Handling Selection of Settlement and Embankment Stability Issues Based on Variations in Embankment Height and Soft Subgrade Thickness
Case Study: Pekanbaru Junction - Pekanbaru Bypass Sta. 176+775 - Sta. 176+975

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ABSTRACT

Trans Sumatra Toll Road (JTTS) is one of the most important infrastructure projects in Indonesia. One of the main sections of JTTS is the Rengat - Pekanbaru Toll Road, Pekanbaru Ring Section (Pekanbaru Junction - Pekanbaru Bypass). Existing conditions at Sta 176+775 - Sta 176+975 are dominated by oil palm plantations with soft soil layers in the form of organic soil to a depth of 1.0 meter; the layer below is clay with medium to stiff consistency. The existing treatment plan is preloading embankment with PVD and 1,0 m deep subgrade replacement. In this study, alternative planning calculations were carried out with variations of subgrade replacement up to 0.5 m and 1,0 m thickness. The study results show that the most cost-optimal treatment design is the treatment design without replacement with geotextile reinforcement. The thicker the subgrade replacement, the smaller the compression and rate of settlement. In terms of embankment reinforcement, the thicker the subgrade replacement, the less reinforcement is required. The thickness of subgrade replacement also affects the cost of the work, the thicker the subgrade replacement, the higher the cost of the work.

Keyword: soft soil, organic soil, peat soil, replacement

INTRODUCTION

The Trans Sumatra Toll Road (JTTS) is one of the most important infrastructure projects in Indonesia. In 2014, Presidential Regulation Number 100 of 2014 was issued on the Acceleration of Toll Road Development in Sumatra, hereinafter referred to as the Trans Sumatra Toll Road (JTTS); JTTS is a toll road network that connects various provinces on the island of Sumatra from Bakauheni to Banda Aceh. The development is part of the government's efforts to accelerate regional development on the island of Sumatra.

One of the main sections of JTTS is the Rengat - Pekanbaru Toll Road, Pekanbaru Ring Section (Pekanbaru Junction - Pekanbaru Bypass). This section connects two JTTS sections that are already operating, namely the Pekanbaru - Bangkinang Section and the Pekanbaru - Dumai Section. Rengat - Pekanbaru Toll Road, Pekanbaru Ring Section (Pekanbaru Junction

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- Pekanbaru Bypass) is located in Pekanbaru City, Riau Province as shown in Figure 1 with a planned handling length of approximately 30 km.

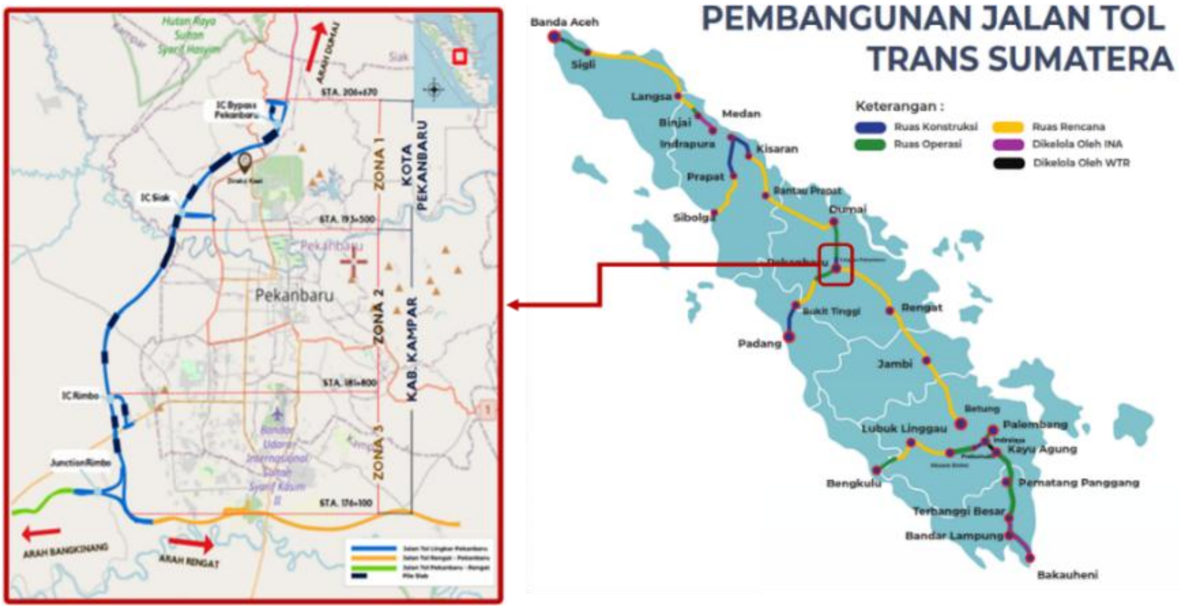

Figure 1. Location of the Trans Sumatra Toll Road, Rengat – Pekanbaru Section, Pekanbaru Ring Section, Pekanbaru Junction (PT. Hutama Karya, 2023)

Based on the results of soil investigation at borelog Sta 176+850 (Figure 3), it can be seen that there is a soft soil layer in the form of organic soil up to a depth of 1.0 meter; while the layer below is clay with a consistency of medium density to stiff. The surface of the area is fairly flat, with no basin or hills with significant elevation differences.

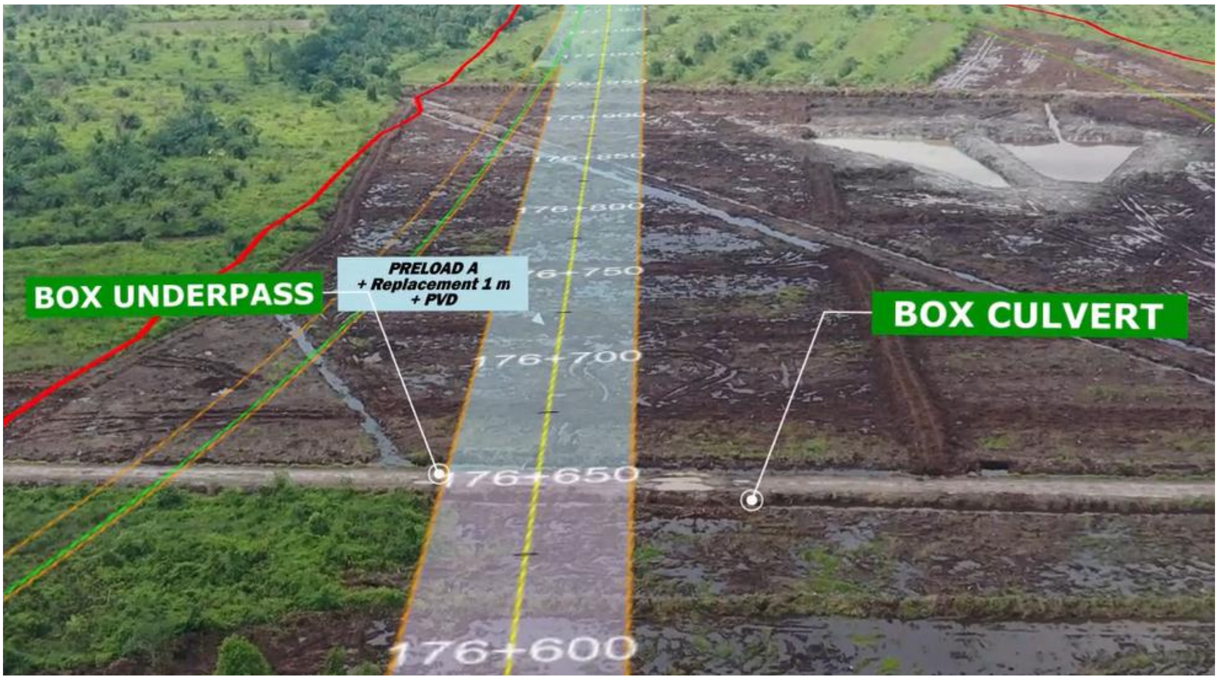

Figure 2. Existing condition of land surface Sta 176+800 (PT. Hutama Karya, 2024)

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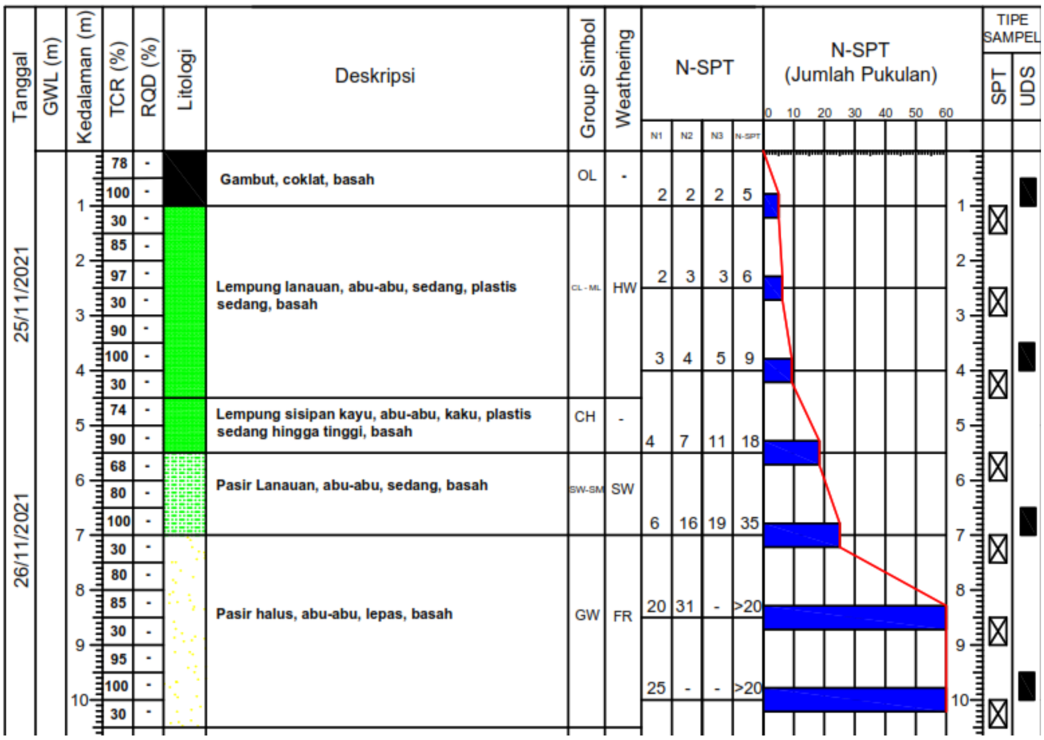

Figure 3. Results of soil investigations using borlog Sta 176+800
(PT. Hutama Karya, 2022)

The existing design is preloading + prefabricated vertical drain (PVD), combined with 1 meter deep subgrade replacement. The cross-sectional of the existing design can be seen in Figure 4.

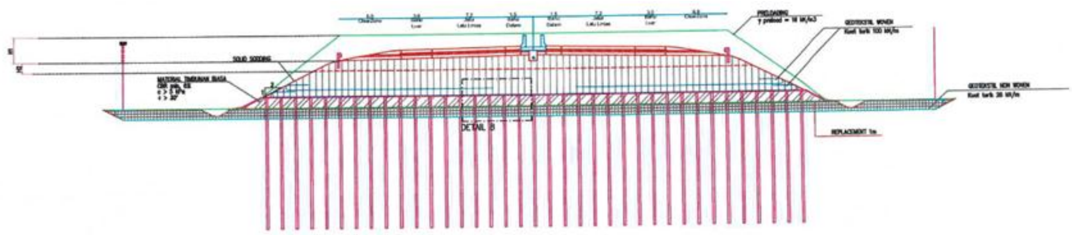

Figure 4. Typical cross section of preload handling + replacement 1 meter + PVD
(PT. Hutama Karya, 2022)

Based on the preliminary data from the soil investigation that has been carried out and the planned handling methods, it is necessary to evaluate the existing design. Then it is necessary to carry out alternative design to obtain handling methods that are more efficient, easier to implement, and can still be completed in accordance with the work contract implementation period.

LITERATURE REVIEW

Soil Parameters and Its Correlation

1. **Soft Soil**

   Soil layers called soft soils are cohesive soils that have N-SPT values of less than 8. Commonly used correlations for determining soil consistency levels are shown in Table 1.

Table 1. Soil Consistency Based on Standard Penetration Test (N-SPT)

Sand		Clay / Silt	
N-SPT	**Relative Density**	**N-SPT**	**Consistency**
0 - 4	Very Loose	< 2	Very Soft
4 - 10	Loose	2 - 4	Soft
10 - 30	Medium	4 - 8	Medium
30 - 50	Dense	8 - 15	Stiff
> 50	Very Dense	15 - 30	Very Stiff
		> 30	Hard

Source: Terzaghi and Peck, 1948

2. Organic Soil

Organic soils are soils categorized by their organic content. Organic soils are defined as having an organic content of 25% to 75% as shown in Table 2.

Table 2. Classification of fine-grained soils based on organic content

No	Organic Content	Soil Type
1	< 25%	Clay or Silt or Sand
2	25% - 75%	Organic Soil
3	> 75%	Peat Soil

Source: ASTM D4427-92, 1992

N-SPT and its Corrections

N-SPT values are corrected based on two correction factors, namely due to groundwater table and due to overburden pressure. The correction of N-SPT values due to the water table is specific to fine sand, silty sand and clayey sand types that are below the water table and only if N > 15. For clay, silt and coarse sand types and if N ≤ 15 then no correction is made. The N-SPT value correction formula is used by taking the smallest value from the formula according to Terzaghi and Peck, 1960 and Bazaraa, 1967 below.

$$N1 = \ 15 + \frac{1}{2}(N - 15) \qquad \ldots (1)$$

$$N1 = \ 0{,}6\, N \qquad \ldots (2)$$

The second correction is the correction of the N-SPT value due to the influence of overburden stress, this correction value is expressed by the notation N1(60) which is taken based on SNI 4153-2008. The formula for calculating the N-SPT correction due to overburden pressure, N1(60) is in accordance with the following equation:

$$N1_{(60)} = \ N_M x C_N x C_E x C_B x C_R x C_S \qquad \ldots (3)$$

$$C_N = 2{,}2/(1{,}2 + \frac{\sigma vo}{Pa}) \qquad \ldots (4)$$

Soil Settlement

1. Primary Settlement

Primary settlement in clay soils is divided into two, namely normally consolidated soil (NC-Soil) and over-consolidated soil (OC-Soil). Normally consolidated soil (NC-Soil), where the effective overburden pressure at this time is the maximum pressure ever experienced by the soil. So for NC-Soil, Equation (5) can be used.

$$Sc \ = \ \frac{Cc\ H}{1+e_0} log \ \left(\frac{\sigma_0{}' + \Delta\sigma}{\sigma_0{}'}\right) \qquad \ldots (5)$$

Over-consolidated soil (OC-Soil), where the current overburden effective pressure is less than the pressure the soil has previously experienced. The maximum previously experienced overburden effective pressure is called preconsolidation pressure. So for OC-Soil, Equation (6) can be used if (Po' + ΔP) ≤ Pc' and Equation (7) if (Po' + ΔP) > Pc'.

$$Sc = \frac{Cs}{1+e0} log \left(\frac{P'o+\Delta P}{P0}\right) H \quad \ldots (6)$$

$$Sc = \left[\frac{Cs}{1+e0} log \frac{Pc'}{P'0} + \frac{Cc}{1+e0} log \frac{P'0+\Delta P}{Pc'}\right] Hi \quad \ldots (7)$$

2. **Secondary Settlement**

Secondary compression occurs after the pore water pressure has disappeared completely. The compression that occurs here is due to plastic adjustment of the soil grains. Secondary compression can be calculated using Equation (8) (Mesri, 1973).

$$Ss = \frac{C_\alpha}{1+e_p} H \ log \left(\frac{t}{t_p}\right) \quad \ldots (8)$$

where Cα' = secondary settlement index = Cα/(1+ep)

According to Dhianty and Mochtar (2018) there is an empirical correlation between the secondary settlement index (Cα') and the initial void ratio (e0), the final void ratio of primary settlement (ep), and the effective consolidation stress (P') as follows:

Cα' = (0.0077 ep – 0.006) P' … (9)

3. **Organic Soil Settlement Gibson & Lo Method**

According to Dhowian and Edil (1980) the type of compression curve (strain vs log time) for fibrous peat soils consists of four strains: direct stress, primary strain, secondary strain and tertiary strain. Gibson and Lo (1961) tried to create a rheological model for soil undergoing compression in the one-dimensional direction. The strain equation as a function of time proposed by Gibson & Lo (1961) is as follows:

$$\varepsilon(t) = \Delta\sigma(a + b\left(1 - e^{-\frac{\lambda}{b}t}\right)) \quad \ldots (10)$$

4. **Consolidation Time**

According to Terzaghi in Das (1985), the consolidation time (t) can be calculated using the equation:

$$t = \frac{Tv.Hdr^2}{Cv} \quad \ldots (11)$$

The value of the time factor (Tv) is influenced by the degree of consolidation (U) and is calculated using Equation (12) for U = 0 to 60% and Equation (13) for U > 60%.

$$T_v = \frac{\pi}{4}\left(\frac{U\%}{100}\right)^2 \quad \ldots (12)$$

$$Tv = 1{,}781 - 0{,}933 \log(100 - U\%) \quad \ldots (13)$$

Parameter Changes Due to Settlement

Settlement causes the voids in the soil to shrink so that the void ratio (e) decreases and the soil becomes denser. The new void ratio value after settlement is calculated using Equation (14). The volume weight of the new soil is calculated using Equation (15).

$$e_1 = e_0 - \frac{1+e_0}{H_0} S_c \quad \ldots (14)$$

$$\gamma_{sat} = \frac{(G_s+e_1)\gamma_w}{1+e_1} \quad \ldots (15)$$

Stability and Reinforcement

Slope stability analysis is performed by calculating the safety factor of the slope under review by comparing the shear stress formed along the surface of the most critical crack plane with the shear strength of the soil (Das, 1985).

1. **Geotextile Reinforcement**

The geotextile planning calculation requires data obtained from the auxiliary program, including the value of safety factor (SF), moment of resistance (Mr), landslide radius (R), and coordinates of the landslide center point. The first layer of geotextile was installed right on top of the subgrade, so the vertical distance between the geotextile installation and the center point of the landslide became the additional holding moment. If the moment of the geotextile installed in the first layer still does not meet the requirement of the difference in retaining moment (∆Mr), it is necessary to install geotextile in the next layer and so on until the cumulative geotextile moment value is greater than ∆Mr. In geotextile planning, the allowable tensile strength of the geotextile material must be considered in accepting or resisting shear forces when a landslide occurs.

The strength of the geotextile material is calculated using the equation:

$$TAllow = TUltimate \times \frac{1}{FSid \times FScr \times FScd \times FSbd} \quad \ldots (16)$$

The cumulative geotextile moment is calculated using the equation:

$$M_{Geotextile} = TAllow \times y\ layer_n + TAllow \times y\ layer_{n+1} + \cdots \quad \ldots (17)$$

2. **Cerucuk Reinforcement**

Reinforcement of the embankment with the use of cerucuk can increase the stability of the embankment against potential landslides. In this case, it is necessary to calculate the strength to accept shear force. The required number of piles is calculated based on the additional holding moment required to stabilize the embankment and the strength of each pile.

The relative stiffness factor (T) is calculated using the equation from NAVFAC DM-7 (1986). The equation for calculating the relative stiffness factor (T) is:

$$T = \left(\frac{EI}{f}\right)^{\frac{1}{5}} \quad \ldots (18)$$

The general equation for calculating the force received by 1 pile is:

$$P = \frac{Mp}{FM \times T} \quad \ldots (19)$$

Based on the magnitude of the P value that 1 pile can withstand, the number of piles (n) required is calculated using the following equation:

$$n = \frac{\Delta Mr}{P1\ Cerucuk \times R} \quad \ldots (20)$$

Replacement

Replacement method is a common method of soil improvement. The soil is stripped and replaced with good quality backfill soil. The disadvantage of this method is that it requires a lot of replacement backfill material, which can damage the environment in the backfill material mining area. In addition, the application of this method also requires a large disposal site for the existing subgrade.

RESEARCH METHODS

This research was conducted by collecting secondary data (soil data, topography, planning data) and primary data obtained through sampling disturbed soil and undisturbed soil for laboratory testing. The next stage is the determination of soil parameters to determine the characteristics of the subgrade, followed by an analysis of the existing design. In this planning, the calculation of soil compression is carried out to ensure that the rate of settlement meets the required standards. Furthermore, alternative treatment is planned with the subgrade replacement method up to 0.5 m and 1.0 m thick. Stability analysis was also carried out, followed by reinforcement planning using geotextiles or piles. Then, the implementation cost for each treatment method was calculated so that the most optimal solution in terms of cost could be selected.

DATA COLLECTION

Soil Data

Based on the BHT-09 borlog data (Sta 176+850) at a depth of 0 - 1.0 meter there is organic soil with a soft consistency. At a depth of 1.0 - 2.0 meters there is silt loam soil with medium consistency. At a depth of 2.0 - 5.5 meters there is silt loam soil with a stiff consistency. While for soil depths below 5.5 meters there are sandy soils with medium to dense consistency. The consistency, physical and mechanical parameters used for the analysis can be seen in Table 3 and Table 4.

Table 3. N-SPT data of BHT-09

Depth (m)	Description	N-SPT	N1(60)	Consistency
0 - 1	Peat	2	3	Soft
1 - 2	Clay	5	7	Medium
2 - 5,5	Clay	9	11	Stiff
5,5 - 10	Sand	35	23	Medium

Source: PT. Hutama Karya (2022)

Table 4. Parameter Data Used for Stability and Settlement Analysis

Depth (m)	Soil Type	Ɣ sat (t/m3)	Wc (%)	Gs	e	Cv (cm2/sc)	Cc	Cs	Φ (°)	C (kg/cm2)
0 - 1	Peat	1,08	351	1,5	5,1	0,015	1,13	0,13	11,9	0,02
1 - 2	Clay	1,66	41	2,6	1,4	0,001	0,43	0,17	13	0,45
2 – 5,5	Clay	1,66	41	2,6	1,4				13	0,45
5,5 - 10	Sand	1,75	29	2,7	1,2				28,7	0,19

Variations of Embankment Height and Replacement

Based on the final engineering plan data obtained from PT Hutama Karya (Persero), it is known that the planned embankment height varies between 6.00 meters to 8.00 meters with a subgrade width of 37.9 m. The variation of the planned embankment height for each location can be seen in Table 5. Replacement is 0.5m and 1.0m thick. The soil used for calculations as embankment and replacement can be seen in Table 6.

Table 5. Variation of Design Embankment Height

STA	RTA Design Method	RTA Reinforcement Method	Embankment Height (m)
176+800	Preload A + Replacement 1 m + PVD	3-layer Geotextile	8,00
176+825	Preload A + Replacement 1 m + PVD	3-layer Geotextile	8,00
176+850	Preload A + Replacement 1 m + PVD	3-layer Geotextile	8,00
176+875	Preload A + Replacement 1 m + PVD	3-layer Geotextile	7,00
176+900	Preload A + Replacement 1 m + PVD	3-layer Geotextile	7,00
176+925	Preload A + Replacement 1 m + PVD	3-layer Geotextile	7,00
176+950	Preload A + Replacement 1 m + PVD	3-layer Geotextile	6,00
176+975	Preload A + Replacement 1 m + PVD	3-layer Geotextile	6,00

Sumber: Hutama Karya

Table 6. Embankment and Replacement Soil Parameters

No	Parameter	Unit	Value
1	Unit Weight	t/m3	1,80
2	Cohesion	kg/cm2	-
3	Friction Angle	°	30,00

RESEARCH ANALYSIS

Primary Settlement

Based on the results of the calculation of clay soil settlement using Equation (7) and organic soil/peat soil using Equation (10) with variations in embankment height of 6 m, 7 m, and 8 m and variations in subgrade replacement; the primary settlement results can be seen in Figure 5.

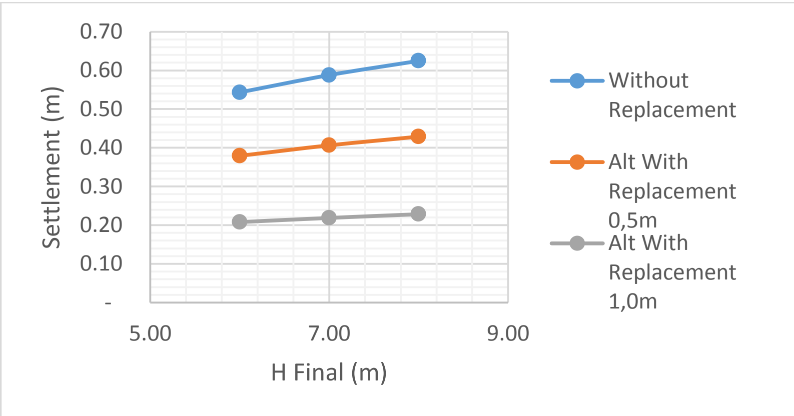

Figure 5. Final embankment height and settlement for each variation of embankment height and replacement thickness

Based on Figure 5, it can be seen that for all variations of embankment height, the greater the final H value, the greater the settlement. For the same final embankment height, the larger the subgrade replacement, the smaller the settlement.

Consolidation Time

The time required for 90% consolidation using Equation (11) with 1-way drainage is 0.28 years. The consolidation time graph can be seen in Figure 6.

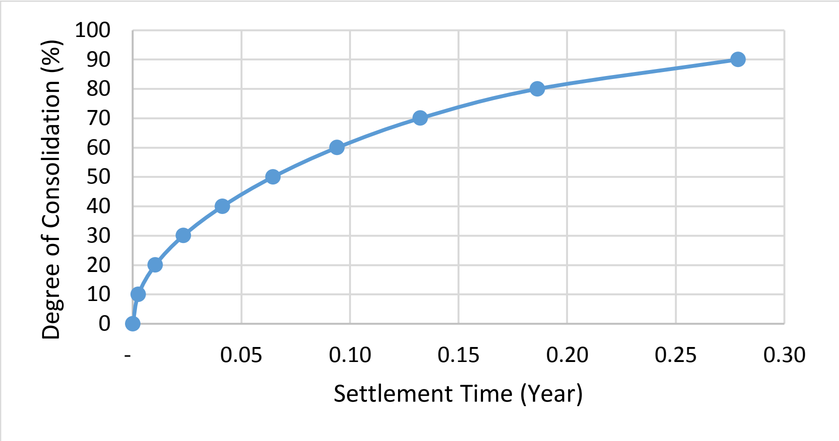

Figure 6. Relationship of settlement time and degree of consolidation

Secondary Settlement

After the primary settlement is completed, secondary settlement will occur during the operational period. Secondary settlement (Ss) is calculated up to 15 years after the completion of primary settlement using Equation (8) and Equation (9). The results of secondary settlement can be seen in Table 7.

Table 7. Secondary Compression Value for Each Variation of Embankment Height and Replacement Thickness

Handling Method	Embankment Height (m)	Ss year- (cm)						
		2	3	5	6	10	12	15
Existing Design	6,00	0,79	0,93	1,11	1,17	1,36	1,43	1,51
	7,00	0,63	0,74	0,88	0,94	1,08	1,14	1,20
	8,00	0,45	0,53	0,63	0,66	0,77	0,81	0,85
Alt Without Replacement	6,00	1,08	1,26	1,51	1,60	1,85	1,94	2,05
	7,00	0,99	1,16	1,39	1,47	1,70	1,79	1,89
	8,00	0,88	1,03	1,23	1,30	1,50	1,58	1,67
Alt With Replacement 0,5m	6,00	1,06	1,25	1,49	1,58	1,82	1,91	2,03
	7,00	0,97	1,14	1,36	1,44	1,67	1,75	1,85
	8,00	0,85	1,00	1,19	1,26	1,46	1,53	1,62
Alt With Replacement 1,0m	6,00	1,05	1,23	1,47	1,55	1,80	1,89	2,00
	7,00	0,95	1,11	1,33	1,41	1,63	1,71	1,81
	8,00	0,82	0,96	1,15	1,22	1,41	1,48	1,57

After knowing the secondary settlement in the year under review, the rate of settlement was calculated in year 2 to year 3 with a settlement condition <2 cm/year, and between year 2 to year 12 with a settlement condition <10 cm/year (assuming an implementation period of 2 years and a maintenance period of 1 year) and in year 5 to year 6 with a settlement condition <2 cm/year, and between year 5 to year 15 with a settlement condition <10 cm/year (assuming an implementation period of 2 years and a maintenance period of 3 years). The calculation results can be seen in Table 8 and Table 9.

Table 8. Rate of Settlement Year 2 to 3 and Year 2 to 12

Handling Method	Embankment Height (m)	Year 2 to 3 (cm)	requirements <2cm/year	Year 2 to 12 (cm)	requirements <10cm/10years
Existing Design	6,00	0,14	ok	0,63	ok
	7,00	0,11	ok	0,51	ok
	8,00	0,08	ok	0,36	ok
Alt Without Replacement	6,00	0,19	ok	0,86	ok
	7,00	0,17	ok	0,80	ok
	8,00	0,15	ok	0,70	ok
Alt With Replacement 0,5m	6,00	0,18	ok	0,85	ok
	7,00	0,17	ok	0,78	ok
	8,00	0,15	ok	0,68	ok
Alt With Replacement 1,0m	6,00	0,18	ok	0,84	ok
	7,00	0,16	ok	0,76	ok
	8,00	0,14	ok	0,66	ok

Table 9. Rate of Settlement Year 5 to 6 and Year 5 to 15

Handling Method	Embankment Height (m)	Year 5 to 6 (cm)	requirements <2cm/year	Year 5 to 15 (cm)	requirements <10cm/10years
Existing Design	6,00	0,07	ok	0,40	ok
	7,00	0,05	ok	0,32	ok
	8,00	0,04	ok	0,23	ok
Alt Without Replacement	6,00	0,09	ok	0,54	ok
	7,00	0,08	ok	0,50	ok
	8,00	0,07	ok	0,44	ok
Alt With Replacement 0,5m	6,00	0,09	ok	0,54	ok
	7,00	0,08	ok	0,49	ok
	8,00	0,07	ok	0,43	ok
Alt With Replacement 1,0m	6,00	0,09	ok	0,53	ok
	7,00	0,08	ok	0,48	ok
	8,00	0,07	ok	0,42	ok

The rate of settlement calculation results show that the requirements for all years under review have been met. Therefore, there is no need for preloading/surcharge to eliminate secondary compression.

Stability Analysis

To obtain the value of the factor of safety, the Limit Equilibrium Method program was used for each variation of the embankment plan under review. The results of the safety factor calculation can be seen in Figure 7.

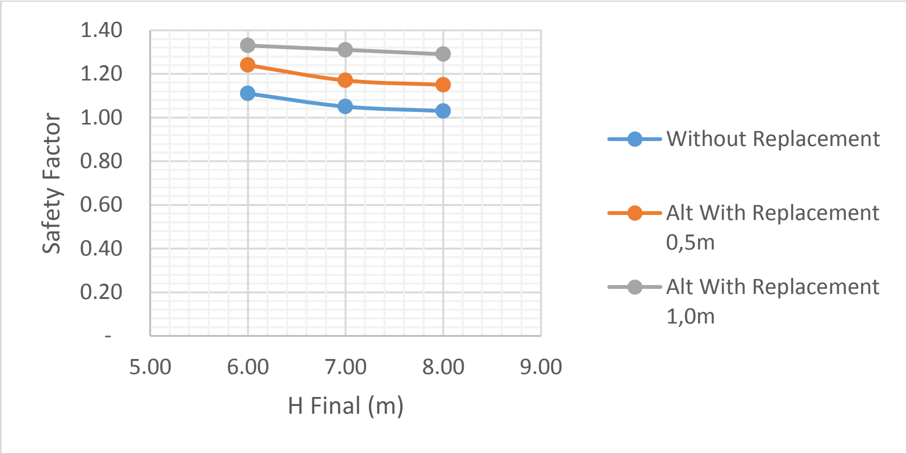

Figure 7. Relationship between embankment height and safety factor

Based on Figure 7, it can be seen that for all embankment variations, the greater the embankment height, the smaller the factor of safety. For the same height, the greater the subgrade replacement, the greater the factor of safety.

Reinforcement with Geotextiles or Cerucuk

In this study, a geotextile with an ultimate tensile strength of 100 kN and a 25 x 25 cm pile cerucuk were used. Reinforcement is used when the SF plan is less than 1.50. To obtain the required amount of geotextile reinforcement, Equation (16) and Equation (17) were used. Meanwhile, to calculate the amount of reinforcement required, Equation (18), Equation (19), and Equation (20) were used. The number of geotextiles and cerucuk for each variation of and subgrade replacement can be seen in Figure 8 and Figure 9.

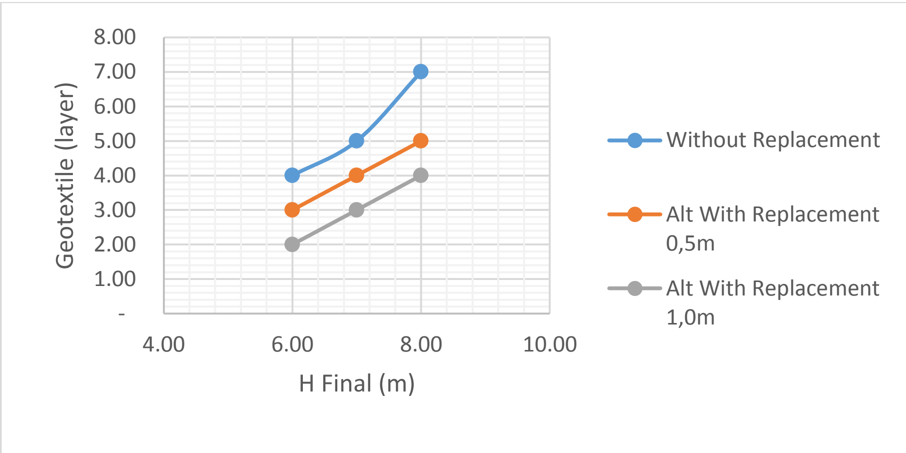

Figure 8. Relationship between the embankment height and geotextile reinforcement for each variation of embankment height and replacement thickness

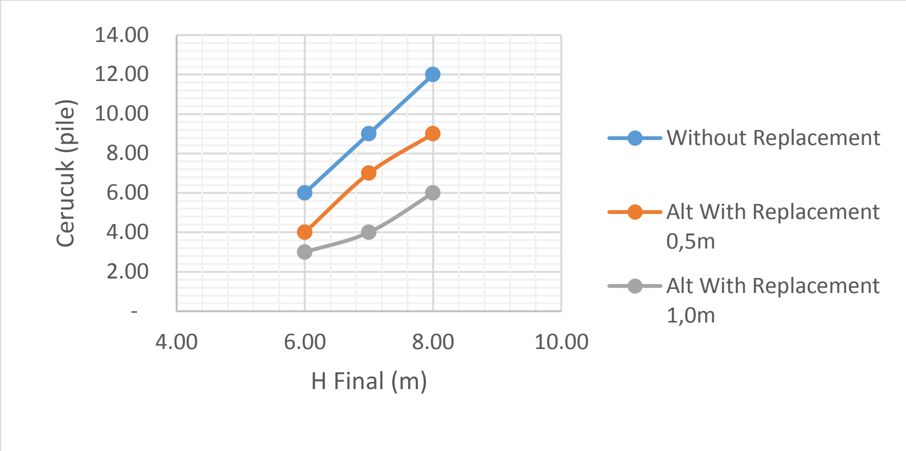

Figure 9. Relationship between the embankment height and cerucuk reinforcement for each variation of embankment height and replacement thickness

Based on Figure 8 and Figure 9, it can be seen that for all variations of embankments, both with geotextile reinforcement and reinforcement of piles, the greater the embankment height, the more reinforcement will be required. For the same embankment height, the greater the subgrade replacement, the smaller the need for additional reinforcement.

Cost Analysis of Work Implementation

The cost of implementing the work is calculated based on the volume of each job and the predetermined unit price. The unit price of work is obtained from the Unit Price Analysis of the Construction Contract Work of the Trans Sumatra Toll Road Project Rengat Pekanbaru Ruas Lingkar Pekanbaru according to the General Specifications for Barriers and Toll Roads in 2020. The unit price used is the unit price applicable at the project site, namely the unit price in the Trans Sumatra Toll Road Project area of the Pekanbaru Rengat Pekanbaru Ring Road Section in Pekanbaru City, Riau Province. The results of the analysis of the calculation of the combined cost of and subgrade replacement work can be seen in Figure 10.

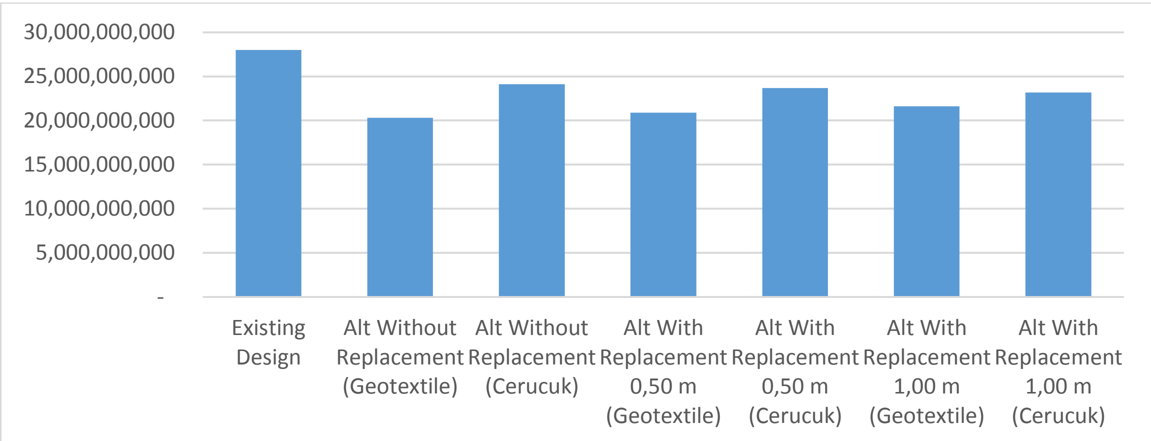

Figure 10. Cost of work for each alternative handling

Based on Figure 10 for the Sta 176+775 - Sta 176+975 review location, it can be seen that the larger the subgrade replacement, the higher the total cost. This is because the volume of soil replacement is larger, resulting in a significant increase in cost. Existing design planning with preloading and subgrade replacement costs Rp27,982,249,128, while embankment planning without subgrade replacement with geotextile reinforcement costs

Rp20,306,592,753. Therefore, a cost efficiency of Rp7,675,656,376.00 will be obtained if planning without subgrade replacement using geotextile reinforcement is used.

CONCLUSIONS

1. The thicker the subgrade replacement, the smaller the rate of settlement. Rate of Settlement for all variations of embankment height and subgrade replacement in years 2 to 3 (>2 cm/year), years 2 to 12 (>10 cm/10 years), years 5 to 6 (>2 cm/year), and years 5 to 15 (>10 cm/10 years) have met the requirements.
2. The higher the final embankment, the smaller the safety rating. For the same final embankment height, the greater the subgrade replacement performed, the greater the safety figure.
3. Geotextile reinforcement with variations in embankment height of 6, 7, and 8 meters as follows:

Design	Embankment Height (m)	T Ultimate (kN/m)	Geotextile	
			Lapis	Length
Without Replacement	6,00	100,00	4,00	252,60
	7,00	100,00	5,00	334,50
	8,00	100,00	7,00	492,80
Alt With Replacement 0,5m	6,00	100,00	3,00	190,20
	7,00	100,00	4,00	268,60
	8,00	100,00	5,00	354,50
Alt With Replacement 1,0m	6,00	100,00	2,00	127,30
	7,00	100,00	3,00	202,20
	8,00	100,00	4,00	284,60

4. Cerucuk Reinforcement with variations in embankment height of 6, 7, and 8 meters as follows:

Design	Embankment Height (m)	Size	Cerucuk	
		(cm x cm)	Pile/m	Length
Without Replacement	6,00	25 x 25	6,00	36,00
	7,00	25 x 25	9,00	54,00
	8,00	25 x 25	12,00	72,00
Alt With Replacement 0,5m	6,00	25 x 25	4,00	24,00
	7,00	25 x 25	7,00	42,00
	8,00	25 x 25	9,00	54,00
Alt With Replacement 1,0m	6,00	25 x 25	3,00	18,00
	7,00	25 x 25	4,00	24,00
	8,00	25 x 25	6,00	36,00

5. The most optimal planning in terms of cost compared to the existing design is the alternative planning without subgrade replacement with geotextile reinforcement. Planning the existing design with preloading and subgrade replacement costs Rp27,982,249,128, while planning the embankment without subgrade replacement with geotextile reinforcement costs Rp20,306,592,753. Therefore, a cost efficiency of Rp7,675,656,376.00 will be obtained if planning without subgrade replacement using geotextile reinforcement is used.

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