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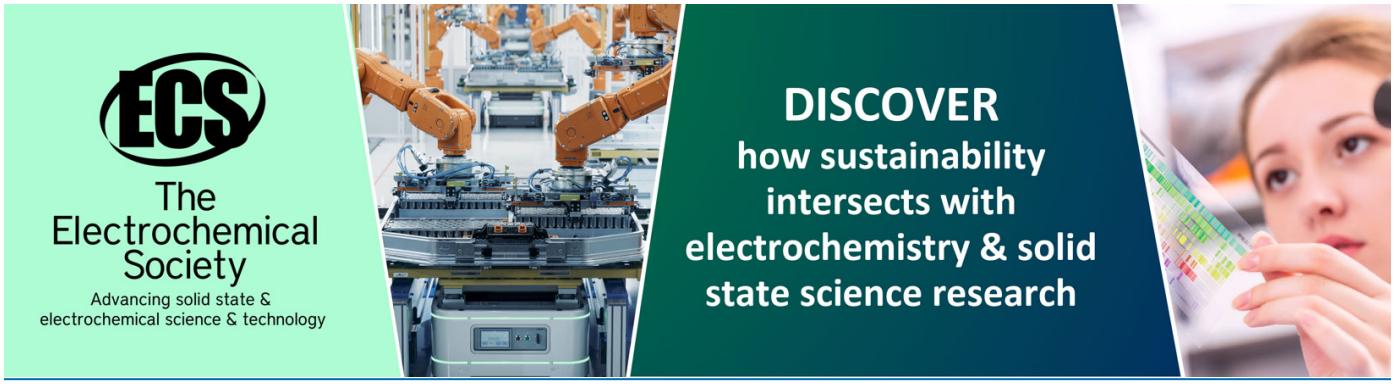

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The Effect of variations in PVD installation distance and thickness of soft soil layer for the degree of consolidation and time of consolidation at Gunung Anyar, Surabaya

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Abstract. Gunung Anyar is one of the areas in East Surabaya which has quite a high indication of the spread of soil clay with The combined Cv is 0.0008 - 0.000125 cm^2/s , which indicates long a consolidation time. The appropriate soil improvement method to speed up the consolidation time is to use a combination of preloading and prefabricated vertical drain. Simple statistical analysis was performed to obtain prefabricated vertical drain's thickness and length in general is 3.33 mm and 100 mm. The analysis consists of the effect PVD installation distance which is 1 m, 1.5 m and 2 m of triangular and rectangular patterns and variations thickness of soft soil clay are 10 m, 15 m, and 20 m. At the same installation distance with different thickness of soft soil layer, the changes of degreethe of consolidation was only <1%. Triangular pattern with an installation distance of 1 m PVD soft soil thickness 20 m, with 90% degree of consolidation the time requirement is 11 – 25 weeks. if soft soil thickness same and the difference in installation distance of 1 m, degreethe of consolidation decreased by 18.32% - 51.05% triangular pattern and 23.75% -45.69% rectangular pattern.

1. Introduction

Zonification of the soft soil in East Surabaya obtained the thickness of the soft soil clay layer ranging 6.5-21 m with combined Cv values ranging between 0.000168 - 0.00228 cm^s/s. Gunung Anyar, a part of East Surabaya has combined CV value of 0.0008 - 0.000125 cm^s/s.[1] That has indicates long consolidation time , therefore soil improvement method that is widely used to speed up the consolidation time is using a combination of vertical drain and precompression. Vertical drain can be divided into two, namely prefabricated vertical drain (PVD) and sand column [2]. Compression time for varying PVD installation distances with a triangular pattern indicating that the thickness of the soft soil layer (Hdr) has no significant effect on the distance of PVD installation that is close together [1].

Apart from that, many designers use PVD from various suppliers where each product has a different thickness and length. The depth and length of the PVD used can affect the target time for achieving the degree consolidation. Therefore, it can be calculated to obtain the depth and length of PVD in

general from some products from some PVD's Suppliers using simple statistical analysis. Then the calculation of consolidation time is based on 90% the degree consolidation with variations in distance and thickness of soft soil.

An analysis of the effect of variations installation distance on numerous variations of soft soil was carried out at Gunung Anyar. The vertical drain installation pattern used is a rectangular and triangular pattern. Changes in soft soil thickness based on zonification are 5 m, 10 m, and 20 m while variations in PVD installation distance are 1 m, 1.5 m and 2 m.

2. Prefabricated Vertical Drain (PVD)

The PVD is a thin, synthetic drainage element comprised of a drainage core wrapped in a geotextile filter [3]. Prefabricated vertical (PV) drains are commonly used to decrease the drainage path within soft soils to accelerate the time of primary consolidation [4]. Prefabricated vertical drains are displacement drains of a small volume that exhibits considerably with fewer disturbances to the soil mass than the displacement sand drains [5]. Excess pore-water pressures, created by preloading, During the compression and rearrangement of the soil structure, the excess pore pressures were maintained at higher levels similar [6].

The degree of consolidation obtained from pore pressures (Up) is consistently less than that from settlements (Us)[7]. Soil improvement methods using PVD are assumed to be slightly disturbed depending on the sensitivity of the soil [8]. This influence is referred to as smear zone PVD which is affected by the installation pattern of PVD, horizontal permeability coefficient, vertical permeability coefficient[9].

$$F_n = \ln\left(\frac{D}{d_w}\right) - \frac{3}{4} \tag{1}$$

Where d_w is the PVD equivalent diameter or in the specification is referred to thick (m) which is affected pattern and D is the installation distance. The duration of consolidation in the design of the vertical drain depends on the value of Ch whereas specified in Table 1.

Table 1. Ch / Cv value comparison parameter [10]

Characteristics of soil clay layers	C_h/C_v
Relatively homogeneous (almost no permeable layers)	1 – 1.5
Sediment clays (there are non-continuous lenses and sand layers)	2 – 4
Clay-coated *(varved day)* or clay with a layer of sand that is more or less continuous	3 – 15

The formula to calculate the average degree of consolidation for vertical water flow and radial flow use PVD are as follows [11]

$$U = 1 - [(1 - Uv)(1 - Uh)] \tag{2}$$

with a Uv value based on

$$U_v = \frac{\left(\frac{4T_v}{\pi}\right)^{0,5}}{\left[1+\left(\frac{4T_v}{\pi}\right)^{2,8}\right]^{1,79}} \quad (3)$$

$$U_h = 1 - \exp\left[\frac{-8\frac{c_h t}{D^2}}{F_n}\right] \quad (4)$$

Calculation prediction method for Ugab which is widely used in PVD planning is the elasto method - flexible finite element, that the results obtained are approximate results that are almost as real as in the implementation. [10]. Calculations for Uv and Uh values are explained in the following equation:

$$U_v = 2\sqrt{\frac{Tv}{\pi}} \times 100\% \quad (5)$$

$$U_h = \left[1 - \left(\frac{1}{e^{\left(\frac{t\times 8\times C_h}{D^2\times 2\times F_n}\right)}}\right)\right] \quad (6)$$

3. Results and Calculations

3.1 Calculation of vertical drains width and length

The collection PVD products used in this paper by collecting brochures from suppliers. Supplier selection is carried out directly from local and imported suppliers. Table 2. shows some examples of vertical drain specifications from several distributors that are distinguished by width and length, where the most differential specifications are the width range of each product.

Table 2.PVD products which are mostly used in a construction project

	Distributor	Product name	Width (mm)	Length (mm)
1	PT.Teknindo Geosystem	Vertical Wick Drain	3,0-5,0	100
2	HB Wick Drains	Membra Drain MD-xx	2,4-3,4	97-98
3	USDS Drainage	USDS Drainage 74	3,3	102
4	Sunzo	High-Performance PVD	4	100
5	Sunzo	PVD SPB (China Standard)	3,5-5,0	100
6	DAEHAN i. m.	PVD (wick drain)	3,0-4,5	105
7	Tencate	Alidrain PVD	3,0-5,0	100

From Table 2, A Simple statistical analysis is performed by grouping data into six classes and 0.4 interval classes. The results of analytical processing for PVD thickness are given in Table 3.

Table 3. Processing of PVD thickness data group statistics

data	frequency	fkk
2.4 – 2.8	1	1
2.9 – 3.2	3	4
3.3 – 3.7	3	7
3.8 – 4 1	1	8
4.2 – 4.5	1	9
4.6 – 5 0	3	12
Total	12	

Table 3 shows that the minimum thickness that often occurs in some PVD products is 3.3 - 3.7 mm and the overall vertical drain length based on Table 2 is 100 mm. The median value of the PVD thickness data in Table 3 is 3.36 mm, and the mean value is 3.74 mm.

3.2 Calculation of time consolidation with PVD

The calculation of time 90% degree of consolidation used $Tv_{90\%}$ value = 0848 [13]. The calculation with a triangle and rectangle installation pattern with variations in distance (D) and thickness of the soft soil layer (Hdr) based on theory [12] and [9]. The Ch / Cv ratio assumption was 1.5 assuming a homogeneous clay soil layer. The target time used in the calculation analysis was limited to 30 weeks.

Table 4. Time consolidation with 90% degree of consolidation

	t (U_{gab} = 90%) (week)											
	Hansbo						Terzaghi					
Hdr	10 m		15 m		20 m		10 m		15 m		20 m	
Installation pattern	Rect.	Tri.	Rect.	Tri.	Rect.	Tri.	Rect.	Tri.	Rect.	Tri.	Rect.	Tri.
S = 1.0 meter	25	30	25	>30	25	>30	13	11	13	11	13	11
S = 1.5 meter	>30	>30	>30	>30	>30	>30	>30	28	>30	29	>30	29
S = 2.0 meter	>30	>30	>30	>30	>30	>30	>30	>30	>30	>30	>30	>30

In general, if the PVD installation distance is the same as the thickness of soft soil, time for degree consolidation is the same. Table 4 shows that a distance of 1 m with variations in soft soil thickness was faster in triangular patterns with a time between 11-25 weeks while 13-30 weeks in rectangular patterns. Whereas with the distance installation PVD 2 m with all variation soft soil layers to gain 90% degree of consolidation need more than 30 weeks

3.3 Effect of distance on the degree of consolidation

An analysis of the degree of consolidation based on variations distance and pattern of PVD installation on the thickness of soft soil clay layer (Hdr) has been done from the time target planning which was 30 weeks.

Table 5. The degree of consolidation with variations distance PVD and Soft soil layer

The degree of Consolidation (%)												
	Hansbo						Terzaghi					
Hdr	10 m		15 m		20 m		10 m		15 m		20 m	
Installation pattern	Rect.	Tri.	Rect.	Tri.	Rect.	Tri.	Rect.	Tri.	Rect.	Tri.	Rect.	Tri.
S = 1.0 meter	90.66	89.83	90.24	89.33	90.03	89.07	91.14	90.64	90.86	90.38	90.72	90.24
S = 1.5 meter	68.64	61.29	67.07	59.35	66.29	58.38	88.69	90.36	88.12	90.68	87.84	90.46
S = 2.0 meter	48.27	42.35	45.68	39.46	44.39	38.02	69.22	73.88	67.68	72.58	66.91	71.92

In general. At the same installation distance with different thickness of soft soil layer, the changes of the degree of consolidation were only <1%. Degree of consolidation 90% achieved at 1 m installation distance, for example from the calculation results with a distance of 1 m with a soft soil thickness of 20 m in the triangular pattern obtained 89.07% [9] and 90.24% [12].

The difference of distance between PVD installations is getting farther, then the degree of consolidation achieved is smaller with the same time target. The smallest degree of consolidation when the distance of 2 m PVD installation with a thickness of 20 m soft soil layer from the calculation of the degree of consolidation that can be achieved is 38.02% [9] and 71.92% [12]. If soft soil thickness same and the difference in installation distance of 1 m, the degree of consolidation decreased by 18.32% - 51.05% triangular pattern and 23.75% -45.69% rectangular pattern.

4. Conclusion

The general PVD thickness products are between 3.3 - 3.7 mm and the overall vertical drain length is 100 mm. The median value for PVD thickness is 3.36 mm, and the average thickness value is 3.74 mm. Triangular patterns PVD with a time between 11-25 weeks while 13-30 weeks in rectangular patterns. Whereas with the distance installation PVD 2 m with all variation soft soil layers to gain 90% degree of consolidation need more than 30 weeks. In general. At the same installation distance with different thickness of soft soil layer, the changes of the degree of consolidation were only <1%. If soft soil thickness same and the difference in installation distance of 1 m, the degree of consolidation decreased by 18.32% - 51.05% triangular pattern and 23.75% -45.69% rectangular pattern.

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