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# An Alternative For New Road Embankment At Belanti Ex-Plg Food Estate Area, Pulang Pisau Regency – 3 (Case Study: Sta. 4+600 – Sta. 4+910 (Segment 1) and Sta. 0+000 – Sta. 0+065 (Segment 2))

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**ABSTRACT**

One of the lands used for the Food Estate program is a former peat land project, which is the Food Estate Area of the former PLG (PLG; *proyek lahan gambut*) of Belanti, Pulang Pisau Regency. In Sta 5+116, there is a market which makes road widening or the creation of road shoulder especially challenging. Therefore, the local government proposed to make an alternative route. The compression calculation analysis results in the first year, there is a settlement of 10.053 cm/year. Referring to MDP 2017, improvements need to be made by adding wood piles, or *cerucuk*, into the subgrade. Another soil improvement method is by using foam mortar, namely base and subbase; the qtimb of the base is 2.4 kN/m$^2$ and the qtimb of the subbase is 3.9 kN/m$^2$ for $\gamma$average = 7 kN/m$^3$ and $\phi$average of 42.5°. The analysis of settlement time shows 3.6 mm/year, while the last step, which is the hydrostatic force analysis, revealed that foam mortar has a safety factor of 4.507, i.e., all have fulfilled existing requirements and are considered safe. The soil improvement method used to remove compression of subgrade employed wood piles, or *cerucuk*. The dimension of the *cerucuk* used is 10 cm for the diameter and 5 m for the depth, and the required number of *cerucuk* is 77. In order to reduce the subgrade compression, foam mortar was used as a road embankment material with consolidation compression occurring in the subgrade being 7,179 cm.

**Keyword :** *cerucuk*, *food estate*, analysis result, foam mortar, Pulang Pisau

## INTRODUCTION

The Food Estate Program is a food development concept carried out in an integrated manner covering agriculture, plantations, and even animal husbandry in a particular area. The Food Estate Program is one of the 2020–2024 National Strategic Programs (PSN). In Central Kalimantan Province, the land used for the Food Estate program is a former peat land project (PLG; *proyek lahan gambut*), namely the Food Estate Area of Belanti ex-PLG, Pulang Pisau Regency, and the Food Estate Area of Dadahup ex-PLG, Kapuas Regency. As the initial stage of the program, preparations were made in the form of rehabilitation of irrigation canals, water gates and bridges, as well as improvements of access roads. The location of Belanti ex-PLG Food Estate Area, Pulang Pisau Regency, and Dadahup ex-PLG Food Estate Area,

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Kapuas Regency, can be seen in **Figure 1.**

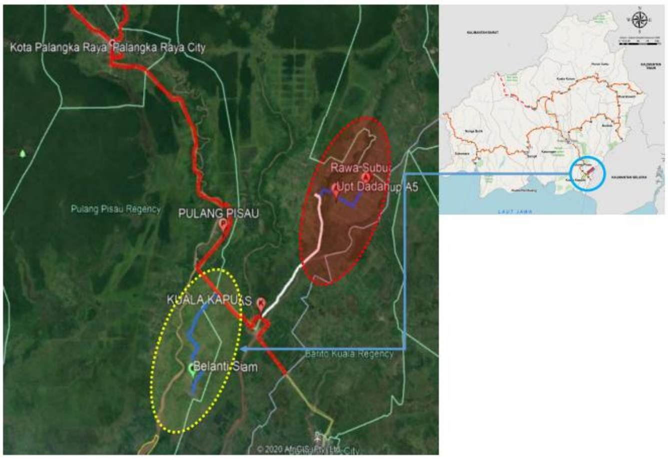


**Figure 1.** The Location of Belanti ex-PLG Food Estate Area, Pulang Pisau Regency, and Dadahup ex-PLG Food Estate Area, Kapuas Regency, Central Kalimantan

**(Road Infrastructure Development Integration [KPIJ] of the National Road Implementation Agency [BPJN] of Central Kalimantan Province)**

The existing road condition, from Section Tahai Jaya (Sta. 0+000) to Tahai Baru (Sta. 5+207), is a single-layer asphalt road with a width of 4 m. This road section does not have a shoulder, where the left and the right sides of the road are empty peat land, people's buildings, and a market; at the end of the road, there is a building for Directorate General of Irrigation Monitoring Office for Tahai Unit, Maliku District, Pulang Pisau Regency, Central Kalimantan Regency. If the traffic is busy when the market is active, widening the road or building a road shoulder will be challenging. Additionally, the activity of this market can at times deter smooth travel connectivity to the location of Belanti ex-PLG Food Estate Area, Pulang Pisau Regency. These issues inspired the local government of Pulang Pisau Regency to submit a proposal to the Directorate General of Highways (Bina Marga), the National Road Implementation Agency (BPJN; *Balai Penyelenggara Jalan Nasional*) of Central Kalimantan Province so that an alternative road route can be provided, which is planned on land where most are still forest, as shown in **Figure 2**.


**Figure 2.** The Proposed Alternative Route Plan for the Tahai Jaya – Tahai Baru Section (KPIJ of the National Road Implementation Agency of Central Kalimantan Province)

***Map Description:***

Planned access road to Belanti ex-PLG Food Estate Area
Proposed alternative route plan (Segment 1)
Proposed alternative route plan (Segment 2)
Market

From the description above, it can be concluded that the construction of an alternative road proposed by the local government of Pulang Pisau Regency is crucial so that market activities at Sta. 5+116 will not impede the smooth connectivity of travel to Belanti ex-PLG Food Estate Area. For this reason, it is necessary to carry out further soil investigations at the location of the alternative road so that the planned road will be stable and not slide, undulate, and be inundated nor flooded.

## LITERATURE REVIEW

Organic soft soil is a type of surface soil that has a mixture of organic matter and the remains of decaying plants or animals. The characteristics of organic soil are that it has a soft texture, are dark in color, and are easily deformed when pressed (easily crushed when they're dry). Organic soil has low shear strength and high compressibility. Organic materials contained in organic soil have a low level of cohesion and plasticity (Wiratama, 2013).

According to Desiani (2013), organic soft soil is soil that contains organic materials derived from plant remains. As explained in ASTM D4427, soil with an organic matter content greater than 25% is considered organic soil. Organic soil is often described as a material that looks 'fresh' and is still in the process of decomposition/decay thereby having a distinct odor, color, and texture.

### Soil Reinforcement using Cerucuk

The use of wood piles (*cerucuk*) as a method for soil reinforcement (Figure 3) is especially effective if used in peat soil that has a layer thickness ranging between 3.0 and 4.0 meters with a layer of sand underneath (Yulianto & Harwadi, 2009; Yulianto & Mochtar, NE., 2012). This wood pile method functions to transfer the load on the upper structure to the lower part of the peat soil, which is a layer of sand, as shown in **Figure 3**.

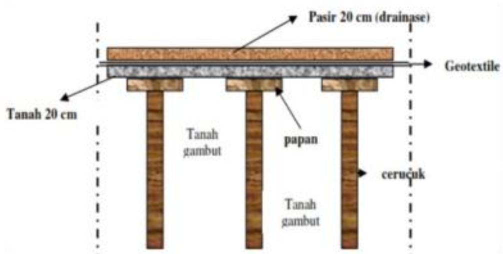


**Figure 3.** The Wooden *Cerucuk* Method

(Ma'ruf & Yulianto, Proceedings of the 2016 National Geotechnical Seminar, 2016)

The use of a *cerucuk* is intended to increase the shear resistance of the soil, therefore increasing the bearing capacity of the soil. In addition, the use of *cerucuk* is relatively effective as an alternative for road or slope reinforcement. Another function of using *cerucuk* is that it can produce resistance against shear failure and can cut slope failure areas. From the description above, an illustration of the use of *cerucuk* for soil can be seen in the following

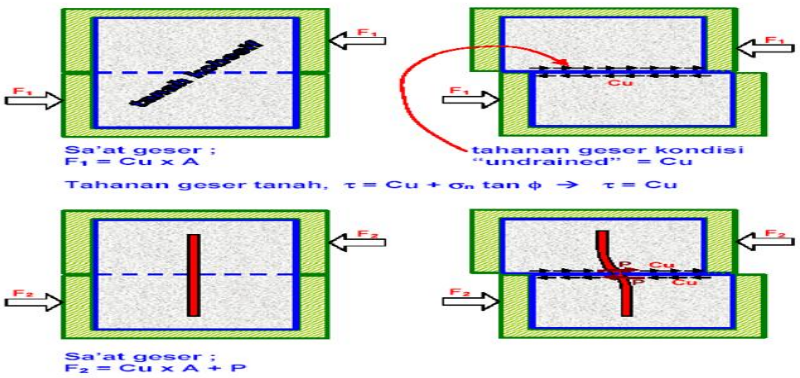


**Figure 4.** An Illustration of Increasing Soil Shear Resistance through *Cerucuk* (Noor Endah M, 2012)

In the illustration above, the application of *cerucuk* on the subgrade must exceed the deepest surface of the slide. Moreover, it is necessary to consider that the span length used is expected to be without joints (Rusdiansyah, 2015).

Assumptions of *Cerucuk* Calculations

The assumptions used in the construction of *cerucuk* can be seen in Figure 2.11. In the figure, *cerucuk* is assumed to be equivalent to the usual pile group with a "rigid cap" at the ground surface that receives a horizontal force and generates shear stress along the plane of the slip as shown in **Figure 5**.

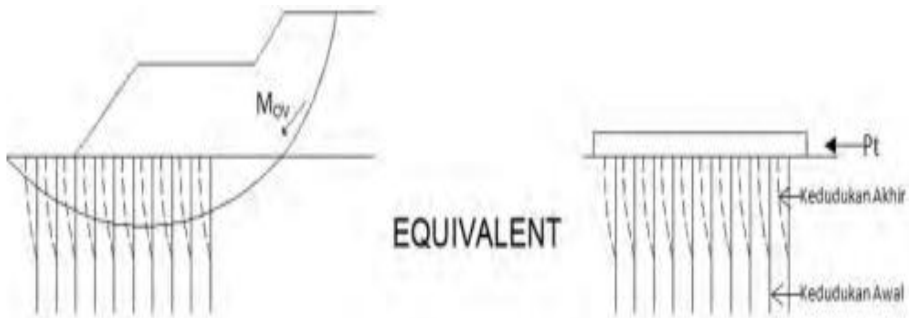


**Figure 5.** The Assumed Force Received by *Cerucuk* (Mochtar, 2012)

From the theory of *cerucuk* by Mochtar I.B (2000), a formula was produced to determine the strength of 1 *cerucuk* (P) in withstanding horizontal forces. Then, from the comparison of the driving moment with the required restoring moment, the number of piles required can then be determined. In this calculation, a safety factor (SF) of at least 1.10 is used for conditions with temporary loads (vehicles) and at least 1.50 for conditions with only embankment loads.

To calculate the strength of 1 *cerucuk*, the relative strength factor (T) of the *cerucuk* must first be determined, as described in NVFAC DM-7, 1971:

1. Calculating the strength of 1 *cerucuk* against the horizontal force
   a. Calculating the relative strength factor (T)

$$T = \left(\frac{EI}{f}\right)^{\frac{1}{5}} \qquad ..... (1)$$

Where :
E = Modulus of elasticity of the pile (*cerucuk*), kg/cm2
I = Moment of inertia of the pile (*cerucuk*), cm4
f = Coefficient of the variation of soil modulus, kg/cm3
T = Relative stiffness factor, cm

The value of *f* can be obtained from the Design Manual, NAVFAC DM-7, 1971, which is is a graph of the relationship between f and unconfined compressive strength, *qu* = 1 *Cu*.

2. Calculating the horizontal force that can be resisted by 1 (one) pile.

$$Mp = Fm\ x\ (P\ x\ T) \qquad ..... (2)$$

Where:
$Mp$ = Bending moment experienced by *cerucuk* due to load *P*, kg-cm
$F_M$ = Moment coefficient due to the lateral force *P* → calculated on *Z* = 0
$P$ = Horizontal force received by *cerucuk*, kg
$T$ = Relative stiffness factor, cm

By plotting the length of *cerucuk* suspended below/above the slip plane (*L*), we get *L/T*. From the value of *L/T* at depth (*Z*) with the help of drawings from the Design Manual, NAVFAC DM-7 1971), the FM price is then obtained. Hence, the horizontal force that can be carried by 1 (one) *cerucuk* is:

$$P = \frac{Mp}{F_M \times T} \qquad ..... (3)$$

The maximum force $P_{max}$ carried by one *cerucuk* occurs when *Mp* = maximum bending moment of *cerucuk* material. If the strength and the dimensions of the material are known, then:

$$F_K = 2{,}643 \left[\frac{0{,}89+0{,}12\left(\frac{L}{D}\right)}{2{,}69}\right]\left[\frac{0{,}855\ (C_u)^{-0{,}392}}{2{,}865}\right] \qquad ..... (4)$$

**The Use of Lightweight Foam Mortar Material for Road Body**

One type of lightweight material that can be used to repair problematic soils is foam mortar. Problematic soil types can be found in expansive soil types, soft soils, and peat. The main problems that occur in these types of soil are construction stability problems, and large and long consolidation settlements. From 2006 to 2010, several technologies for addressing problematic soil types have been researched and developed at the Road Geotechnics Agency, Road and Bridge Research and Development Center. These technologies have been tested on a full scale in the field. One of the studies on soft soil management with road embankment technology is the use of foam-mortar road embankment material. The technology has been tested full-scale; In 2010, a full-scale trial of light embankment was carried out as a road body on the Pangkalan Lima – Kumai Section, Pangkalan Bun, Central Kalimantan. The length of the trial pile is 400 m with the height of the foam mortar pile at 1.1 meters (Maulana Iqbal, 2012).

The minimum compressive strength of lightweight mortar-foam material with unconfined compressive strength testing for road foundation construction with a minimum thickness of 30 cm.

The specifications for physical and mechanical tests of lightweight mortar-foam material must be in accordance with **Table 1** (for a maximum dry density of 0.8 g/cm$^3$) and **Table 2** (for a maximum dry density of 0.6 g/cm3).

**Table 1.** Unconfined Compressive Strength (14 days old) of Light Material Foundation or Base Layer

| Max Dry Density (g/cm$^3$) | Unconfined Compressive Strength (UCS) | |
|---|---|---|
| | kPa | kg/cm$^2$ |
| 0.8 | 2000 | 20 |

(Specification Guide for Lightweight Material with Foam Mortar for Road Construction, 2015)

**Table 2.** Unconfined Compressive Strength (14 days old) of Lightweight Material For the Lower Foundation Layer or Subbase

| Max Dry Density (g/cm$^3$) | Unconfined Compressive Strength (UCS) | |
|---|---|---|
| | kPa | kg/cm$^2$ |
| 0.6 | 800 | 8 |

## DATA COLLECTION

### Soil Data in Study Location

The soil data used in this analysis include secondary data in the form of soil and boring data obtained from the KPIJ Section of the Central Kalimantan National Road Implementation Agency. There are 2 locations for taking soil and boring tests in the field, namely point S1, which is located in segment 1 (Sta. 4+910), and point S2, which is located in segment 2 (Sta. 0+000). From the results of the boring data, it can be seen that the condition of the basic soil layer is soft soil. In other words, it has a low ability to support loads and has a large compressive capacity

Based on the N-SPT data obtained and the use of empirical correlation, the physical and technical parameters of the subgrade are obtained, as shown in **Table 3** and **Table 4**.

**Table 3.** Physical Parameters of Subgrade

| Depth (m) | Soil Types | Wc (%) | Gs | ɤsat (kN/m$^3$) | e | LL (%) | IP (%) |
|---|---|---|---|---|---|---|---|
| 0 – 2 | Brownish Silt | 90.00 | 2.41 | 13.48 | 2.40 | 58.42 | 17.65 |
| 2 – 17 | Gray Silt | 86.27 | 2.41 | 13.98 | 2.22 | 56.89 | 16.64 |
| 17 – 18 | Red Clay | 72.00 | 2.42 | 14.80 | 1.81 | 50.80 | 14.81 |
| 18 – 19 | Red Clay | 72.00 | 2.45 | 14.80 | 1.85 | 50.80 | 14.81 |

(Source: Analysis and Data Results from the BPJN of Central Kalimantan)

**Table 4.** Technical Parameters of Subgrade

| Depth (m) | Soil Types | Cc | Cs | Cv (cm$^2$/det) | Cu (kg/cm$^2$) |
|---|---|---|---|---|---|
| 0 – 2 | Brownish Silt | 0.97 | 0.14 | 0.0013 | 0.13 |
| 2 – 17 | Gray Silt | 0.86 | 0.12 | 0.0013 | 0.13 |
| 17 – 18 | Red Clay | 0.60 | 0.09 | 0.0015 | 0.20 |
| 18 – 19 | Red Clay | 0.62 | 0.09 | 0.0015 | 0.40 |

(Source: Analysis and Data Results from the BPJN of Central Kalimantan)

**Embankment Material and Planned Traffic Load**

**Table 5.** Embankment Material

| No | Type of Material | Thickness (m) | Volume Weight ($t/m^3$) | Weight/$m^2$ |
|---|---|---|---|---|
| 1 | Excavated Sand (Regular Embankment) | 0.2 | 1,670 | 0.334 |
| 2 | Selected Embankment | 0.3 | 1,918 | 0.575 |
| 3 | Selected Embankment | 0.3 | 1,918 | 0.575 |

(Source: Analysis and Data Results from the BPJN of Central Kalimantan)

Due to the absence of *sirtu* (sand and stone) material supplies at the work site, the volume weight for the *sirtu* layer is equated with the volume weight of the excavated sand layer. Therefore, the application at the work site for the *sirtu* layer is supplemented with excavated sand material.

At this study location, the pavement material is planned to have several layers, which will affect the pavement material load at the work site. The width and thickness dimensions of each pavement material can be seen in **Table 6**.

**Table 6.** Pavement Material

| No | Material Type | Thickness (m) | Volume Weight ($t/m^3$) | Weight/$m^2$ |
|---|---|---|---|---|
| 1 | Class A Aggregate | 0.25 | 2,360 | 0.590 |
| 2 | Class B Aggregate | 0.125 | 2,270 | 0.283 |
| 3 | HRS - Base | 0.035 | 2,249 | 0.078 |
| 4 | HRS - WC | 0.03 | 2,239 | 0.671 |

(Source: Analysis and Data Results from the BPJN of Central Kalimantan)

Moreover, the traffic load is applied evenly across the width of all road surfaces and the traffic load used in this study is 1 $t/m^2 \approx 10$ $kN/m^2$ (Guideline for Geotechnics 4, 2002).

**Galam Wood *Cerucuk* for Fortification**

The value of the pile strength (*cerucuk*) in receiving the load is referred to as the pile P1 that supports horizontal load. Calculating pile P1 can be done by considering the condition of the subgrade fortified with *cerucuk*. The steps of calculating *cerucuk* in supporting load are:

a. Calculating soil modulus factor (f) using**:**

$$f = 2 \quad ton/ft^3$$
$$= 0.064 \quad kg/cm^3$$

b. Calculating material moment of inertia

$$I = 1/4 \times \pi \times r^4$$
$$= 1/4 \times \pi \times 5\text{^}4$$
$$= 490.87 \ cm^4$$

c. The value of the elastic modulus of galam wood based on PKKI 1961 is E = 100,000 $kg/cm^2$.

d. Calculating the relative stiffness factor (T) uses the equation**:**

$$T = \left(\frac{EI}{f}\right)^{\frac{1}{5}} \quad ..... (5)$$

T = ((100000 x 490.87 / 0.064)^(1/5))
= 59.835 cm
= 0.598 m

e. Calculating the Coefficient due to Lateral Force (Fm)

Calculation of the value of Fm:

| | | |
|---|---|---|
| Lb | 3.04 | m |
| Lb/T | 5.081 | |
| Z | 0 | m |
| Fm | 0.88 | |

Calculating the maximum moment of 1 *cerucuk*:

$$Mp = W \times \sigma lt \quad ..... (6)$$

| | | | | | |
|---|---|---|---|---|---|
| W | = | I / c | = | 98.17 | $cm^3$ |
| C | = | ½ x D | = | 5.00 | cm |
| Mp | = | 9817.48 | | kg.cm | if σlt 100 $kg/cm^2$ |

f. The force supported by 1 *cerucuk* can be measured using the equation:

$$P\ 1\ \text{cerucuk} = \frac{9817.48}{0.88 \times 0.59}$$
= 186.45 kg
= 0.19 t
= 1.86 kN

Therefore, the capacity of 1 *cerucuk* for supporting horizontal load is 1.86 kN with a circular dimension of 10 cm and a length of 5 m. The type of wood for *cerucuk* is Galam wood with a Wood Strength Class of II and σlt 100 $kg/cm^2$.

**Foam Mortar**

The minimum compressive strength of lightweight mortar-foam material with unconfined compressive strength testing for road foundation construction is with a minimum thickness of 30 cm.

Specifications for physical and mechanical tests of lightweight mortar-foam material must be in accordance with **Table 1** (for a maximum dry density of 0.8 $g/cm^3$) and **Table 2** (for a maximum dry density of 0.6 $g/cm^3$). A typical illustration of road construction with foam mortar is depicted in **Figure 6.**

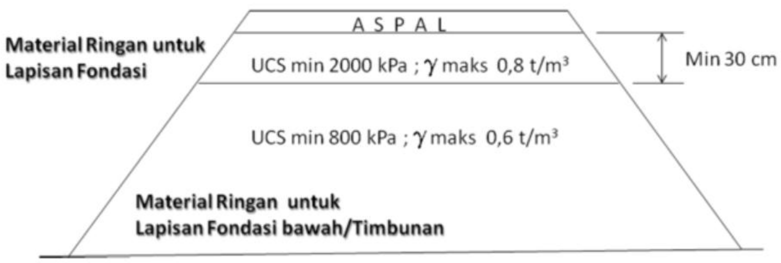


**Figure 6.** Typical Road Construction Using Light Foam Mortar Material

(Specification Guide for Lightweight Material with Foam Mortar for Road Construction, 2015)

| | | | | |
|---|---|---|---|---|
| qtimb base | = | γt | x | Htimb base |
| | = | 8 | x | 0.3 |
| | = | 2.4 | kN/m2 | |
| qtimb subbase | = | γt | X | Htimb Subbase |
| | = | 6 | X | (H-Htimb base) |
| | = | 6 | X | 0.65 |
| | = | 3.9 | kN/m2 | |
| qtimb total | = | qtimb base + qtimb subbase | | |
| | = | 6.3 | kN/m2 | |

## RESEARCH ANALYSIS

### Compression due to Embankment on the Alternative Road

Compression analysis was carried out in the middle and on the edge of the embankment. The embankment width used in the calculation is 10 m. The embankment load used in the calculation is 17.35 kN/m$^2$. Other data used in the calculations are as follows:

H embankment = 0,95 m
Slope/Inclination = 1 : 2
Consolidated soil layer thickness = 19 m
MAT fluctuation = 1 m

The results of calculating the amount of compression due to embankment are summarized in Table 5.1. The amount of settlement that occurred in the middle of the embankment is 16.636 cm and the amount of settlement that occurred at the edge of the embankment is 10.904 cm.

**Table 7.** Recapitulation of the Calculation of Compression due to Embankment

| Location | | Sc Cum. (cm) |
|---|---|---|
| Middle | Without *Cerucuk* $H_{initial}$ 1 m | 16.363 |
| Edge | Without *Cerucuk* $H_{initial}$ 1 m | 10.904 |

(Source: Analysis Result)

### Initial Height of Planned Road Embankment on the Alternative Road

The calculation of the $H_{initial}$ requirement was carried out by means of q with a value of 10 kN/m$^2$; 30kN/m$^2$; 50kN/m$^2$; 70kN/m$^2$; and 90 kN/m$^2$. The $H_{initial}$ value of the embankment was identified by graphing the relationship between $H_{final}$ vs $H_{initial}$ and settlement vs $H_{initial}$. From each compression size, the $H_{initial}$ and $H_{final}$ are calculated, which are shown in **Table 8.**

**Table 8.** Recapitulation of Calculation of Settlement, $H_{initial}$, $H_{final}$ on the Alternative Road

| Load (q) (kN/m$^2$) | Settlement due to q (m) | $H_{initial}$ (m) | $H_{final}$ (m) |
|---|---|---|---|
| 10 | 0.220 | 0.668 | 0.448 |
| 30 | 0.537 | 1.937 | 1.400 |
| 50 | 0.770 | 3.159 | 2.389 |
| 70 | 0.961 | 4.359 | 3.398 |
| 90 | 1.110 | 5.536 | 4.426 |

(Source: Analysis Result)

The obtained linear equation:

Required $H_{initial}$: y = 1.221x + 0.1865

So if the embankment height on the alternative road is 0.95 m, rounded to 1 m, then the $H_{initial}$ value from the linear equation is:

$$\begin{aligned} H_{initial} &= 1{,}221x + 0{,}1865 \\ &= 1{,}4075 \quad \text{m} \\ &= 1{,}41 \quad \text{m} \end{aligned}$$

From the required $H_{initial}$, the settlement can then be calculated as follows:

$$\begin{aligned} Sc &= 0{,}221x + 0{,}1865 \\ &= 0{,}4075 \quad \text{m} \\ &= 0{,}41 \quad \text{m} \end{aligned}$$

**Analysis of the Duration of Consolidation for the Subgrade**

The consolidated soil thickness is 19 m, and the degree of consolidation used in the calculation is 90%. The combined Cv value obtained on the subgrade is 4.261 $m^2$/year. The duration needed for the consolidation to settle for $H_{initial}$ is:

$C_{vaverage}$ = 4.261 $m^2$/year

$H_{dr}$ = 19 m 9.5

$T_{90\%}$ = 0.848 *(Table 7.3 Soil Mechanics Book)*

$$t = \frac{T_{90\%}(Hdr)^2}{Cv}$$

$$t = \frac{0.848 \times (19/2)^2}{4.261}$$

t = 17.960 years

From the results of the Rate of Settlement calculation on the $H_{initial}$ embankment of 1.4 m, it shows that, in the first 1 year, the decrease that occurred was 8.692 cm/year. If these conditions are adjusted to the regulations from the 2017 Pavement Design Manual regarding total settlement occurring in cases of general settlement, then the amount of settlement that happens is 8.692 cm/year, which is <10 cm. Therefore, the $H_{initial}$ condition will be improved by adding a *cerucuk* to the subgrade.

**Methods for Improving Existing Condition of Subgrade**

The stability analysis used was Xstabl with a $H_{final}$ of 0.95 m, and the axle load used is 10 kPa. This analysis was used to determine the depth of the landslide field and the length of the landslide.

The $P_{max}$ value of 1 *cerucuk* in holding a horizontal load is 1.86 kN. The depth of the planned *cerucuk* is 5 m. Requirements for *cerucuk* used to eliminate compression on the alternative road are as follows:

P 1 *cerucuk* = 186.45 kg ➡ If σlt 100 kg/$cm^2$
= 0.19 t
= 1.86 kN

SF = 0.613 ➡ the number of *cerucuk* uses the smallest sf value
MR = 869.50 kN.m
R = 4.81
SF = MR/MD

| | | |
|---|---|---|
| MD | 1,418.4 | kN.m |

| | | | |
|---|---|---|---|
| If SF min | = | 1,1 | |
| Then MRmin | = | 1560,3 | kN.m |

Therefore, ΔMR that is needed = MR planned – MR existing
= 1,560.3 – 869.5 kN.m
= 690.777 kN.m

As a result, there is a need for additional *cerucuk* as many as:

n = ΔMR / (P*R(radius))

n = 77.03 ≈ 77 piles

**The Use of Lightweight Foam Mortar**

The planning steps using foam mortar are as follows:

1. Identifying the value of $H_{critical}$

$$Hc = \frac{4\,Cu}{\gamma}$$

| | | | |
|---|---|---|---|
| $\gamma_{average}$ of foam mortar | = | 7 | $kN/m^3$ |
| Cu subgrade | = | 0.125 | $kg/cm^2$ |
| | = | 12.5 | $kN/m^2$ |

Then $H_{critical}$ :

$$Hc = \frac{50}{7} = 7.14286 \text{ m}$$

2. Calculating Soil Bearing Capacity

Carrying capacity is calculated on very-soft and soft clay layers. From the analysis of the basic soil data, the subgrade layer is at a depth of 0–18 m. The Cu value and shear angle obtained are:

| | | | |
|---|---|---|---|
| Cu average | = | 0.13289474 | $kg/cm^2$ |
| | = | 13.2894737 | $kN/m^2$ |
| ϕ (°) | = | 0 | |
| γ average | = | 13.95 | $kN/m^3$ |

The ultimate bearing capacity can refer to Terzaghi's general equation (Das, 1990), which is shown in below:

$$q_{ult} = cN_c + \gamma D_f N_q + 0{,}5 B_w N_\gamma \quad \text{..... (7)}$$

Because this is in the form of embankment, then Df = 0, and q ult is the C NC value.

| | | | |
|---|---|---|---|
| qult | = | 75.75 | $kN/m^2$ |
| working load is sub-base and base load | | | |
| q | | 6.3 | |
| total | = | | $kN/m^2$ |
| SF | = | 12.0238095 | |

The safety value for bearing capacity is fulfilled because of the obtained SF = 12.

a. Calculating Stability

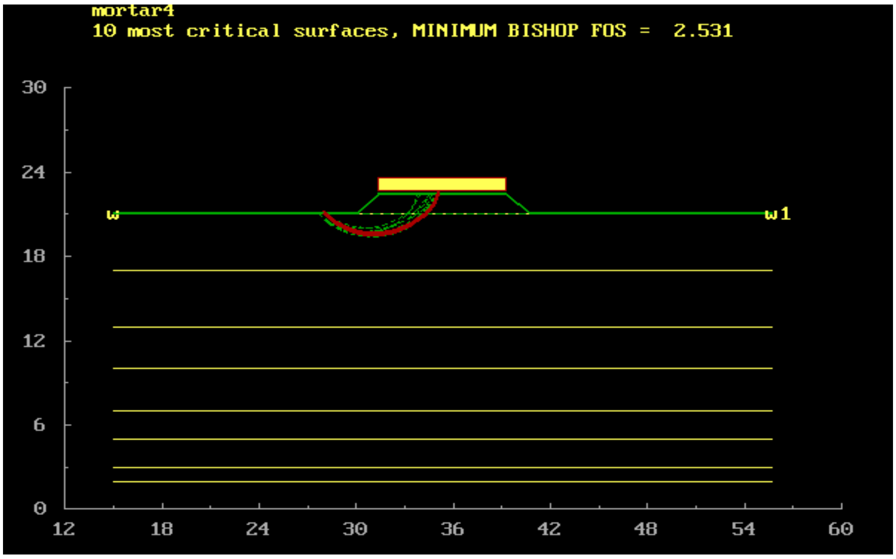


**Figure 7.** Stability Analysis with SF = 2.570
(Analysis Result)

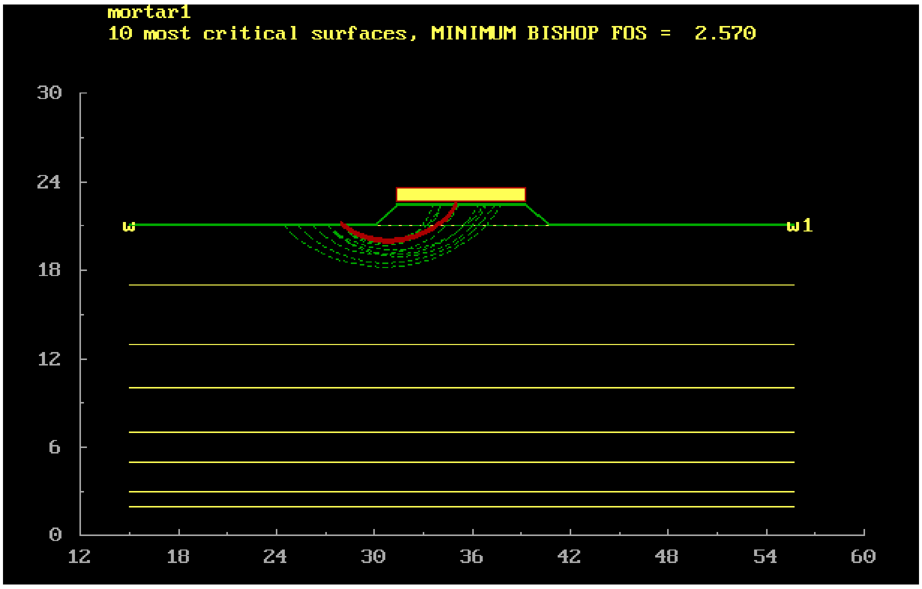


**Figure 8.** Stability Analysis with SF = 2.531
(Analysis Result)

b. Calculating Settlement

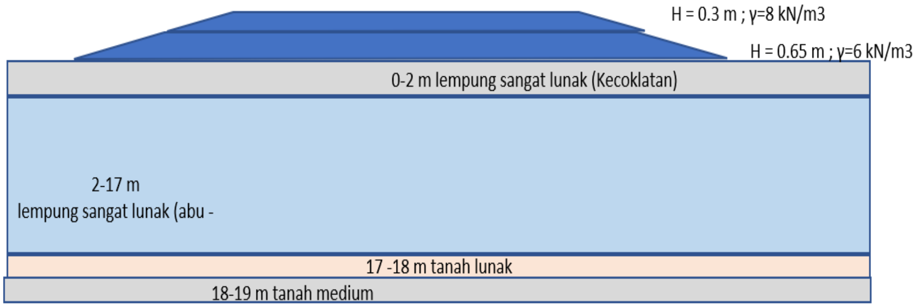


**Figure 9.** Illustration of the Amount of Settlement that Occur
(Analysis Result)

The calculation of the settlement that occur:

| | | | | |
|---|---|---|---|---|
| Stotal | = | 0.0718 m | | |
| Tv | = | (π/4) | x | U(50%) |
| Tv | = | -0.093 x log 1-U(90%)-0.085 | | |
| U(50%) | = | 0.50095 | = | 50.10% |
| U(90%) | = | 0.904 | = | 90.40% |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| St (50%) | = | U (50%) | x | Stotal | = | 0.035965273 | m | x | Stotal | = | 0.035965273 | m |
| St (90%) | = | U (90%) | x | Stotal | = | 0.064901316 | m | x | Stotal | = | 0.064901316 | m |

Based on the embankment height of 0.95 m, this study found that the consolidation settlement of 90% is 64.9 mm for 17.960 years. The rate of settlement per year is calculated by $S_{total}$ divided by the length of time it takes to set, which is 3.6 mm/year. According to road class I, settlement of the high speed is < 20 mm/year; the settlement is **SAFE.**

c. Calculating Hydrostatic Lift Force

The calculation of hydrostatic lift force is:

Wfoam mortar (per meter run) = Volume of embankment x γmortar
= 32.9175 kN

Ww is assumed to only compress one side of the embankment with water level assumed at 0.5 m.

| | | | | |
|---|---|---|---|---|
| Lift force underneath embankment | | = | h.γw x 0.5 Bw 1 | |
| OREQ | | = | 0 | |
| Bw | | = | 9.9 | m |
| Stot | in the third step | = | 0.0718 | m |
| FK | | = | 4.507 | |

Analysis on the hydrostatic lift force fulfilled, i.e., **SAFE.**

## CONCLUSION

From the data and results of the analysis that have been carried out in the previous chapters, several conclusions can be drawn as follows:

1. The type of subgrade on the alternative road, which consists of two investigation points, is not in the form of organic soil nor peat soil. BH 1 soil type consists of silt, clay, and sand. The dominant BH 2 soil type is silt and clay.
2. The height of the road embankment that must be built to prevent inundation or flooding is $H_{initial}$ = 1.41 m.
3. The type of embankment material for the road body is foam mortar so that the subgrade soil is compacted. When using foam mortar, the amount of consolidation that occurs on the subgrade is 7.179 cm.
4. The soil improvement method used to eliminate compression on the subgrade is to use wood piles, or *cerucuk*. The dimension of the *cerucuk* used is 10 cm in diameter and 5 m in depth, with the required number of cones being 77.

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