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Effect of Adding Surcharge Load Stress on the Acceleration of Soft Soil Consolidation

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Abstract: One type of soil that needs to be considered is soft soil. Soft soil has characteristics of large compression, long consolidation time, and low bearing capacity. Soft soil can be overcome using soil improvement methods to accelerate consolidation by using Surcharge Load coupled with Prefabricated Vertical Drains (PVD). This research uses GeoStudio 2018 software to determine how the addition of surcharge load to the embankment will affect the consolidation of soft soil. Modelling in GeoStudio is done using the Sigma/W model with the type of material model in the original soil using the Soft Clay model. The results of the analysis will be presented with a graph showing the relationship between the amount of settlement (m) and the settlement time (days). The results of the analysis were varied based on three surcharge load height models, namely 1.25 m, 2.50 m, and 3.50 m. The settlement is taken when the degree of consolidation has reached 90% (U90%). The time required to know the degree of consolidation has reached 90% is taken from the relationship graph of pore water pressure (PWP) with time. When the pore water pressure has dropped and has not changed, it is assumed that the degree of consolidation has reached 100%, therefore the days needed to reach 90% consolidation degree can be known. From the results of the analysis using Soft Clay material, a decrease of 0.71 m, 0.79 m, 0.86 m was obtained with the time to reach U90% for 88 days.

Keywords: GeoStudio, Surcharge Load, Consolidation

Introduction

One of the soils with problematic characteristics is soft soil, which has a very high pore water content. If there is a load that occurs on the soil, the soil will experience consolidation (Hanna, 2024; Liang, 2024; Lin, 2024). Consolidation is the process of dissipation of excess pore water in soil material caused by the load applied to the soil layer (Han, 2015). Consolidation causes subsidence due to compression of soil grains. This can damage the structure of the building above it if not handled (Boucias, 2024; Li, 2024; Zong, 2024).

Soft soil is one of the challenges of construction, where to overcome this problem, soil improvement methods can be used (Saikia, 2024; Xu, 2024; Yuan, 2024). There are various methods that can be taken to improve the soil, one of which is using the preloading method (Kapor, 2023; Sharmeelee, 2024; Wu, 2024). The preloading method requires a considerable amount of time to achieve the desired consolidation, therefore there are many developments related to this soil improvement method (Wang, 2023; Wei, 2023; Y. Zhang, 2023). The latest breakthrough is the use of prefabricated vertical drain (PVD) to accelerate consolidation time, this method is considered quite relevant to accelerate achieving the desired consolidation time (Drbe, 2023; Pradhan, 2023). Over time this method has developed and added where one of these developments is preloading using Prefabricated Vertical Drains (PVD) and added with Surcharge Load (Lei, 2023; Shen, 2023; Z. Zhang, 2023).

Soil improvement methods using preloading coupled with PVDs are often used because they are effective in reducing consolidation time. Many studies have examined this method and mentioned that it takes 45 days to achieve 90% consolidation using the preloading method coupled with PVDs (Susiazti, et al, 2020). PVD has been proven to accelerate the consolidation time of a soil layer. In the research of Gunawan et al. (2020), a 21 m thick soil layer loaded with a 5 m high embankment will reach 90% consolidation degree in 68.54 months. Meanwhile, with the help of PVD, the 90% consolidation degree was achieved in only 9.68 months. This is because PVDs minimize the drainage path distance of soft soil so that pore water can move horizontally towards the PVD and flow out vertically (Hansbo, 1979).

The preloading method using PVD is often used but construction work in the field often wants fast work, so a combination of preloading using PVD coupled with a surcharge load emerged.The additional surcharge load serves to increase the stress on the soil so that soil pressure will increase and pore water will quickly escape.The surcharge load material is temporary until the required time.Surcharge load materials can be water, rocks, and materials that have not or are not used in the construction area.

Methodology

This research method uses GeoStudio 2018 software to determine how the addition of surcharge load on the embankment will affect the consolidation of soft soil. The soil data comes from the secondary data of the Tanjung Selor MHP construction project, North Kalimantan. The soil in this project is layered and has various levels of clay. This research will discuss the modeling analysis of the relationship between settlement and time required in GeoStudio 2018 software using the Soft Clay material type.

Embankment Geometry and Material Properties

Modeling in GeoStudio will use two-dimensional (2D) modeling. The analysis that will be used is Sigma/W. Figure 1 shows the model geometry to be used and the material input to the modeling. Embankment soil data and surcharge load are assumed. Table 1. until tabel 4. shows the parameter data of subgrade material, PVD, Sand Drain, used.

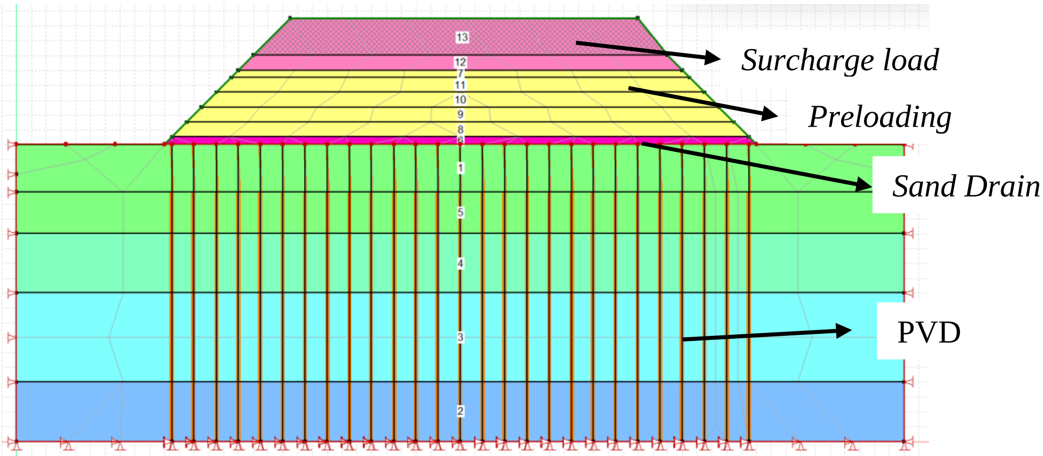

Figure 1. Embankment Geometry in GeoStudio modeling

Table 1. Embankment soil parameters

Material	Material Category	Parameter	Unit	Value
Preloading	*Linear Elastic (Total)*	E-modulus	kN/m2	20.000
		Volume weight	kN/m3	18,00
		Poisson ratio	-	0,49
		Ko	-	0,96
Surcharge Load	*Linear Elastic (Total)*	E-modulus	kN/m2	20.000
		volume weight	kN/m3	18,00
		Poisson ratio	-	0,49
		Ko	-	0,96

Table 2. Soft soil parameters for Soft Clay material

Material	Material Category	Parameter	Layer 1	Layer 2	Layer 3	Layer 4	Unit
Soft Soil	*Soft Clay* (w/PWP Change)	Ratio O.C.	7,43	2,23	1,46	1,01	-
		Poisson's ratio (v)	0,32	0,34	0,34	0,34	-
		Ko	0,48	0,51	0,52	0,51	-

Material	Material Category	Parameter	Layer 1	Layer 2	Layer 3	Layer 4	Unit
Soft Soil	*Soft Clay* (w/PWP Change)	Lambda (λ)	0,02	0,01	0,04	0,01	-
		Kappa (κ)	0,02	0,01	0,04	0,01	-
		Pore Number (e)	2,03	1,87	1,90	1,89	-
		Volume weight (γ)	12,90	13,14	12,84	13,15	kN/m³
		Deep sliding angle (φ)	5,83	5,82	7,73	8,33	°
		Water content (w)	46,09	40,68	38,61	41,08	%
		Compressibility coefficient (mv)	4,8E-04	5,8E-04	5,9E-04	5,1E-04	m²/kN
		Permeability coefficient (k)	9,2E-10	9,9E-10	9,9E-10	1,3E-09	m/detik

Table 3. Sand Drain Parameters

Material	Material Category	Parameter	Unit	Value
Sand Drain	*Linear Elastic (Effective)*	E-modulus	kN/m²	20.000
		Volume Weight	kN/m³	18,00
		Poisson ratio	-	0,49
		Ko	-	0,96

Table 4. Prefabricated Vertical Drain (PVD) Parameters

Material	Material Category	Parameter	Unit	Value
PVD	*Linear Elastic (w/PWP Change)*	E-modulus	kN/m²	3000
		Volume Weight	kN/m³	12,98

Material	Material Category	Parameter	Unit	Value
PVD	*Linear Elastic (w/PWP Change)*	Poisson ratio	-	0,337
		Ko	-	0,5
		Water content	(%)	41,62
		Compressibility Coefficient (*mv*)	m²/kN	0,000511
		Permeability Value (*k*)	m/detik	3,35E-05
		ky/kx	-	1

Stages of Modeling

Modeling stages are based on the time of embankment construction, embankment construction is carried out in stages and layered as high as one meter. After the embankment is five meters high, the surcharge load is given gradually. For the variation of the surcharge load height used in this study are 1.25 m, 2.50 m, and 3.50 m. After reaching the specified time, the surcharge load will be removed.

Results and Discussion

Modeling with the Soft Clay material model uses parameters obtained by laboratory consolidation tests. These parameters include O. C. Ratio, Lambda, and Kappa. The results of modeling using the Soft Clay material mode are shown in figure 2 below.

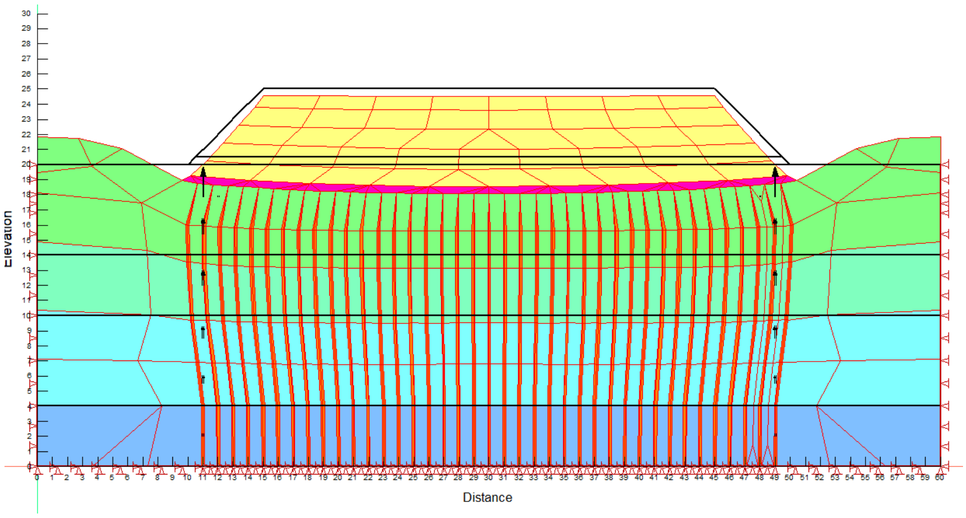

Figure 2. Results of deformation pattern analysis in GeoStudio 2018

Figure 2. is the result of deformation that occurs in Soft Clay modeling after the construction period ends where the surcharge load has been removed. The results of modeling on Soft Clay modeling are taken when it reaches 90% consolidation degree (U90%) in each variable. The 90% degree of consolidation is taken from the relationship graph between pore water pressure and time. The results of modeling the Soft Clay model obtained a graph of the relationship between pore water pressure and time as follows:

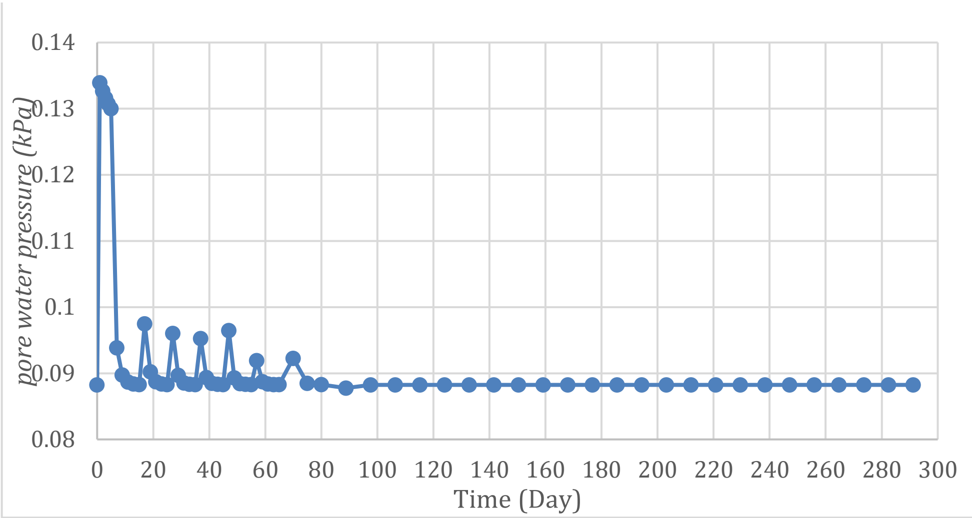

Figure 3. Graph of the relationship between pore water pressure and time

Figure 3 shows that the time to reach 100% consolidation is when the pore water pressure has not changed where the graph occurs on day 98. After that, to find U90%, it was obtained on day 88. After obtaining the time to reach 90% consolidation degree, then the value of the decrease at U90% can be known. The decline that occurs in the Linear Elastic model is obtained in the following table 5:

Table 5. Results of U90% consolidation settlement analysis

No.	variation	Time U90% (Day)	Displacement U90% (m)
1.	Increased surcharge load height 1,25 m	88	0,71
2.	Increased surcharge load height 2,50 m	88	0,79
3.	Increased surcharge load height 3,50 m	88	0,86

Table 5. Shows that the higher the addition of surcharge load, the greater the decrease that occurs. This can occur due to increased stress on the surface layer of the soil. Modeling results on Soft Clay in the form of a graph of the relationship between the decline that occurs with the time required as shown below:

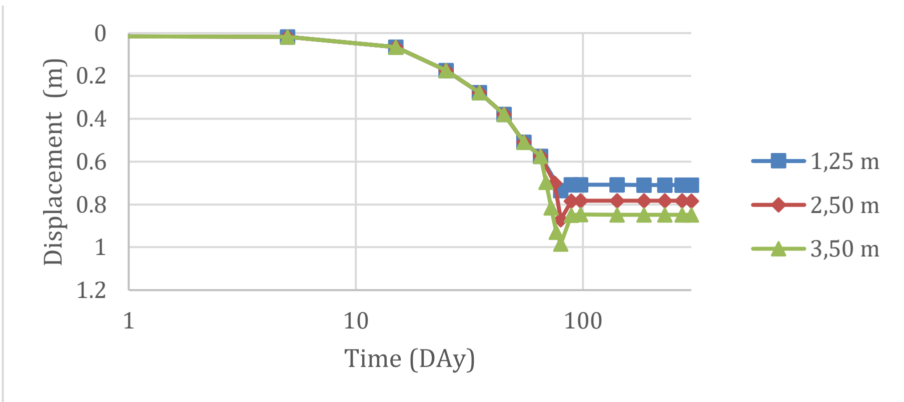

Figure 4. Soft Clay modeling settlement graph

Figure 4. shows the relationship between the decrease and the time required. The results of the graph show that every additional load that occurs the amount of decline will also increase.

Conclusion

GeoStudio modeling results using sigma/W analysis on the Soft Clay material model have a pattern that decreases when the stress increases due to the surcharge load. The results obtained from the deformation value due to the addition of a surcharge load of 1.25 is 0.71 m, for the addition of a surcharge load of 2.50 m a defotation value of 0.79 m is obtained, and for the addition of a surcharge load of 3.50 m a decrease value of 0.86 m is obtained.

Soft Clay material has elastic-plastic properties, this causes when the stress is removed, the soil will try to return to its original condition. In the graph the state of decline does not return to its full state due to the characteristics of Soft Clay material such as plastic which is slightly hardened in its elastic-plastic properties.

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