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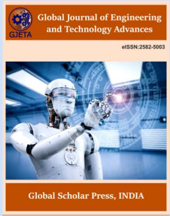

(Review Article)

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Improvement of soft soil for road construction on the north brebes tegal ring road project

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Abstract

The Brebes-Tegal North Ring Road is a primary arterial road located in the Central Java North Coast (Pantura) corridor that crosses Brebes Regency (12,385 km) and Tegal City (4,715 km), this road was built with the aim of breaking up the traffic congestion that occurred in the City Center of Brebes and Tegal City. In 2010, the construction of the Brebes-Tegal North Ring Road began. However, in 2013 development activities temporarily stopped due to a number of problems, one of which was the condition of the soil at some of the construction sites in the form of swamps and ponds resulting in low soil carrying capacity which affected the construction of roads on it. This condition starts from STA. 8+800 to STA. 17+377 from the direction of Brebes to Tegal. therefore, in December 2019 the project was resumed with a design change to improve the subgrade so that it could withstand the burden of road construction and passing traffic. Soil improvement is carried out using geotextiles, PVD and PHD in the selected soil embankment work process so as to increase the CBR value of the subgrade for the better (higher CBR). In addition, in bridge construction work it is necessary to use pile slabs to prevent high pile failures.

Keywords: Soft soil; Soil improvement; PVD – PHD; Brebes-Tegal North Ring Road

1. Introduction

Brebes Regency and Tegal City are areas located in the northernmost western part of Central Java Province, and are directly bounded by Cirebon Regency to the west and Tegal Regency to the east, and are passed by a national road network that divides the center of trade, services and the district government center. Brebes and Tegal City.

The traffic condition on the North Coast route (Pantura) of Brebes Regency, especially those entering the inner city road, is quite dense. In fact, for a certain time vehicle traffic becomes congested and even congestion occurs. This congestion is caused by the development of various economic sectors that are centralized especially in the middle of the city, as well as increased traffic flows between provinces as a result of increased national economic activity, plus the types of vehicles that cross the northern coast route vary, both from small, medium or large vehicles.

To facilitate traffic transportation on the Brebes Pantura route, the idea emerged to build a new road that would later function as a ring road. The location for the construction of this ring road is located in the corridor of the North Coast of Java (Pantura) Central Java which crosses Brebes Regency (12,385 km) and Tegal City (4,715 km) which is known as the Brebes-Tegal North Ring Road. The handling of this road section begins in front of the Puskud Office of Klampok Village, Brebes Regency, then leads diagonally to the North then to the East until it crosses the Kaligangsa River, then enters the Tegal City boundary area via Jalan Sipelem Raya, Jalan Tendean and ends at Jalan Yos Sudarso (Sta. 17+100).

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Characteristics of roads that have been built are as follows:

- Type road : 2 undivided two-way lane (2/2UD)
- Functionroad : primary artery
- Widelane : 3.50 m
- Wideshoulder : 1.00 m

The construction of the Brebes-Tegal North Ring Road itself has been carried out, with the realization of physical implementation on 13 February 2013 of 48 percent, where backfill activities have been completed for 15 kilometers and asphalting has been completed for 5 kilometers from the starting point (Sta. 0+000) . However, due to several obstacles, the construction of this road was stopped. One of the obstacles causing the construction of the Brebes-Tegal North Ring Road to stop is the condition of the soil at the location of the development plan, which is partly in the form of swamps and ponds, making it difficult to carry out project planning and implementation. This is related to the nature of the original soil which has a high water content so it is easy to experience swelling and shrinkage. This condition starts from STA. 8+800 to STA.17+377 from the direction of Brebes to Tegal. Whereas in the previous STA there were no problems whatsoever and part of the road construction had already been carried out.

From the point of view of Civil Engineering, swamps or ponds have a high water content and have high expansive properties (swelling and shrinking due to changes in water content) in addition to a low CBR value, expansive soil is a major hazard in the geotechnical field which can cause severe damage to performance. and infrastructure service life. Therefore it is necessary to improve the subgrade so that it is able to withstand the construction load on it so that construction/building failures can be avoided and can reach its age or service life.

2. Literature review

Research and writing aboutSoft soil improvement methods have been widely used, including preloading a combination of PVD/PHD, geotextiles, vacuum has been widely used in the construction of road embankments in Indonesia. The use of PVD combined with preloading is seen as quite optimal as a method of improving soft soils on the Pejagan-Pemalang Toll Road (Zakia and Kuswanda, 2019). Ali and Wulandari conducted a comparative study of soft soil improvement using PVD combined with preloading and vacuum on the Betung Ship Toll Road (Kayu Agung - Palembang - Betung). The same study by Rahadian,

3. Theoretical Basic

3.1. Soft Soil

Soft soils are cohesive soils, most of which are composed of small grains such as clay and silt (Zakia, 2019). Soft soils are generally found in swamp plains, floodplains, tidal flats, and river alluvial plains (Munawir, 2019). To find out the type/classification of a soil, it is necessary to carry out soil testing, such as a sondir test and drill test. The properties of soft soil include high water content, low permeability coefficient, high compression, and low shear and bearing capacity which can cause potential construction problems in the form of settlement.

3.2. Soil Incompressibility (Consolidation)

Soil consists of minerals, organic matter content, and various loose deposits, which are located on bedrock. The space between soil particles can contain water, air, or both (Hardiyatmo, 2018). If a layer of soil is given a load on it, it will cause compression (consolidation) in the soil. Soil compression occurs as a result of soil deformation, water or air escaping from the soil pores, and particle relocation.

Land settlement is divided into 2 (two) types, namely: immediate settlement and consolidation settlement. Settlement occurs immediately due to elastic deformation of dry, wet, and water-saturated soils without any change in moisture content. Meanwhile, a decrease in consolidation occurs when the saturated soil that is loaded on it causes the pore water to gradually release, resulting in a decrease in soil volume (Hardiyatmo, 2020). In general, land subsidence is divided into 3 (three) stages, namely:

- Initial compression, which is caused by the heap of preload.
- Primary consolidation, namely the period of land subsidence during the continuous transfer of pore water pressure into the effective stress of the soil and as a result of water escaping from the soil pores.

- Secondary consolidation, namely soil subsidence that still occurs after all pore water pressure has been released and as a result of the adjustment of plastic soil grains.

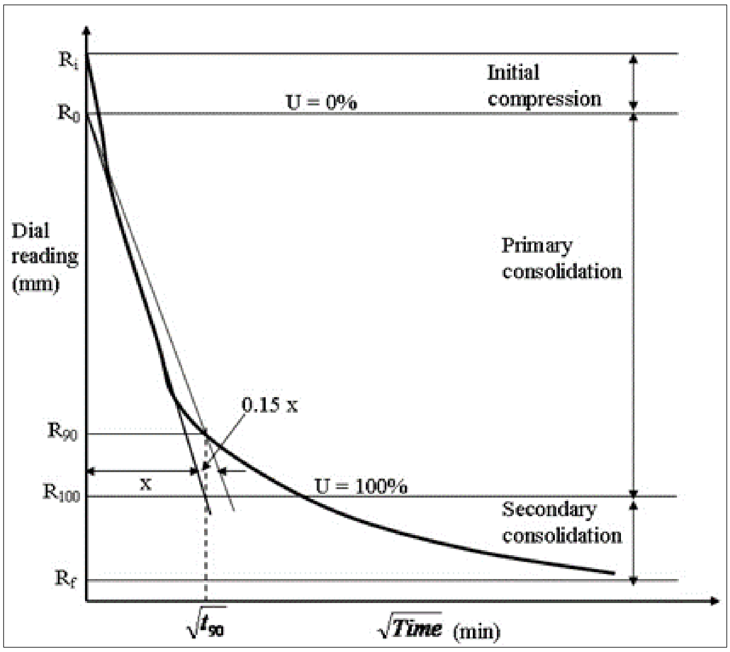

Figure 1 Graph of Relationship between Land Consolidation Stages and Time

Figure 1 shows the relationship between consolidation stages and soil consolidation time. The amount of settlement value and waiting time for consolidation will vary, which is influenced by the type and thickness of soft soil, permeability or flowability, and the intensity of the work load (Dewi & Faisal, 2020). Soft soils with low permeability cause the process of release of pore water pressure due to loading on it to occur in a long time. This condition has the potential to create long-term problems for the construction above it, so that improvement methods are needed so that land subsidence due to consolidation can be achieved immediately. The consolidation process is declared accomplished when the land subsidence value has reached 90% of the primary consolidation value or the target degree of consolidation is 90% (Hardiyatmo, 2018).

3.3. Soft Soil Improvement Method

The types of soil improvement methods according to Ruswanda are presented in the following table:

Table 1 Soil Improvement Methods

Ground Improvement Method	**Type of Soil**		**Ground Improvement Objectives**				
	Granular	Cohesive	Bearing Capacity	Settlement Control	Lateral Stability	Environmental Control	Liquefaction Resistance
Vibrocompaction	v	-	v	v	-	-	v
Dinamic compaction	v	-	v	v	-	v	v
Blasting	v	-	v	v	-	-	v
Compaction grouting	v	-	-	v	-	-	-
Preloading / VD	-	v	v	v	-	-	-
Electro osmosis	-	v	v	v	-	-	-
Vacuum consolidation	-	v	v	v	-	-	-
Lightweight Fill	v	v	-	v	-	-	-
Mechanical stabilization	v	-	v	v	v	-	-
Soil Nailing	v	-	-	-	v	-	-
Soil Anchoring	v	-	-	-	v	-	-
Micropiles	v	-	v	v	v	-	-
Stone coloums	-	v	v	v	v	-	v
Fiber reinforcement	v	-	v	v	v	-	-
Permeation grouting	v	-	v	v	-	v	-
Jet grouting	v	v	v	v	v	v	v
Deep soil mixing	v	-	v	v	v	v	v
Lime colomns	-	v	v	v	v	v	v
Fracture grouting	-	v	v	v	-	v	-
Ground freezing	v	v	-	-	v	v	-
Vitrification	v	v	-	-	-	v	-
Electrokinetic treatment	-	v	-	v	-	v	-
Electroheating	-	v	-	v	-	v	-
Biotechnical stabilization	v	-	-	-	v	v	-

3.3.1. Geotextiles

Geotextiles are thin, flexible, permeable synthetic sheets used for soil stabilization and improvement associated with civil engineering works. The use of geotextiles is a modern way of strengthening soft soils.

Figure 2 Geotextile

Some of the functions of geotextiles are:

- For strengthening soft soil.
- For civil engineering construction which has a long design life and supports large loads such as rail roads and retaining walls.
- As a separation field, filter, drainage and as a protective layer.
- Geotextile can be used as a reinforcement of soil embankments in cases of: • soil embankment on soft soil • embankment on pile foundation • embankment on soil prone to subsidence

The use of reinforcing construction in a wetland was first reported using steel mesh under tidal embankment construction in France. Comparisons between stockpiles on peat in Africa with and without reinforcement are reported. It was stated that apart from the woven polypropylene fabric, the tensile stress of all types of geotextile samples taken from the previous year's installation reduced between 25% and 36% of their initial tensile stress, although this did not significantly affect their function.

Implementation of road construction on wetlands with geotextile reinforcement can prevent local collapse on soft soils due to low soil carrying capacity. The advantage of installing geotextile on the construction of roads on soft soil is the speed in implementation and relatively cheaper costs compared to conventional backfilling methods.

Geotextiles on roads function as a reinforcement layer as well as a separator layer (separator) between the embankment material and the subgrade so that the road construction becomes stable, not bumpy and flat on the surface.

3.3.2. Vertical Drain

Saturated soft clay is soil with very small capillary cavities so that the consolidation process when the soil is loaded requires quite a long time, so to remove water from the soil quickly is to make a vertical drain at a certain radius so that the water contained in the soil will mobilize out through the vertical. installed drains.

This vertical drain can be in the form of a stone column or using fabricated materials produced by geosinindo or other factories. This vertical drain work is usually combined with pre-load work in the form of a landfill, with the intention of providing a load on the soil so that the water contained in the soil can be mobilized more quickly.

3.3.3. Bamboo Pile or Corduroy

Several studies on the use of bamboo as a construction material. The use of bamboo reinforcement can increase the compressive strength and shear strength of the soil (Kandolkar & Mandal, 2012). Bamboo as soil reinforcement is better than geotextiles (Marto & Othman, 2011). The combination of bamboo grids and bamboo poles as embankment reinforcement on peat soils shows the ability to reduce settlements and deflections so that embankment stability is maintained (Maulana et al., 2018).

The working principle is that before backfilling is carried out, first place a cushion made of either bamboo (cerucuk) or logs (corduroy) so that when the land is spread out it does not mix with the original soil underneath and the piled up soil forms a unit that floats on the original land like a floating pontoon. on the water. There is a bamboo cerucuk foundation that has been modified and patented by Mr. Mansyur Irsyam (ITB lecturer) which has been applied to several regions in Indonesia and has proven its benefits.

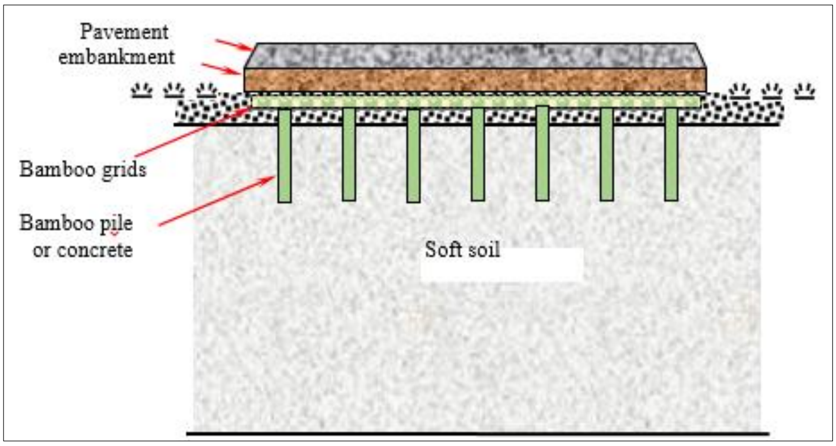

Figure 3 Construction of soil reinforcement with bamboo cones

3.3.4. Pile

can be in the form of bore pile or PC spun pile, so that the structure that we will build on the land is no longer resting on the soft soil, it will still be supporting on the hard soil layer below it. One thing to consider when planning pile foundations on soft soils is negative skin friction.

Each soil improvement method has advantages and disadvantages for each method, the application of these methods depends on soil conditions from laboratory results. laboratory results will show the type of soil, so we can choose the method to be applied by considering several aspects such as: economic, environmental aspects and the type of construction to be built.

3.4. PVD and PHD

PVD-PHD (Prefabricated*VerticalDrain*and Prefabricated Horizontal Drain) is an alternative method that can be applied to overcome a problem in soft soil (Kuswanda, 2019). Soft soils contain water and air that occupy soil pore areas (soil cavities). This method is used to accelerate the process of removing water and air above the soil surface vertically through the PVD and then flowing horizontally through the PHD which is covered with sand (sand). ditch). The sand ditch functions to hold back the flow rate of water and air so they don't seep out of the PVD before it reaches the PHD. The use of the PVD-PHD method allows the release of pore water from the soil with low permeability to be accelerated so that the soil compression time becomes shorter.

Figure 4 PVD (left) and PHD (right)

PVD has a shape like a grooved sheet with 2 (two) parts, namely a core of polypropylene and a jacket of polymer material. The core (core) functions to drain water out of the soil while the core blanket functions to prevent the entry of soil particles which can clog or reduce the efficiency of water flow in the PVD core. Similar to PVD, PHD is a material with a core (core) shaped like a pipe made of polypropylene and covered with a jacket made of polymer material. PVD and PHD illustrations are presented in Figure 4.

The PVD installation pattern is divided into 2 (two), namely the triangular pattern and the square pattern as shown in Figure 5. Puspita and Capri made a comparison of the effect of the PVD pattern on subsidence of soft soil on the Palembang-Indralaya Toll Road Project (Puspita & Capri, 2017). Consolidation using the PVD method with a triangular pattern with a distance of 1.0 meters between the PVDs gives a settlement of 1.354 meters with a waiting time of 25 days faster consolidation when compared to the rectangular pattern with the same distance. According to (Munthe et al., 2021) installing PVD using a triangular pattern at a distance of 1.1 meters provides a faster consolidation time than distances of 1.3 meters and 1.5 meters with the same pattern. Thus, the installation pattern and spacing between PVDs (space)

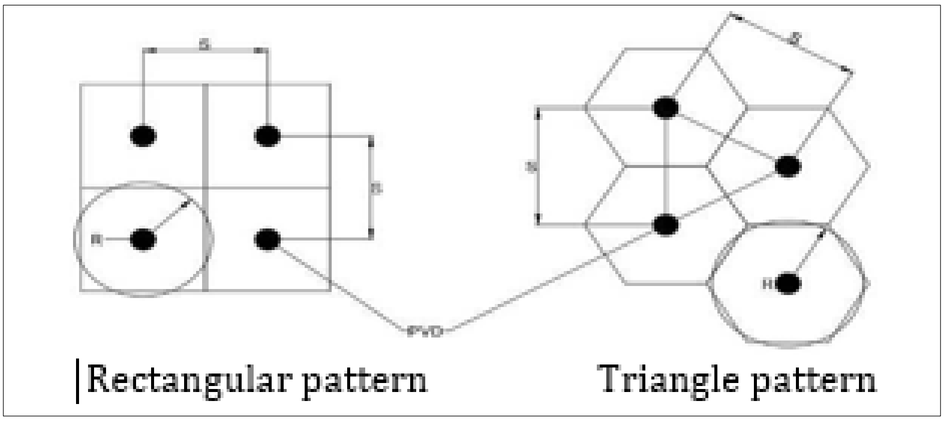

Figure 5 PVD Installation Pattern

Prior to installing PVD, a woven geotextile made of polyester or polypropylene which is water-permeable is first installed as a separator between the existing soil particles and the soil particles in the platform embankment. Next, install the PVD using a mandrel with a predetermined depth, distance between PVDs, and patterns. The next step is to install the PHD and cover it with a layer of sand ditch. The final stage is the installation of non-woven geotextile as a separator between platform embankments and ordinary embankments.

3.5. Settlement Plate

Settlementsplates is a geotechnical tool/instrument used to monitor land subsidence. Settlement plates are generally used for embankment, slope and excavation work. This tool is used to monitor the amount of settlement that occurs due to compression of pore water and air space in the original soil due to preloading (Lilabsari et al., 2019). The observation process on the settlement plate was carried out using a waterpass measuring device. The measurement results are in the form of settlements that occur and consolidation time. Settlement monitoring activities with settlement plates are presented in Figure 6.

Figure 6 Monitoring of Land Subsidence with Settlement Plates

4. Results and discussion

4.1. Project Data

As explained in the background, this project has been stalled since 2013 with a progress of 48%, and was resumed in December 2019 by the contractor PT. Adi Karya. The constraints and methods of implementation that occurred in the previous stage have been analyzed, so it is hoped that this project can run according to schedule, there have been several redesigns carried out considering the function of this project as an alternative route, especially to break down congestion between Brebes and Tegal.

Figure 7 Project Location

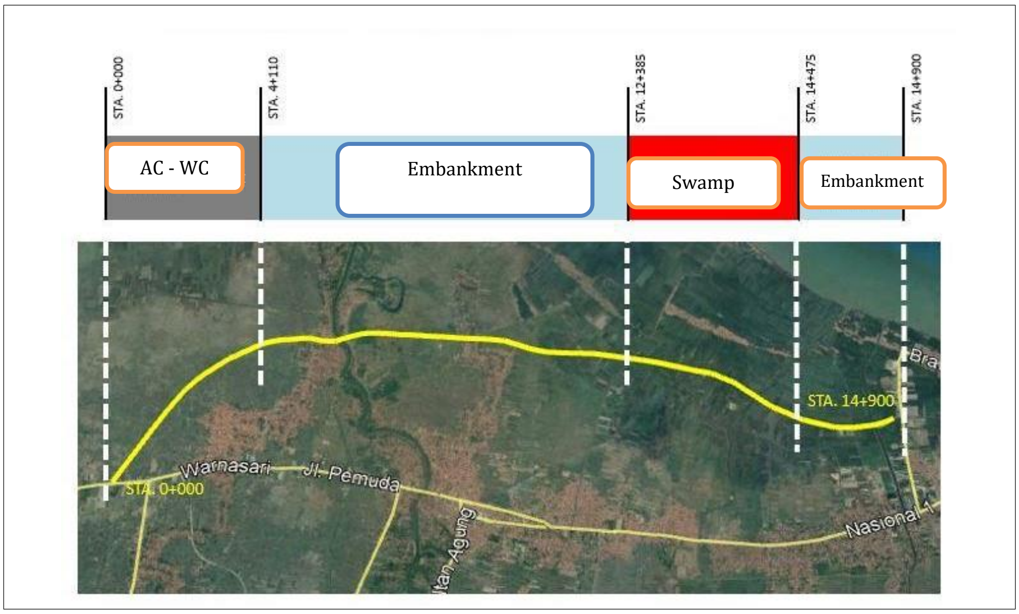

Figure 8 Existing Conditions of the Project in 2020

4.2. Soil Data Analysis

In highway planning, it is important to know the condition of the original soil because it is one of the foundations for pavement thickness planning.

Based on the test results of existing soil samples, the bearing capacity of the subgrade is expressed in qc (conus resistance) with a value of 2 kg/cm^2 to 4 kg/cm^2, however, in road planning, soil carrying capacity data is used which is expressed in CBR subgrade, so an approach is taken from the sondir test value to the CBR value with the help of a graph as can be seen in Figure 9.

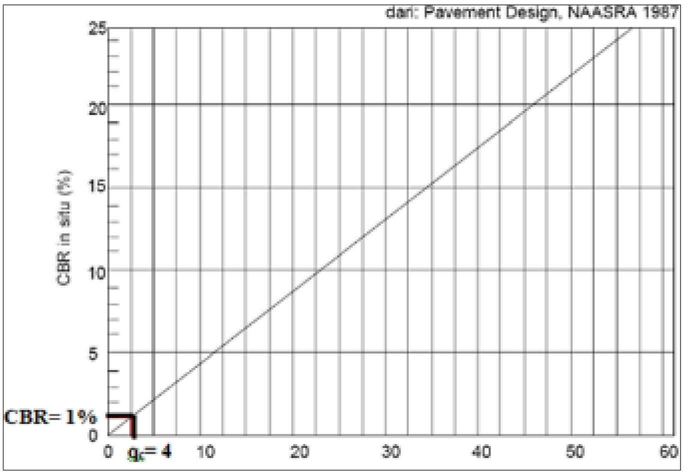

Figure 9 Correlation of CBR and Conus Values

From the results of plotting the qc values in Figure 9 above, it is obtained that the carrying capacity of the soil in the form of CBR is around 1% (including in soft soils). To improve the condition of the original soil, soil improvement is carried out.

4.3. Soil Improvement

PVD (Prefabricated Vertical Drain) is a plastic sheet for long vertical drainage in the form of fins and pockets which is a combination of high mechanical strength polypropylene core material and a packing layer of geotextile material or a jacket of polymer material. PVD serves to speed up the soil consolidation process, especially in soft/clay soil types by planting it vertically into the soil to drain water from the soft soil layer to the surface. PVD is made from geosynthetic materials that are produced in factories.

Figure 10 PVD installation process

PHD (Prefabricated Horizontal Drain) or horizontal drain is a material with a hollow cylindrical core or core made of polypropylene wrapped in a jacket made of polymer material. PHD is installed with a certain installation method that functions as a converter.

After the PVD is installed, proceed with the installation of the PHD and also the provision of special sand. Prior to adding landfill, non-woven geotextiles are first installed as a separator between the PVD and PHD with the landfill.

Figure 11 Process of installing PHD, sand and non-woven geotextiles

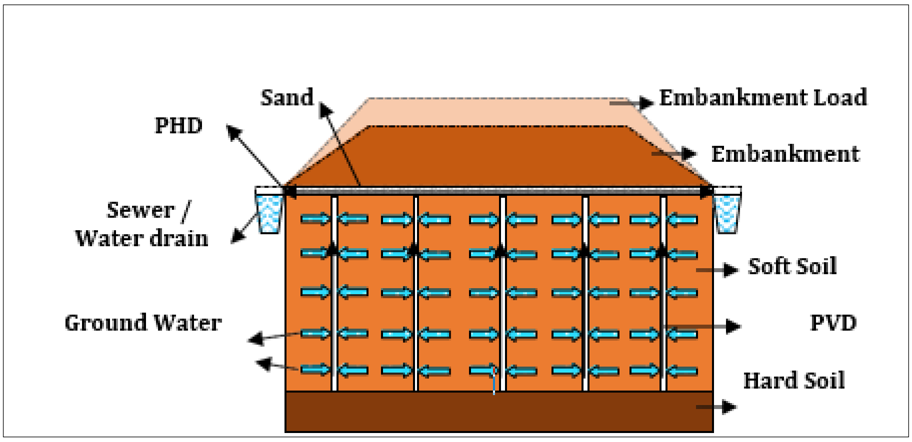

Figure 12 Cross section of road construction with subgrade improvement

5. Conclusion

What can be drawn from the results of the discussion are:

- Most of the Brebes Tegal North Ring Road project is on soft soil, starting from STA 8,800 to STA 17,377, so that subgrade improvement is required.
- Soil improvement methods used geotextiles and a combination of PVD – PHD and Preloading
- The method for carrying out soil improvement begins with piling up soil accompanied by compaction until it reaches the working floor elevation for the installation of PVD - PHD followed by installation of PVD with a rectangular pattern of 22 meters deep, at the top end of the PVD connected to the PHD which is forwarded to the canal on the edge according to the plan, after completion The surface is covered with sand followed by the laying of non-woven geotextiles, then continued with selected soil stockpile until it reaches the planned subgrade elevation while being monitored with a settlement plate to monitor the settlement that occurs.
- The benefits obtained, the soil becomes more compressed thereby increasing the carrying capacity while the functions of each soil improvement element used are:
- PVD to remove water and air from soft soil, so that the soil can be denser and increase its carrying capacity.
- PHD to channel air and water from the PVD to the channels that have been provided outside the area that will be used for road construction
- Non-woven geotextile, as a coating between the subgrade and the selected soil so that it does not mix, where the selected soil has been tested to be able to withstand the load of the road construction on it.

Suggestion

That can be provided to complement so that the quality of the project is better, is

- It needs to be reviewed or evaluated because the initial planning for this road trace was carried out in 2002 – 2005, while this road was only operational in April 2022, the traffic volume has changed a lot.
- The construction of bridge oprites that cross on soft soils needs to use millipede construction or pile slabs to avoid high embankments that have a risk of construction failure.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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