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ANALYSIS OF SOIL SUBSCRIPTION ON SOIL LACK COMBINATION OF PVD AND PHD WITH ANALYTICAL AND NUMERICAL METHODS USING 3D PLAXIS IN STA 103 + 550 CONSTRUCTION OF HIGH CLICK TOLL ROAD RANGE, STAGE 1

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Abstract

The construction of transportation facilities on soft soil will cause problems where the bearing capacity of soft soil is low and the process of land subsidence will require a long period of time. As is known, the land subsidence factor causes many problems in the process of building transportation facilities, besides that, there will also be problems at the level of service (serviceability). Therefore, this problem must be anticipated before the transportation facility begins to function. There are many methods that can be done. Where in the selection of methods, the efficiency and effectiveness factors are very dominant. One method that can be done is to fill the soil combined with vertical drain and horizontal drain. This method was chosen to be one of the most widely used methods because it is easy to do and quite efficient. The purpose of writing this thesis is to analyze thereduction of settlement each layer of soft soil that is repaired using the soil filling method combined with prefabricated vertical drain and prefabricated horizontal drain using the PLAXIS 3D program. The results of this calculation will then be compared with observations made in the field using a settlement plate for later analysis. Calculation of the size of the consolidation settlement using the Terzaghi 1 dimension consolidation method obtained a decrease of 16.09 cm. This result is relatively close to the results of observations made in the field of 16.3 cm. In the PLAXIS 3D modeling approach using 1 PVD line and 1 PHD line, the result is a decrease of 16.52 cm without taking into account the effect of the smear zone and 16.22 cm taking into account the effect of the smear zone. In the PLAXIS 3D modeling approach using 2 PVD lines and 2 PHD lines, the result is a decrease of 16.54 cm without taking into account the effect of the smear zone and 16.28 cm by taking into account the effect of the smear zone. And when modeling without using PHD the value of the decrease obtained is 9.7 cm. When modeling using sand blanket as a substitute for PHD, the decrease value is 13.3 cm.

Keywords: prefabricated vertical drain, prefabricated horizontal drain, PLAXIS 3D, konsolidasi,

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Introduction

With the ever increasing population and rapid economic growth, the need for land for development as well as the need for transportation development as a means of connecting between cities will also increase rapidly. This results in the unavoidable use of land that is structurally unfavorable condition. The limited land available for the location of the construction of transportation facilities has become a problem in itself. Therefore, the unfavorable structural condition of the land should not be a problem that can hinder the development of transportation facilities.

The construction of transportation facilities on soft soil will cause problems where the bearing capacity of soft soil is low and the process of land subsidence will require a long period of time. As is known, the land subsidence factor causes many problems in the process of building transportation facilities, besides that, there will also be problems at the level of service (serviceability). Therefore, this problem must be anticipated before the transportation facility begins to function.

There are many methods that can be done as shown in Figure 1. Where in the selection of methods, the efficiency and effectiveness factors are very dominant. One method that can be done is to fill the soil combined with vertical drain and horizontal drain. This method was chosen to be one of the most widely used methods because it is easy to do and quite efficient. The following is a list of soil improvement methods that can be performed on soft soil.

GROUND IMPROVEMENT METHOD	TYPE OF SOIL		GROUND IMPROVEMENT OBJECTIVES				
	GRANULAR	COHESIVE	BEARING CAPACITY	SETTLEMENT CONTROL	LATERAL STABILITY	ENVIRONMENTAL CONTROL	LIQUEFACTION RESISTANCE
Vibrocompaction	√	-	√	√	-	-	√
Dynamic Compaction	√	-	√	√	-	√	√
Blasting	√	-	√	√	-	-	√
Compaction Grouting	√	-	-	√	-	-	-
Preloading / Vertical Drains	-	√	√	√	-	-	-
Electro-osmosis	-	√	√	√	-	-	-
Vacuum Consolidation	-	√	√	√	-	-	-
Lightweight Fill	√	√		√	-	-	-
Mechanical Stabilization	√	-	√	√	√	-	-
Soil Nailing	√	-	-	-	√	-	-
Soil Anchoring	√	-	-	-	√	-	-
Micropiles	√	-	√	√	√	-	-
Stone Columns	-	√	√	√	√	-	√
Fiber Reinforcement	√	-	√	√	√	-	-
Permeation Grouting	√	-	√	√	-	√	-
Jet Grouting	√	√	√	√	√	√	√
Deep Soil Mixing	√	-	√	√	√	√	√
Lime Columns	-	√	√	√	√	√	√
Fracture Grouting	-	√	√	√	-	√	-
Ground Freezing	√	√	-	-	√	√	-
Vitrification	√	√	-	-	-	√	-
Electrokinetic Treatment	-	√	-	√	-	√	-
Electroheating	-	√	-	√	-	√	-
Biotechnical Stabilization	√	-	-	-	√	√	-

Figure 1
Soft soil improvement method
(Kuswanda, 2016)

Soil improvement using embankment combined with vertical drain and horizontal drain is a relatively practical method compared to other methods. This is due to the ease of implementation and relatively cheap in terms of cost. In addition, the location conditions which are difficult to obtain sand (materialsand blanket) cause the use of horizontal drain to be an alternative to sand blanket. The purpose of stockpiling the soil is to consolidate the soil as a bearing stratum so that it consolidates first and increases the shear strength (gain of strength) of the soil before the soil is given the actual final load. The process of loading for landfilling can use various methods of loading, one of which is the method of loading in the form of an embankment.

In the combined landfill method With PVD (prefabricated vertical drain) and PHD (prefabricated horizontal drain), soil improvement is carried out by placing embankment loads on the subgrade in accordance with thework loadandconstruction loadplanned. The duration of loading is carried out until the planned consolidation. If the degree of consolidation of the subgrade has reached the planned value, road construction work can begin.

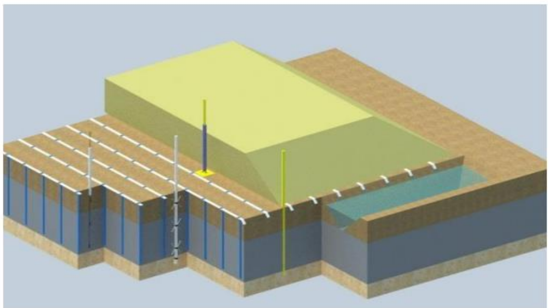

Figure 2
Soil filling system with PVD and PHD
(Kuswanda, 2016)

From Figure 2 it can be understood that soil filling is carried out to compress the soil so that it undergoes consolidation first and increases the shear strength of the soil before the soil is given the actual final load. To avoid failure during soil filling, the embankment load can be planned so that in the end the original soil will be able to carry the service load and avoid excessive settlement.

Soil improvement by means of stockpiling soil and vertical drain can be combined, where landfill will function as a medium for compression, while vertical drain will function as a medium for eliminating excess pore water stress. Furthermore, the combination of soil stockpiling and PVD results in the consolidation process going fast, so that the planned land subsidence will be in accordance with the soil compaction plan according to the age of the project. This can be seen in Figure 1.3.

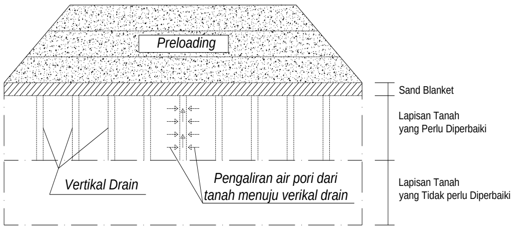

Figure 3
Overview of backfill combined with vertical drain (Maryono, 2011)

Repair of soft soil with soil filling combined with PVD is a soil improvement system consisting of load-bearing work, PVD, PHD and geotechnical instruments. Backfill serves to apply pressure to the subgrade. PVD serves to accelerate the process of soil compaction. PHD functions to drain water from the PVD in a horizontal direction to the outside of the site where the soil is undergoing improvement. Meanwhile, geotechnical instruments function to monitor the process and determine the performance of the results of soil improvements carried out.

The process of loading with soil embankment will serve to shorten the length of drainage so that it will reduce the consolidation time as shown in Figure 4. In its application there are various methods of soil improvement that can be done. Of the many methods, themethod Prefabricated vertical drain (PVD) is currently very commonly used in various engineering work. The PVD is plugged into the soil to be repaired, in this case usuallysoil undrained or soil with very low permeability so that excess pore water due to loading with soil piles can flow into the PVD. As it is known that the function of PVD is to shorten the length of drainage, a number of PVDs are needed in the area to be repaired (Holtz, 1987).

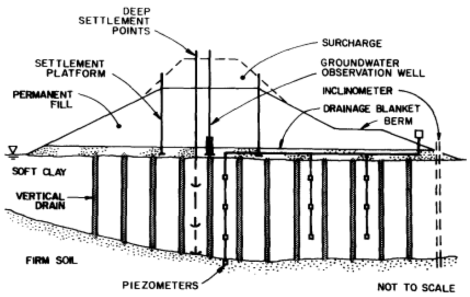

Figure 4
Cross section of soil loading (Holtz, 1987)

Prefabricated Horizontal Drain (PHD) is starting to be commonly used as an instrument to accelerate the soil compaction process which is faster than the use of Preloading and Vertical Drain (Feng, J., Ni P., Chen Z., Mei G., 2020). This horizontal drain actually replaces the function of sand (sand blanket) with an installation pattern of 1 PVD: 1 PHD so as to avoid bending the PVD tape. So that the water from the PVD filter can enter almost completely into the PHD filter.

The success of the horizontal drain is only if the water that comes out is equal to the total water carried by the PVD minus the volume of the cavity contained in the PHD. Because the principle of PHD releases water, namely by filling the PHD cavity with water from the PVD so that the water will flow out through the edges by itself. This means that there must be a difference in total head so that water can flow. So when the volume of water is equal to the volume of the PHD stretch, then at that level the total head does not have a difference. This means that water will still settle in the PHD as large as the PHD cavity in conditions after soil subsidence due to loading with soil piles (Anjana et al. 2020).

In this study, an analysis will be carried out to determine the level of subsidence of the soft soil layer at STA 103 + 550 on the Tebing Tinggi-Kisaran Toll Road Development Project which has been improved by applying a load technique using soil stockpiling combined with PVD and PHD using analytical methods and numerical methods using PLAXIS 3D. Furthermore, the results obtained from the subsidence of soft soil will be compared with field monitoring using theinstrument settlement plate as a control for the modeling carried out.

Method

A. General Project Data The project

Location in this research is the Tebing Tinggi – Kisaran Toll Road Development Project Phase 1 carried out by PT. Hutama Karya at STA 103 + 550. The review carried out will refer to the field monitoring process using theinstrument settlement plate 139which is installed in the middle of the cross-section of the road where the soft soil will be repaired using the method of giving the soil embankment load combined with prefabricated vertical drain and prefabricated horizontal drain instead of sand blanket. The description of the location used as research is shown in Figure 5 below.

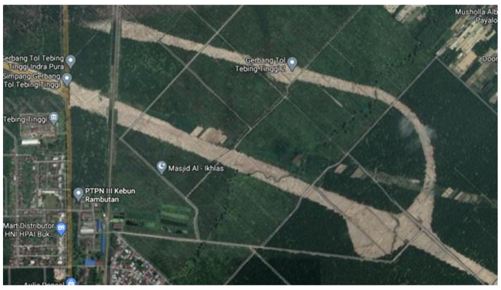

Figure 5
Map of the research location

To find out the repair process that will be carried out at STA 103 + 550, it is necessary to have a soft drawing of the improvement plan that will be carried out at the research location. So that the right modeling process can be chosen to get a modeling process that is close to the conditions in the field. The soft drawing of the management plan for the improvement of soft soil at STA 103 + 550 is shown in Figure 6.

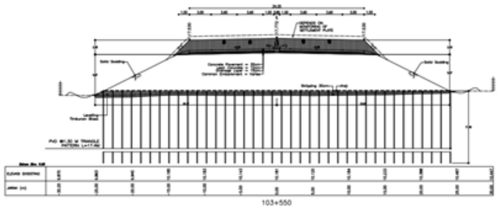

Figure 6
Cross section STA 103 + 550

B. Overview of Soil Conditions

In writing this thesis, the author analyzes soil conditions based onsoil data Bore Hole-40which represents the surrounding soil conditions. This bore hole was chosen because it is the closest test point to the research location, namely STA 103 + 550. The data obtained from this bore hole will later be used as the basis for determining the soil parameters to be used in 3D PLAXIS modeling.

Determination of soil conditions is based on the results of f ield soil test data and then a line is drawn on the type of soil and soil characteristics that are considered the same or have similarities. The selected test point conditions are considered capable of representing the soil parameter values for each layer in this STA 103 + 550. Determination of soil conditions is supported by 2 laboratory testing processes carried out on 2 different types of soil layers, namely at a depth of 3.5 – 4 meters and a depth of 11.5 – 12 meters. And for the determination of soil parameters in the soil layer that was not carried out laboratory testing was carried out with a correlation approach based on the N-SPT value data obtained from the Table Bore Log as shown in Figure 7.

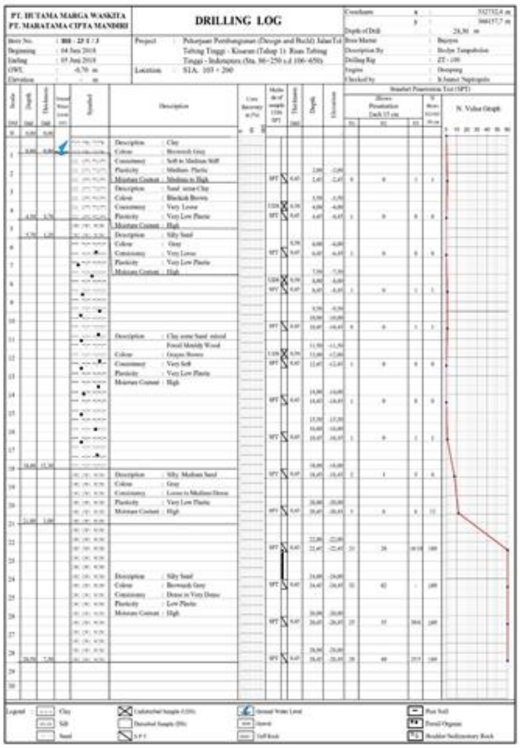

Figure 7
Boring Log

From Figure 7, several soil parameters will be determined that will be used as the basis for modeling in PLAXIS 3D. Determination of these soil parameters will also refer to the results of laboratory test research conducted on several layers of soil contained in bore hole 40. And for several other soil layers that are not subjected to laboratory testing, correlations are carried out using the references described in Chapter II.

The following are the results of laboratory tests carried out for soil layers at a depth of 3.5 – 4 meters and a depth of 11.5 – 12 meters are shown in Table 3.1. And due to the limited data available from laboratory test results, the selection of the soil model that will be used in the PLAXIS 3D modeling is to use thesoil model Mohr-Coloumb. It is expected that the modeling value with thesoil model Mohr-Coloumb carried out in this study is close to the data value of the actual conditions that occur in the field which are monitored by monitoring using a settlement plate. To support the writing of this thesis, the authors obtained data from the contractor, namely PT. Waskita Karya. The data obtained are:

a) Job layout,
b) Boring Log
c) Soil parameter data
d) PVD and PHD specifications
e) Geotechnical instruments (settlement plate)

Table 1
Laboratory test results

Bore No.		BH-40/3	BH-40/3
Depth		3.50 - 4.00 m	11.50 - 12.00 m
Moisture Content	W (%)	46,14	56,45
Natural Density	∂_w (gr/cc)	1,429	1,506
Dry Density	∂_d (gr/cc)	0,978	0,962
Specific Gravity	Gs	2,468	2,569
Void Ratio	e	1,5246	1,6693
Porosity	n	0,6039	0,6254
Degree of Saturation	Sr (%)	74,69	86,86
Atterberg Limit Test			
Liquit Limit	LL (%)	29,95	57,83
Plastic Limit	PL (%)	17,81	24,61
Plastic Index	PI (%)	12,14	33,22
Soil Classification			
AASTHO		A - 2 - 6	A - 7 - 6
USCS		ML	ML
Sieve Analisis Test			
No. 4 Passing Percent		99,26	100,00
No. 10 Passing Percent		61,67	100,00
No. 20 Passing Percent		52,00	100,00
No. 40 Passing Percent		49,00	99,32
No. 60 Passing Percent		43,56	99,04
No. 100 Passing Percent		38,71	98,23
No. 200 Passing Percent		32,44	96,48
Hydrometer Test			
Sand	%	66,82	3,53
Silt	%	10,84	9,68
Clay	%	21,60	86,80
Direct Shear Test			
Internal Friction	Φ (Degree)	12° 47' 1.29"	-
Cohesion	c (Kg/cm^2)	0,024	-
Triaxial Test			
Internal Friction	Φ (Degree)	-	3° 36' 17.53"
Cohesion	c (Kg/cm^2)	-	0,039
Internal Friction	Φ' (Degree)	-	3° 32' 52.07"
Cohesion	c' (Kg/cm^2)	-	0,041
Consolidation Test			
Insitu Void Ratio	eo	1,511	1,668
Coefisien of Consolidation	Cv (Cm^2/sec)	3,01E-02	1,31E-02
Compression Index	Cc	0,6664	1,5720
Permeability	K (Cm/sec)	3,71E-06	1,31E-06

C. Overview of Handling in the Field

In the soil improvement process using the soil filling method used at this location, it is necessary to use several approaches in the modeling process which will later be used in the Plaxis 3D program. This approach needs to be done to be able to model the value of the decline that occurs in the field. Considering the conditions in the field, of course, some adjustments will be made that are deemed necessary to save costs.

For example, the use of 1 PHD to connect 2 PVDs can be done because at the time of use in the field the horizontal flow value is not disturbed by the use of this method. Of course, during modeling this will be quite difficult because in PLAXIS 3D modeling line drains can only be used to connect two points.

Figure 8
Installation of PVD and PHD in the field

Figure 8 shows the work process carried out in the field. Where in the field work the use of PHD is more optimized by using 1 line of PHD to flow 2 lines of PVD. This can be done because in the previous soil improvement process, when trying to optimize the use of PHD, there was no blockage in the horizontal flow.

D. Stages of Research

In writing this thesis, the authors carry out several stages of implementation in order to achieve the aims and objectives of the research, as summarized in Chapter I. To facilitate the achievement of these goals, the authors perform the following stages:

1. The first; stage is to collect various types of literature in the form of books and scientific writings related to this thesis.
2. The second; stage is to collect data that will be used in analyzing. The subject of this thesis is the construction of the Tebing Tinggi - Kisaran Toll Road. The data needed for writing this thesis was obtained from PT. Hutama Karya as contractor. The data obtained are the results of the SPT (Standard Penetration Test), soil parameters, PVD and PHD specifications and geotechnical instruments.
3. The third; stage At this stage, activities will be carried out to analyze the settlementsettlement ofof the soft soil layer which is improved by the method of applying the load using soil piles combined with PVD and PHD using PLAXIS 3D. This analysis process will use the basic modeling method Hird (1995) which performs analysis using the Mohr-Coloumb soil model to model the soil in the PLAXIS 3D program so that it is expected to be close to soil conditions that have improved in the field.
4. Fourth; stage At this stage, activities are carried out to analyze the decrease in total settlement of soft soil layers repaired with PVD and PHD using the PLAXIS 3D program to then be compared with field monitoring data obtained from theinstrument settlement plate.

Furthermore, the research flow chart is attached in Figure 9 in order to make it easier to understand the steps taken by the author in this study.

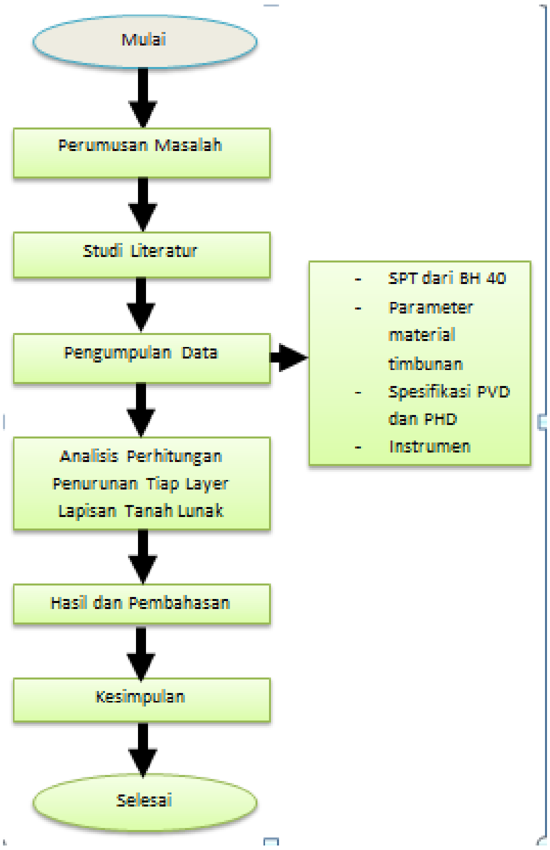

Figure 9
Research Flowchart
General

Result and Discussion

A. The results of the analytical calculation obtained the amount of land subsidence of 16.09 cm. This result is relatively close to the actual decrease observed in the field, where the decrease is 16.3 cm. There is a difference of 0.21 cm because the laboratory data do not represent the entire soil layer in the field, where from the boring data only 2 samples of laboratory testing were carried out, namely at a depth of 3.5 - 4 meters and a depth of 11.5 - 12 meters.

B. After analyzing using plaxis 3d modeling with several approaches, the results are obtained as shown in table 4.3. From the results of this approach, it can be concluded that the modeling value with 2 pvd lines and 2 phd lines taking into account the smearzone effect is closer to the decrease in results from field monitoring.

C. The modeling approach used to determine the soil parameters that were not carried out by laboratory testing obtained results close to the results of observations in the field, with a percentage value of < 1.5%.

D. The modeling approach, although different from the work in the field, obtained results that were quite close to the data from the monitoring carried out in the field. This shows that phd as horizontal drains can drain 1 line of pvd or 2 lines of pvd.

E. The pattern of decline shown in figure 4.9 illustrates that the predicted decline obtained from plaxis 3d is larger and faster than the decline observed in the field. This is because the mohr-coloumb soil model only uses one value of the soil stiffness modulus (e). From the graph it can be concluded that the e value that occurs in the field is smaller than the modeled e value. However, if in plaxis 3d the value of e is reduced, then the results obtained will be greater than the results obtained in the field. This can be anticipated by using soil modeling with the hardening soil model which can model the secant stiffness and tangential stiffness of the soil.

F. The depiction of the smear zone effect with the disturbed zone value described as 2 x the mandrel dimension and the k value of disturbed soil is 2 times smaller than the initial k of the soil, obtaining results that are quite close to the results of monitoring in the field. This shows that the modeling that has been done is appropriate. Due to the reality on the ground, the soil will experience a smearzone effect as a result of the pvd erection process on a 17.4 meter long soil layer.

G. Phd is proven to function as horizontal drains to replace the sand blanket function. This can be used as an alternative in the future for the improvement of soft soil with the method of loading with soil piles combined with pvd, which is difficult to access sand as a sand blanket material can use phd.

Conclusion

Based on the results of the analysis and discussion, it can be concluded that: 1). Calculation of consolidation settlement using analytical theory is close to the actual settlement results that occur in the field with a value of 16.09 cm compared to field monitoring of 16.3 cm with a percentage difference of 1.31% . This difference in settlement occurs because the laboratory data values cannot represent the entire soil layer under review. 2). The decrease in consolidation using plaxis 3d modeling with 2 lines of pvd and 2 lines of phd and taking into account the effect of the smear zone resulted in the most accurate calculation model with a value of 16.28 cm compared to field monitoring of 16.3 cm with a percentage difference of 0, 12%. 3). Phd works well as a substitute for sand blanket material to drain water horizontally from the end of the pvd to leave the repaired soil location. With this, phd can be used as an alternative to horizontal drains in soil improvement with the loading method using soil heap combined with pvd, if the location is difficult to find sand material as a sand blanket. 4). The pattern of decline that occurs in the 3d plaxis modeling is greater in a shorter time than the decline that occurs in the field. This is because in this study modeling was carried out using the mohr-coloumb soil model. This can be corrected by soil modeling using a hardening soil model, with a more complete laboratory test value.

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