Analysis of PVD Installation Methods Due to Limited Vertical Clearance in the Lamongan North Ring Road Construction Project Section 1 STA 0+400 to STA 0+426

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ABSTRACT

The construction of the Lamongan North Ring Road is planned to be built on soft soil. Based on the results of the soil investigation, it is known that the subgrade condition is classified as soft to very soft soil with a depth of 18 meters. One of the problems of this very soft soil is the settlement. Therefore, the National Road Implementation Agency of East Java - Bali Region conducted subgrade improvement using preloading combined with Prefabricated Vertical Drain (PVD). The configuration of the PVD installation is 18 meters deep with a triangular pattern and the distance between PVDs is 1 meter. To stake the PVDs 18 meters deep, a piling rig with a minimum height of 24 meters is required. In the STA 0+400 to STA 0+426 section there is a 150 kV Lamongan - Paciran High Voltage Air Line (SUTT) cable crossing the road with a conductor to platform distance of 18 meters. The existence of this cable is a challenge in the PVD driving as deep as 18 meters. Therefore, this journal will analyze the PVD piling implementation method that can be carried out in this segment. The method carried out in this study is to start with the collection of secondary data such as shop drawings as a reference for the implementation of work in accordance with the planned design. Based on the design plan, an implementation method that can be applied to limited vertical clearance conditions is obtained. Based on the results of the research, an 18-meter deep PVD installation method was obtained that can be applied to limited vertical clearance conditions in the Lamongan North Ring Road construction project Section 1 STA 0+400 to STA 0+426. In addition, it was also found that the time required was 34.75 minutes to stake 1 PVD point using the pulled hole PVD method.

Keywords : soft soil, pulled hole PVD, limited vertical clearance

INTRODUCTION

The construction of the Lamongan North Ring Road is a government effort to unravel the congestion that occurs along the national road where there are two railroad crossings on the existing national road that form a sharp angle. This sharp angle reduces safety for road users, especially for heavy vehicles passing through. This road will replace the existing national road and eliminate the two railroad crossing points. The construction of this road is expected to increase the level of safety for road users, especially for large vehicles and two-wheeled vehicles.

This road was constructed on soft soil, as determined by the results of soil investigations. These investigations were carried out using the deep drill/core drilling method at nine locations: seven along the main road and two at the bridge site. The purpose was to obtain SPT (Standard Penetration Test) values and assess soil characteristics by analyzing undisturbed samples in the laboratory, ensuring accurate calculations of soil bearing capacity. The investigation revealed that the subgrade consists of soft to very soft soil, with depths ranging from 12 to 18 meters

One of the challenges associated with very soft soil is settlement, which is expected to occur during the construction period. To address this, subgrade improvement measures are essential. The National Road Implementation Agency of East Java - Bali Region has planned soil improvement using a combination of preloading and PVD/PHD. The principle of this method is to accelerate the soil consolidation process by removing pore water through preloading, allowing the planned soil compression to occur earlier in the construction timeline.

There is a High Voltage Air Line (SUTT) Lamongan - Paciran with a voltage of 150 kV located between STA 0+400 and STA 0+426, crossing the road with a conductor-to-platform distance of 18 meters. The position of the SUTT cable crossing the planned roadway can be seen in Figure 1.

Figure 1. Position of the SUTT cable crossing the planned roadway

Based on the Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia Number 13 of 2021 concerning Clearance Space and Minimum Clearance Distance for Electric Power Transmission Networks and Compensation for Land, Buildings, and/or Plants Located Under the Clearance Space of Electric Power Transmission Network, states that for SUTT 150 kV, the minimum vertical clearance distance from the conductor to the road location is 9 meters. Due to the limitation of this minimum vertical clearance, it presents a challenge in this segment to install PVDs to a depth of 18 meters. Therefore, in this journal an analysis of possible PVD piling methods will be carried out.

LITERATURE REVIEW

Soft soil

Soft soils relate to those soils that if not recognized and investigated carefully can cause intolerable long-term instability and settlement problems; the soils have low shear strength and high compressibility (Geotechnical Manual 4, 2002). Soft soils are generally classified as cohesive with a consistency of very soft to soft. Soft soil properties are low strength, low cohesion, small internal shear angle, low permeability, high deformation and high plasticity. (Wahyudi, 2018).

Problems in Soft Soils

In the construction of roads on soft soils, there are really only two problems that must be faced, namely that the embankment must be stable throughout its planned life, and the settlement that occurs in road construction is still acceptable. The settlement of the subgrade occurs due to the additional load on it. The increase in weight on top of a soil surface can cause the soil layer underneath to compress. The compression is caused by deformation of soil particles, relocation of particles, escape of water or air from the pores, and other causes. Some or all of these factors have a relationship with the state of the soil itself. In general, settlement in soils caused by loading can be divided into two major groups, namely: consolidation settlement and immediate settlement. Immediate settlement results from the elastic deformation of dry, wet, and water-saturated soils without any change in moisture content. Consolidation settlement results from changes in the volume of water-saturated soil as a result of the release of water that occupies the soil pores (Braja M. Das, 1995). In soft soils, this consolidation settlement is significant and occurs over a long period of time. The low bearing capacity of the soil can result in sliding of the embankment above. In planning road embankments on soft soil, stability and settlement analysis is required so that the desired embankment height for the road body will not decrease again after construction or at least the decline that occurs in road construction is still acceptable and the stability of the embankment slope can be fulfilled.

Surcharge

Surcharge is a method of eliminating or reducing long-term settlement by imposing a temporary additional load on top of the embankment to accelerate primary settlement. The applied load must be sufficient, so that the settlement that occurs during implementation will be equal to the total settlement or the residual settlement will be less than the allowable post-construction settlement. When the required settlement has been achieved, the additional load is removed or relocated. Implementation time may be the main limitation of using this method of adding load. If time is not available and the option to extend the contract is not accepted, then to be effective, this method should be combined with other methods to accelerate consolidation, such as vertical drains (Geotechnical Manual 4, 2002).

Prefabricated Vertical Drain

Prefabricated Vertical Drain (PVD) is a ribbon-shaped material consisting of a core and a jacket installed vertically by a specific installation method that functions as a diverter. The PVD core is a plastic material that supports the filter layer and allows the flow of water along the drain. The PVD blanket is a material that physically separates the core from the surrounding soil and filter to limit soil escape into the core (Binamarga, 2021). These PVDs are installed to part or all of the depth of the soft soil at specified distances. For deeper soft soil layers, the presence of PVDs will reduce the drainage path, and therefore accelerate the consolidation process.

PVDs are installed by driving them into the soft soil using specialized equipment. In general, the PVD piling tool is an excavator as the base machine. The excavator arm and bucket are removed and replaced by a rig. The rig is a series of iron structures that support a mandrel in the center of the rig. The mandrel is an iron sleeve that acts as a casing for the PVD against ground disturbance. The mandrel can be plugged and retracted. During piling, the PVD and mandrel are deployed together. When the mandrel is withdrawn, the PVD will be left behind along with the armature. The anchor is a material placed at the end of the PVD in the form of a bar or pipe or plate that serves as an anchor for the end of the PVD. After the mandrel is fully raised, the PVD is cut approximately 30 cm from the land elevation. The rig height and mandrel length should be at least equal to the planned depth of the PVD pile

The minimum vertical clearance distance from the conductor

Based on the Regulation of the Minister of Energy and Mineral Resources of the Republic of Indonesia Number 13 of 2021, the minimum vertical clearance distance from the conductor is the shortest vertical distance between the transmission line conductor and the Earth's surface or objects above the surface, which must not be less than the specified distance for the safety of humans, living creatures, and other objects, as well as the security of the Electric Power Transmission Network's operation. The minimum vertical clearance distance from the conductor allocated for the road is 9 meters. A visualization of the minimum vertical clearance distance can be seen in Figure 2.

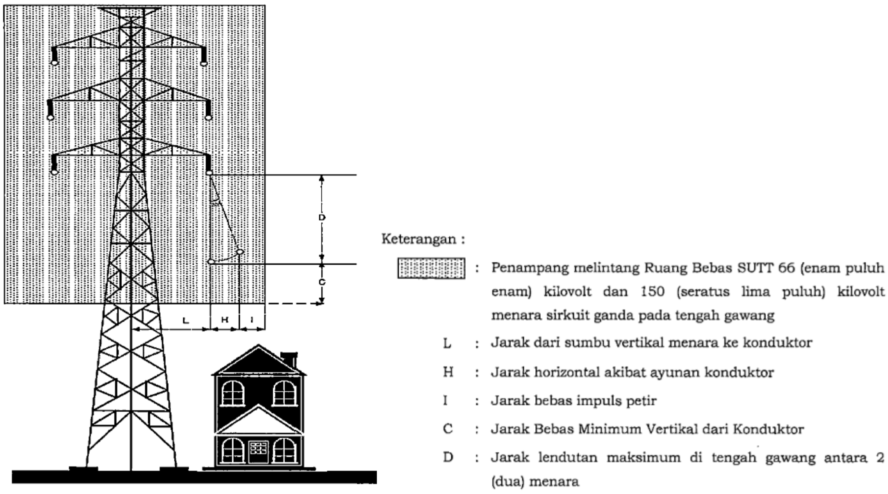

Figure 2. Clearance space of SUTT

RESEARCH METHOD

The method used in this research is to firstly search for the secondary data needed in this research. This research uses secondary data obtained from the National Road Implementation Agency of East Java - Bali Region. Secondary data obtained include DED, shop drawings, soil test data and data on the calculation of additional plan loads (pavement loads and traffic loads). This study aims to determine the implementation method of 18-meter deep PVD installation in the Lamongan North Ring Road Construction Project Section 1 STA 0+400 to STA 0+426 due to limited vertical clearance due to SUTT cables crossing the road section plan.

DATA COLLECTION

From the shop drawings obtained, it is known that in the STA 0+400 to STA 0+426 segment, the soil improvement to be carried out is to use a combination of preloading and using PVDs which are staked in soft soil 18 meters deep with a triangular pattern and a distance of 1 meter.

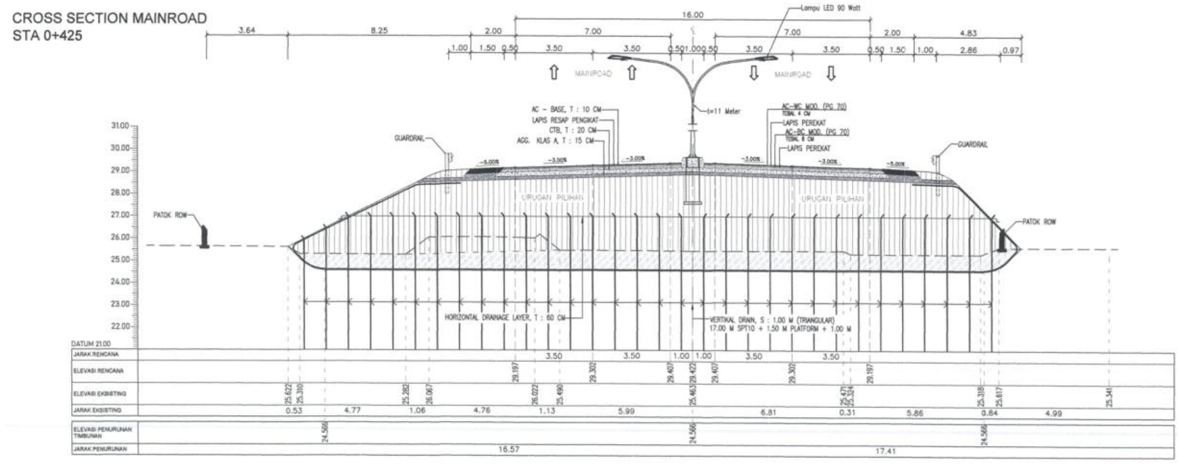

Figure 3. Cross section mainroad STA 0+425

RESEARCH ANALYSIS

Identification of Vertical Clearance

Based on information from PT Jaya Konstruksi - Gorga KSO, coordination has been conducted with PLN, confirming that the minimum vertical clearance, which should remain undisturbed, is 7 meters measured from the conductor cable. As a result, a clearance of 11 meters is allowed for heavy equipment to operate beneath the conductor cable at the location between STA 0+400 and STA 0+426, as shown in Figure 4.

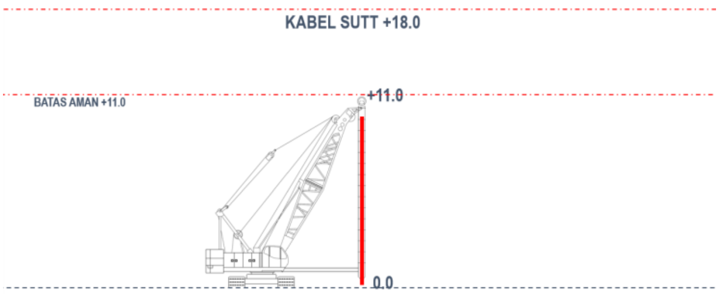

Figure 4. Permitted vertical clearance

Implementation of Platform Embankment

Before driving the PVDs, a platform embankment, which is part of the preloading embankment, was constructed with a thickness of 1.5 meters. This platform fill was carried out to overcome the flood water level at the project site and as a foundation for heavy equipment. The platform fill material used the same material as the preloading fill, namely lime stone material weighing 1.88 tons/m3.

Implementation method of PVD installation

With the available distance of 11 meters from the platform, an implementation method can be analyzed that can be applied to install PVDs 18 meters deep. The equipment used specifically in this segment is a 50 tonne capacity crawler crane, PC 200 excavator, static rig with a maximum length of 11 meters, two mandrels (mandrel-1 in the crane with a length of 9 meters and mandrel-2 detachable with a length of 9 meters). The PVD installation method that can be carried out in the STA 0+400 to STA 0+426 segment is shown in Figure 5 with the following explanation:

1. The ground or work floor must be free of rocks.
2. The distance between the work platform and the lowest available cable conductor is 18 meters.

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3. The maximum allowed height of PVD installation equipment is 11 meters.
4. Make PVD point markings with a pattern that matches the design, which is a triangle pattern with a distance of 1 meter.
5. Punching process using crawler crane and rig, i.e. piling without material to a depth of -9 meters with mandrel-1.
6. Slide the crane position away from the hole area.
7. Inserting PVD material into mandrel-2 and installing anchor plates at the bottom and tying PVD ends at the top.
8. Mandrel-2 and PVD material are inserted into the hole using an excavator.
9. A connection was made between the mandrel-1 on the crane rig and the mandrel-2 that had been anchored. For the provision of PVD connection, a 20 cm overlap was made between the old and new connections, where 6 strapless connections were made at the old connection and 6 at the new connection.
10. Crawler cranes and rigs carried out piling to a depth of -18 meters.
11. Remove mandrel-1 from a depth of -18 meters to a depth of -9 meters with the crane.
12. Unattach mandrel-1 and mandrel-2 and hold mandrel-2 with the help of excavator so t hat mandrel-2 does not fall into the hole.
13. Remove mandrel-2 with an excavator.
14. PVD installation is complete and can proceed with embankments in stages.

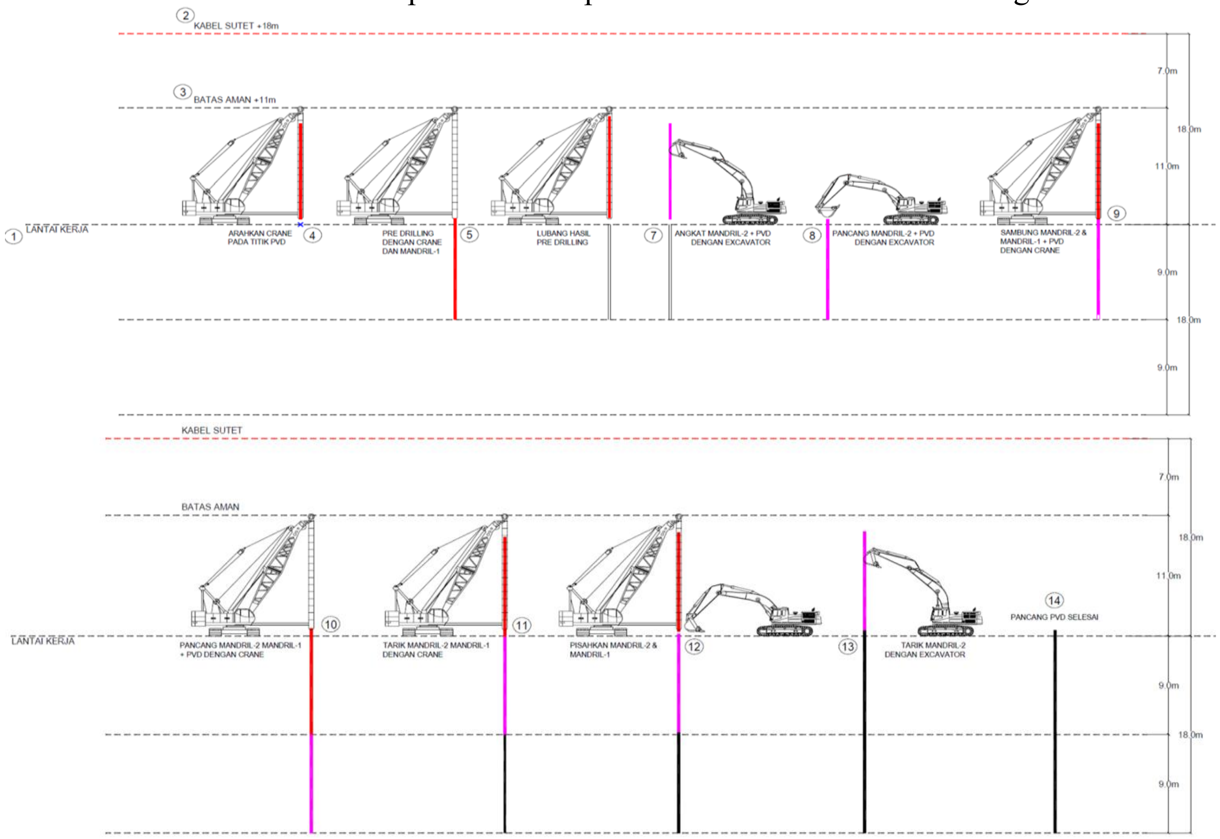

Figure 5. Stages of PVD installation in limited vertical clearance

Calculation of Time Requirements for the Pulled Hole Method's Implementation

Using the method outlined above, a trial installation was carried out in the field. The time required to install one PVD point, based on the field trial results, is presented in Table 1 through Table 4.

Table 1. Time Requirement for PVD Installation at Point 1

No	**Tools**	**Work Step**	**Time**		
			Start	**Finish**	**Duration (minutes)**
1	Mandrel	Install PVD on Mandrel	10:01	10:04	3
2	Crawler Crane	Drilling without PVD to a depth of ± 9 m (location change due to obstruction by large-diameter material)	10:04	10:10	6
	Crawler Crane	Drilling without PVD to a depth of ± 9 m	10:13	10:14	1
3	Excavator	Install mandrel (+PVD) to a depth ± 9 m	10:14	10:23	9
4	Crawler Crane	Connect both mandrels then remove mandrel with crawler crane	10:23	10:33	10
5	-	PVD Installation Finished	10:33	10:35	2
6	Excavator	Remove mandrel + place it to the closest position to the excavator	10:35	10:41	6
			Total Time		37

Table 2. Time Requirement for PVD Installation at Point 2

No	Tools	Work Step	Time		
			Start	Finish	Duration (minutes)
1	Mandrel	Install PVD on Mandrel	14:05	14:07	2
2	Crawler Crane	Drilling without PVD to a depth of ± 9 m	14:07	14:10	3
3	Excavator	Install mandrel (+PVD) to a depth ± 9 m	14:10	14:21	11
4	Crawler Crane	Connect both mandrels then remove mandrel with crawler crane	14:21	14:22	1
5	-	PVD Installation Finished	14:32	14:34	2
6	Excavator	Remove mandrel + place it to the closest position to the excavator	14:34	14:38	4
			Total Time		23

Table 3. Time Requirement for PVD Installation at Point 3

No	Tools	Work Step	Time		
			Start	Finish	Duration (minutes)
1	Mandrel	Install PVD on Mandrel	14:41	14:45	4
2	Crawler Crane	Drilling without PVD to a depth of ± 9 m	14:45	14:48	3
3	Excavator	Install mandrel (+PVD) to a depth ± 9 m	14:48	14:59	11
4	Crawler Crane	Connect both mandrels then remove mandrel with crawler crane	14:59	15:23	24
5	-	PVD Installation Finished	15:23	15:25	2
6	Excavator	Remove mandrel + place it to the closest position to the excavator	15:25	15:28	3
			Total Time		47

Table 4. Time Requirement for PVD Installation at Point 4

No	Tools	Work Step	Time		
			Start	Finish	Duration (minutes)
1	Mandrel	Install PVD on Mandrel	14:41	14:45	4
2	Crawler Crane	Drilling without PVD to a depth of ± 9 m	14:45	14:48	3
3	Excavator	Install mandrel (+PVD) to a depth ± 9 m	15:28	15:37	9
4	Crawler Crane	Connect both mandrels then remove mandrel with crawler crane	15:37	15:49	12
5	-	PVD Installation Finished	15:49	15:51	2
6	Excavator	Remove mandrel + place it to the closest position to the excavator	15:51	15:53	2
			Total Time		32

The average was calculated from Tables 1 to 4 to determine the time required for the PVD work under the SUTT cable in the segment from STA 0+400 to STA 0+426. The average time obtained is 34.75 minutes to install one PVD point.

Calculation of Surcharge

The embankment used in soft soil improvement work with a combination of preloading and PVD in the Lamongan North Ring Road Section 1 construction project has a function, which is as embankment to fulfill the elevation design and also as a preloading load. Based on the shop drawing, it is known that the final top subgrade embankment height is 3.409 meters. To reach the final height, it is necessary to calculate the additional load plan consisting of pavement loads and traffic loads including the prediction of the settlement that occurs due to the load received by the soil. The calculation of the plan load is as follows:

a. Traffic load.
   Calculation of traffic load based on SNI 8460:2017 on geotechnical planning requirements for class I roads the traffic load is planned at 15 kPa.
b. Pavement load.
   The calculation of pavement load is described as follows:

Table 5. Calculation of pavement load

Uraian	**Thickness**	**Unit weights**	**Total Load**
	m	**t/m3**	**t/m2**
AC-WC	0,04	2,30	0,092
AC-BC	0,06	2,30	0,138
AC-Base	0,10	2,30	0,230
CTB	0,20	2,30	0,460
Agregat Base A	0,15	1,80	0,270
Total pavement load (t/m2)			1,190
Total pavement load (kPa)			11,90

c. Plan load $= traffic\ load + pavement\ load$
$= 11{,}9\ kPa + 15\ kPa$
$= 26{,}9\ kPa \sim 1{,}431\ m$

Load ratio 1.3, maka $H_{surcharge} = 1{,}3\ \times 1{,}431 = 1{,}860\ m$ …(1)

CONCLUSION

Based on the results of the analysis and calculations presented in the previous chapter, the following points can be concluded:

1. PVD installation to a depth of 18 meters with limited vertical clearance conditions in the Lamongan North Ring Road construction project Section 1 STA 0+400 to STA 0+426 can be carried out using the pulled hole PVD method.
2. The time required is 34.75 minutes to stake 1 PVD point using the pulled hole PVD method.
3. The height of the additional embankment based on the calculation of the preloading load design, that is, the additional plan load consisting of pavement loads and traffic loads is 1.86 meters high.

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