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Analysis of the soil reinforcement by using geotextile on the pile of Medan – Kualanamu of highway project (STA 35 + 901) with the finite element method

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Abstract. Consolidation is the process of discharge of water from the soil through pore cavity. Poor subgrade condition which is in the form of plates, is necessary to be repaired so that the subgrade will be able to support the load of construction. One method used as soil improvement is by geotextile. The type of geotextile used on the road construction project (STA 35 + 901) Medan Kualanamu freeway is PP woven polypropleen geotextile. This study aims to determine the magnitude of the settlement, horizontal deformation, tensile strength of geotextile by using finite element method that affect the length of time the land decline to reach 90% consolidation or in other words does not decrease again or is considered zero. The results obtained from the calculation of this study obtained a decrease that occurred using geotextile with finite element method of 0.45 m, the horizontal deformation obtained by using the most extreme elemental method with geotextile was 0.08 m while the horizontal deformation occurring with no geotextile was 0.09 m and the tensile stress obtained by the geotextile tensile stress calculation was 19.51 KN/m^2.

1. Introduction

One of the obstacles on the foundation of road construction is excessive settlement. Foundation settlement process is usually caused because the foundation is not strong enough to withstand the load or the layer of soil under the foundation is compressed due to structural load. Construction has a very varied load, it is consisting of the load of the building itself and the load from the outside (wind, earthquake, etc.).

Generally, the settlement on the ground caused by loading can be divided into two major groups:

- The consolidation settlement, which is the result of changes in the volume of saturated soil as a result of the discharge of water occupying the soil pores
- Immediate settlement, which is the result of elastic deformation of dry, wet, and water-saturated soils without any changes in its water content.

Consolidation is a process of reduction in volume or reduction in pore cavity of a low saturated soil permeability due to loading, wherein the process is influenced by the speed of pore water discharge from the soil cavity. When a layer of saturated soil with a low permeability is given load, then the pore water pressure in the soil will increase immediately. The differences in pore water pressure in the soil layer resulted in water flowing into the soil layer with lower pore pressures, followed by its settlement. This process takes time due to low soil permeability. Consolidation is any process which involves a decrease

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in water content of saturated soil without replacement of water by air. In general it is the process in which reduction in volume takes place by expulsion of water under long term static loads.
Geotextile is a thin, flexible, permeable sheet used for stabilization and soil improvement attributed to civil engineering work. Utilization of geotextiles is a modern way of reinforcing soft soil. The function of geotextile besides as reinforcement of soft ground, as the pile ; geotextile is also used as field separator, filter, drainage and as a protective layer.

There are 2 types of geotextile:

1. Woven Geotextile
   Woven geotextile is a type of geotextile made from Polypropilene as the base material. In order to make it easier to apply, Woven Geotextile is made like a rice sack but it is not made of jute material but black from synthetic materials. Woven geotextile has a function as subgrade stabilization material, especially soft soil base so that the soil can be coated and the surface is not easily down, because the tensile of this geotextile is 2 times higher than non-woven geotextile for the same gramation or weight per m^2.
2. Non-woven Geotextile
   Non-woven geotextile is a Fabric Filter shaped like rugs. Generally the base material of non-woven geotextile is made of Polyesther or Polypropylene polymer. Another function of geotextile is as a substitute for gunny sack in the curing process of concrete because it can prevent the occurrence of cracks during the process of draining new concrete.

The advantages of using geotextile:

1. Prevent subbase and base aggregate contamination by soft base soils and distribute an effective traffic load through layers of heap.
2. Eliminate the loss of heap aggregate into soft and basic soil and minimize the costs and additional needs of the 'wasted layer aggregate'.
3. Reduce the thickness of stripping excavation and minimize preparatory work.
4. Increase the aggregate of heat resistance to local collapse on the location of load by strengthening the heap.
5. Reduce uneven settlement and deformation of the finished structure.

1.1. Tensile stress of geotextile

The tensile strength of the geotextile must be strong enough to withstand tears at encounters with collapsing surfaces. In this case geotextile is designed with force in the directions. In the analysis phase consists of two stages, that are:

1. Boundary balance analysis without any reinforcement.
2. Boundary balance analysis with reinforcement

The tensile strength of geotextile can be calculated by this formula:

$$\tau g = (cg + \sigma g \tan\delta) \quad (1)$$

Where in equation one, τg is geotextile tensile stress (KN/ m^2), Cg is soil adhesion with geotextile (KN/ m^2), (For soft soil, the adhesion between soil and geotextile (cg) can be considered the same as the cohesion (cu) of the soil, so cg = cu), σg is bearing capacity of geotextile (KN/ m^2) and δ is shear angle with geotextile (-).
Bearing capacity of geotextile can be calculated by this formula:

$$\sigma g = \frac{E\in}{a\sqrt{\left(1+\frac{a}{s^2}\right)}} \quad (2)$$

Where in equation two, σg is geotextile bearing capacity (KN/ m^2), E is modulus of *geotextile*(-), (Efficient value of friction from geotextile to soil (E), for geotextile E = 0.6 - 0.8), $\in$ is tension pressure of geotextile (KN/ m^2), a is geotextile length divided by 2 (m) and S is settlement under the load (m)

1.2. Vertical Drain

Table 1. Prefabricated Vertical Drain Installation Method

Type of Drain	Installation Method	Drain Diameter (m)	Distance between Drain (m)	Maximum length (m)
Sand drain	Pushing into the ground with the vibrating system	0,15 – 0,6	1 - 5	≤ 30
Sand drain	Using a long hollow bar with auger	0,3 – 0,5	2 - 5	≤ 35
Sand drain	Jet grouting method	0,2 – 0,3	2 - 5	≤ 30
prefabricated sand drains (sandwicks)	inserting a tool with vibrating systems using the mandrel tip of the tool, using auger	0.06-0.15	1,2 - 4	≤ 30
Prefabricated band-shaped drains	Inserting the tool into the ground using the mandrel at the end.	0,05 – 0,1 (Equivalent diameter)	1,2 -3,5	≤ 60

Source: *(TenCate Polyfelt® Alidrain Prefabricated Vertical Drain)*

1.3. Finite Element Method

Table 2. The Plane-Strain and Axysimetry models

No	Model	Parameter	Remarks
1	Mohr-Coulomb (MC)	E, ν, ϕ, c, dan ψ	Perfect elastic - plastic, is the most widely used models in geotechnical analysis
2	Jointed Rock (JR)	E, ν, G, ϕ, c , ψ	Anisotropic elastic - plastic, used to model the behavior of rock layers that have stratification and certain directions
3	Hardening-Soil (HS)	ϕ, c , ψ, ν, E50, Eur,Eoed, p, Ko, Rf, σ	Isotropic, this model can be used for all types of soil
4	Soft-Soil-Creep (SSC)	ϕ,c, ψ, κ, λ, μ, ν,M, Ko,	Used for soft soil conditions that have time-dependent behavior
5	Soft Soil (SS)	ϕ, c , ψ, κ, λ, ν, M,Ko	The Cam-Clay model, used for the analysis of primary compression and normal consolidated clay

Source :(Chu et. al. 2004)

2. Research Method

- Collect various types of literatureS and scientific papers related to this thesis.
- Collecting data from the results of soil investigation such as data of standart penetration test (SPT), colsolidation, direct shear, and geotextile technical data. The data was obtained from PT. BINA KARYA as a consultant planner and CHEC - CSCEC - HK - JO as contractor implementer.
- Analyze the data obtained from the field with reference sources related to the thesis.
- Calculate the settlement of soil with or without geotextile with existing methods.

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- Calculationg the amount of settlement using finite element method, by modeling the soil behavior on the finite element method. The soil modeling used is Mohr-Coulomb model.
- Comparing the calculation of the soil settlement obtained by analytical method with the calculations performed with finite element method, then make conclusions and suggestions.

3. Result and Discussion

3.1. Magnitude of Settlement

The calculation of settlement obtained by finite element method is 0.45 meters

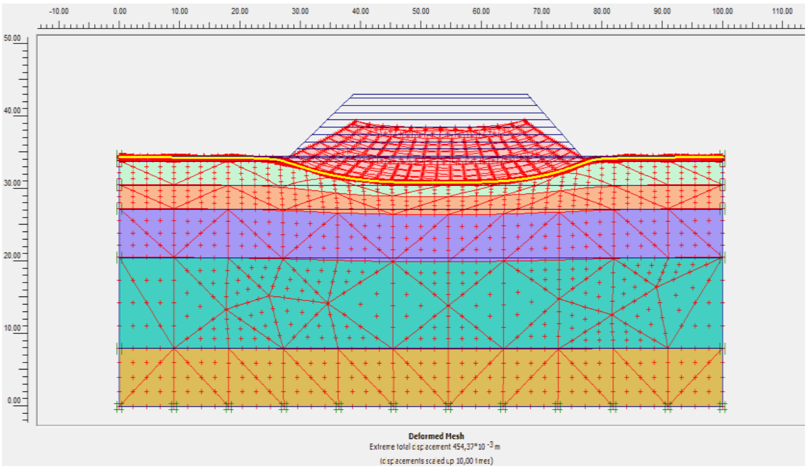

Figure 1. Soil Settlement in Finite Element Method

3.2. Results of Horizontal Deformation Modeling with Finite Element Method

The parameters used in searching the result of horizontal deformation modeling are the same as the settlement parameter as well as the way it works. The result of horizontal deformation calculation obtained by using finite element method and using geotextile is an extreme horizontal deformation which is equal to 0.08 m. While horizontal deformation obtained without using geotextile obtained 0.09 m.

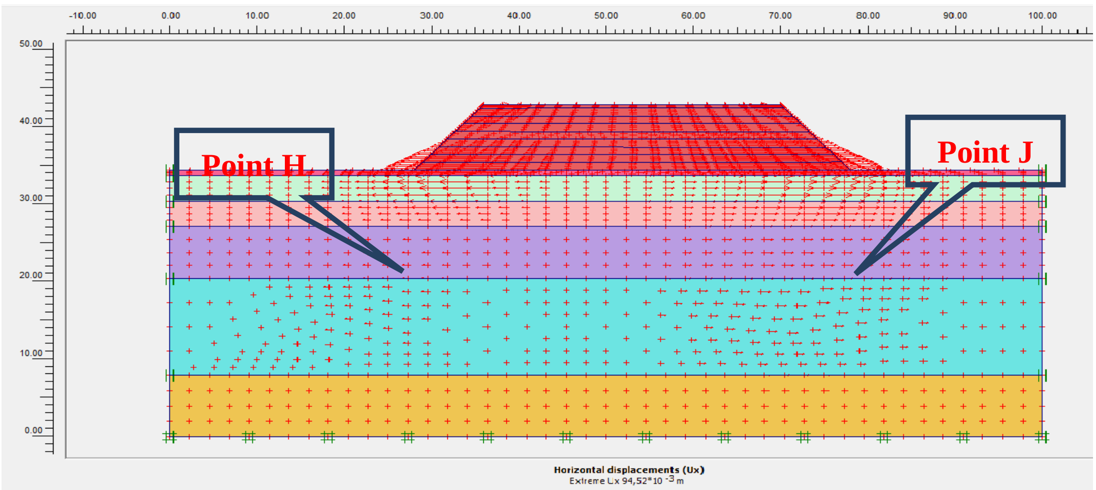

Figure 2. Horizontal Deformation without geotextile

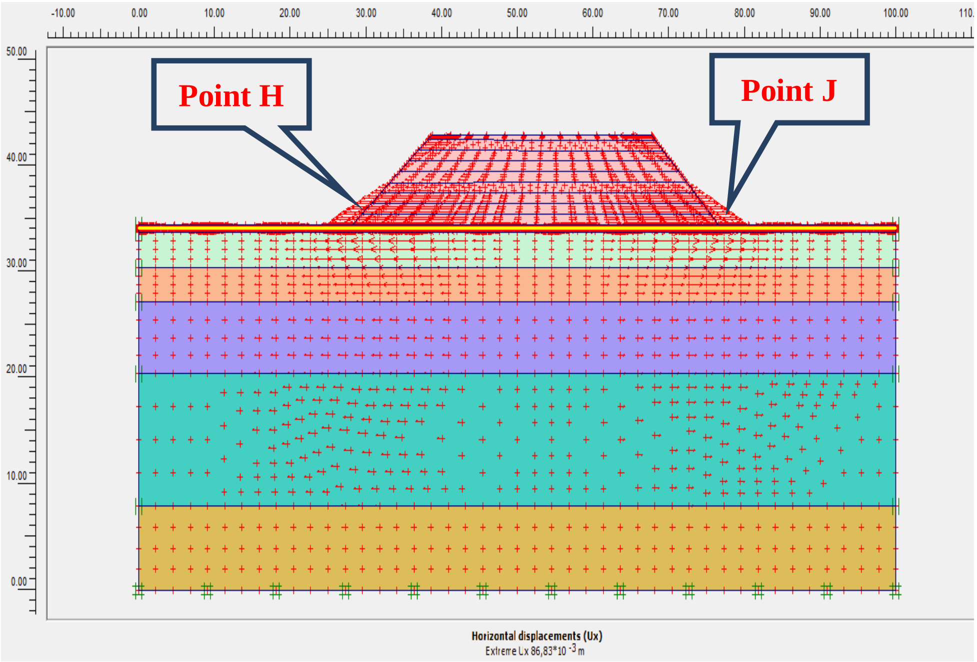

Figure 3. Horizontal Deformation with Geotextile

3.3. Tensile stress on Geotextile

Equation formula 2.6 and 2.7 to calculate the tensile stress of geotextile:

$$\tau g = (cg + \sigma g \tan\delta)$$
$$\tau g = (19{,}5 + \sigma g \tan 7)$$
$$\text{Calculating, } \sigma g = \frac{E\epsilon}{a\,(1+\frac{a}{s^2})}$$
$$\sigma g = \frac{0{,}7\ (60{,}01)}{23\sqrt{(1+\frac{23}{0{,}36^2})}}$$
$$\sigma g = \frac{40{,}007}{307{,}05}$$
$$\sigma g = 0{,}13\ \text{KN}/m^2$$
so,
$$\tau g = (19{,}5 + \sigma g \tan 7)$$
$$\tau g = (19{,}5 + 0{,}13 \tan 7)$$
$$\tau g = 19{,}51\ \text{KN}/m^2$$

The magnitude of Tensile stress on geotextile is 19,51 KN/m^2

4. Conclusions and Sugestions

1. According to the calculation using finite element method, soil settlement on STA 35 + 901 without using Geotextile until it reached 90% of consolidation degree is equal to 0,46 m. While the total

settlement obtained from the finite element method program on STA 35 + 901 using Geotextile until it reached 90% of consolidation degree is 0.45 m.

2. The result of horizontal deformation obtained by using finite element method and located at the point that is observed (the most extreme point H and point J) with geotextile is 0.08 m while horizontal deformation that occurs without geotextile is 0.09 m.
3. The soil improvement technique obtained on the project is that geotextille has the utility of being a separator.
4. According to the calculation, obtained that tensile stress of geotextile is 19,51 Kn/m^2

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