The low permeability of soft soil results in slow water flows from the consolidation process. In addition, the settlement that occurred was relatively large, and the soil bearing capacity was low. Efforts made on the characteristics of low-quality soft soil so that it can be used properly are by making soil improvement.

One of the efforts in soil improvement is to use preloading and PVD (Prefabricated Vertical Drain); this method is very effective because PVD installation significantly reduces the length of the pore drainage path and hasten the dissipation process of excess pore water pressure \cite{6–9}. PVD is the preferred method to speed up the consolidation of soft cohesive soils under preloaded embankment fills \cite{10}. PVD is a sheet made from a combination of the core material and spun non-bonding geotextile as a wrapping. While preloading is an additional burden placed on the ground that has PVD installed. The
use of preloading and PVD can accelerate the process of settlement, with the release of water from the soil pore, the soil density will increase and affect the rise in the modulus of the subgrade reaction. This research discusses the effect of soil improvement using preloading and PVD on increasing the modulus of subgrade reactions.

2. Method

The method used in this research is testing in the laboratory. Load plate testing is carried laboratory referring to AASHTO T 222-81. The soil used in this research is soft clay from Gedebage, Bandung City.

To find out the effectiveness of using preloading and PVD in soil improvement is necessary to do field testing, but it creates some difficulties in its implementation. Therefore, testing in the laboratory can be used as an alternative method [11].

Experimental testing uses a laboratory model scale with a steel box measuring 1000 mm \( \times \) 1000 mm \( \times \) 1000 mm. The soil material used previously was dried and filtered using No. filter 4, then the water content is adjusted to the conditions in the field. Load media using 304.8 mm diameter plates which are pressed using OPT hydraulic pump. The experimental testing scheme can be seen in Figure 1.

![Figure 1. Load plate test.](image)

The modulus of subgrade reaction is based on a pressure of 69 kN/m\(^2\), which determines a certain settlement. The modulus of the subgrade reaction is obtained by using Equation 1.

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k = \frac{69}{\delta}
\]

Tests were carried out on 3 samples, soil without PVD, soil with PVD spaced 100 mm, and soil with PVD spaced 150 mm. PVD is planted into a 500 mm deep soil layer. Then the layer of sand is placed on the soil which was previously coated by geotextile non-woven with the aim of separating the sand and soil layers from mixing.

Before the test is carried out, a preloading process is carried out first, which aims to help the water get out faster through PVD. Preloading is carried out using 10 mm thick steel plate media which is then pressurized until the soil drops when a 50% consolidation degree is reached. Tests are carried out by giving pressure, and the settlement of soil that occurs is recorded using dial gauge.
3. Results and discussion
The results of the plate load test are pressure and soil settlement. The result of the plate load test can be seen in table 1.

| Pressure (kN/m²) | Settlement (m) | without PVD | PVD 100 mm | PVD 150 mm |
|-----------------|----------------|-------------|------------|------------|
| 6.58            | 0.00098        | 0.00120     | 0.00088    |
| 13.16           | 0.00371        | 0.00176     | 0.00140    |
| 19.74           | 0.00589        | 0.00226     | 0.00249    |
| 26.32           | 0.00835        | 0.00286     | 0.00398    |
| 32.90           | 0.01145        | 0.00331     | 0.00602    |
| 39.48           | 0.01560        | 0.00385     | 0.00721    |
| 46.06           | 0.01937        | 0.00443     | 0.00968    |
| 52.64           | 0.02381        | 0.00495     | 0.01035    |
| 59.22           | 0.02766        | 0.00552     | 0.01246    |
| 65.80           | 0.03047        | 0.00600     | 0.01464    |
| 72.39           | 0.03454        | 0.00662     | 0.01594    |
| 78.97           | 0.03739        | 0.00719     | 0.01690    |
| 82.55           | 0.03983        | 0.00784     | 0.01807    |
| 92.13           | 0.04140        | 0.00810     | 0.01970    |
| 98.71           | 0.04325        | 0.00841     | 0.02074    |

Based on tables 1, they are then graphed into a graph between pressure and settlement, which can be seen in Figure 2.

Figure 2. Plate load test results.
At a pressure of 69 kN/m$^2$, a settlement value for each condition was obtained, which then calculated the modulus of the subgrade reaction using equation 1. The calculation results can be seen in table 2.

**Table 2. Modulus reaction of subgrade.**

| Sample               | Settlement (m) | k (kN/m$^3$) |
|----------------------|----------------|--------------|
| Without PVD          | 0.03166        | 2179.24      |
| With PVD 100 mm      | 0.00610        | 11311.09     |
| With PVD 150 mm      | 0.01385        | 4980.94      |

The modulus value of soil reactions in soil conditions that have been improved using PVD has a greater value than the soil without repairs. The most significant increase in modulus of soil reaction was found inland with 100 mm PVD, i.e., 80.73%. Whereas when compared to PVD 150 mm, the increase occurred at 56.25%.

4. Conclusion

Soil improvement with preloading and PVD can increase the modulus of subgrade reaction value. The closer the PVD distance, the greater the modulus of the subgrade reaction.

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