CERUCUK
Volume 6 No. 4 2022 (277-294)

DESIGN OF SHEET PILE AS AN ALTERNATIVE FOR HANDLING LANDSLIDE SLOPES ON JATI BARU ROAD, ASTAMBUL DISTRICT, BANJAR REGENCY

Muhammad Rifaldi, Muhammad Afief Ma'ruf, Rusdiansyah

Department of Civil Engineering, Faculty of Engineering, Lambung Mangkurat University

Author: 1610811210050@mhs.ulm.ac.id

ABSTRACT

Road conditions on the banks of river bends are certainly very potential to experience landslides or declines caused by changes in soil properties due to the influence of water flow velocity. Therefore, a retaining wall is needed to prevent landslides and subsidence, but in the case that is currently being reviewed the soil still experiences landslides and subsidence even though a retaining wall has been built. Therefore it is necessary to evaluate in this case to find the cause of landslides and subsidence.

Evaluations were carried out using sondir data and NSpt data, which of the data will be made a correlation to determine the type and parameters of the soil. Then the slope stability evaluation was carried out using the GEO-SLOPE 2018 software, calculating soil bearing capacity, soil settlement and analysis of existing retaining walls.

From the evaluation results, it was found that several aspects of the existing condition were stated to have safety numbers that did not meet the safe requirements. So that the cantilever sheet pile type retaining wall is made as an alternative handling. From the results of the stability analysis using Geoslope/W 2018 obtained a safety rate of 2,646 at low tide conditions and 4,234 at high tide conditions, so that the design of the cantilever sheet pile type retaining wall used in the design is safe against landslides.

Keywords: retaining wall, stability, landslide, subsidence

1. INTRODUCTION

Roads are land transportation infrastructure that plays an important role in the growth sector, especially for the continuity of the distribution of goods and services. The existence of roads is very necessary to support the rate of economic growth along with the increasing need for transportation facilities that can reach remote areas, So if there is damage to the road, it will definitely interfere with economic activities and other activities. One of the factors causing damage to the road is the soil factor. Soil behavior is different from one place to another, so a deeper identification is needed regarding the reaction that will be caused by the soil to certain treatments. The behavior of the soil on the edge of the river bend is certainly different from the soil in other places, because the influence of high water velocity can change the nature of the soil, so that in some cases the land on the banks of the river experiences landslides. As in the case of slope landslides located on Jati Baru road, Aatambul District, Banjar Regency, South Kalimantan Province. The road, which is right at the bend of the river, experienced a landslide after the construction of the retaining wall and only dredging was carried out, but the land actually experienced a landslide.

2. THEORETICAL STUDY

Definition of Landslide

Understanding landslides and ground movement have in common. Each definition, especially avalanches, needs an explanation of both. Soil movement is the movement of soil/stone mass in an upright, horizontal or oblique direction from its original position. Soil motion includes creep and flow motion as well as landslides. From this definition, according to Purbohadiwidjojo in Pangular 1985, landslides are part of the ground movement.

Lateral Earth Pressure

In designing retaining walls, knowledge of lateral earth pressure is required. According to Hardiyatmo (2014), the magnitude and distribution of soil pressure on retaining walls is highly dependent on the lateral strain of the soil relative to the wall.

Rankine theory

According to Rankine (1857) theory, the lateral earth pressure analysis is carried out with the following assumptions:

1. Soil is in a position of plastic equilibrium, ie any soil element in the right condition will collapse.
2. Non-cohesive fill soil (c = 0).
3. The friction between the wall and the fill is negligible or the wall surface is considered perfectly smooth (δ = 0).

• ***Horizontal fill soil surface***

$$P_a = K_a z \gamma$$

with the value of K_a in the equation ,

$$K_a = tg^2 \left(45 - \frac{\varphi}{2}\right)$$

The total active earth pressure (P_a) for the retaining wall of height *H* is expressed by the equation:

$$P_a = 0{,}5\, H^2 \gamma\, K_a$$

with the point of capture of the force at *H/3* of the base of the retaining wall.

Loads Working Behind the Walls

• ***Loads are evenly distributed (Traffic Load)***

The evenly distributed load *(q)* on the fill soil can be considered as a soil load with a thickness of *hs* with a certain volume weight *(γ)*. Thus the height $h_s = \frac{q}{\gamma}$. The active earth pressure at depth *hs* from the assumed soil height is:

$$P_a = h_s\, \gamma\, K_a = q\, K_a$$

So, due to the evenly distributed load, there is an additional active earth pressure force ($P_a{}'$) of:

$$P_a{}' = q\, K_a H$$

with,

K_a = active earth pressure coefficient

q = evenly distributed load (kN/m2)H

= height of retaining wall (m)

γ = volume weight of backfill (kN/m3)

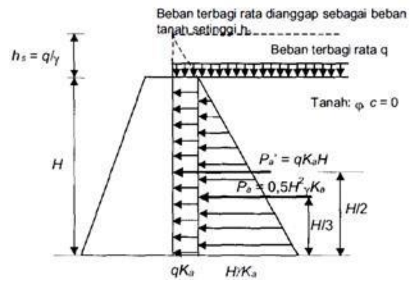


Figure 1 example of an evenly distributed load

Sheet Pile

Sheet pile is a construction that can withstand the pressure of the surrounding soil, preventing landslides and usually consists of a sheet pile wall and its supports. Sheet pile construction consists of several sheets of sheet pile that are driven into the ground, and form a continuous vertical wall formation that is useful for holding back soil piles or sloping soil. Sheet pile consists of parts that are made in advance (prefabricated) or printed in advance (pre-cast). (Sri Respati, 1995).

Slope Stability with Geoslope/W 2018

According to Ferdiannur (2017), geoslope is a program that uses the boundary equilibrium method to calculate the safety factor of a slope. With this program we can model slopes in the form of drawings on a computer in a computer aided design (CID) application. After inputting the soil material properties data and setting the analysis as desired.

3. DESIGN METHOD

Flowchart

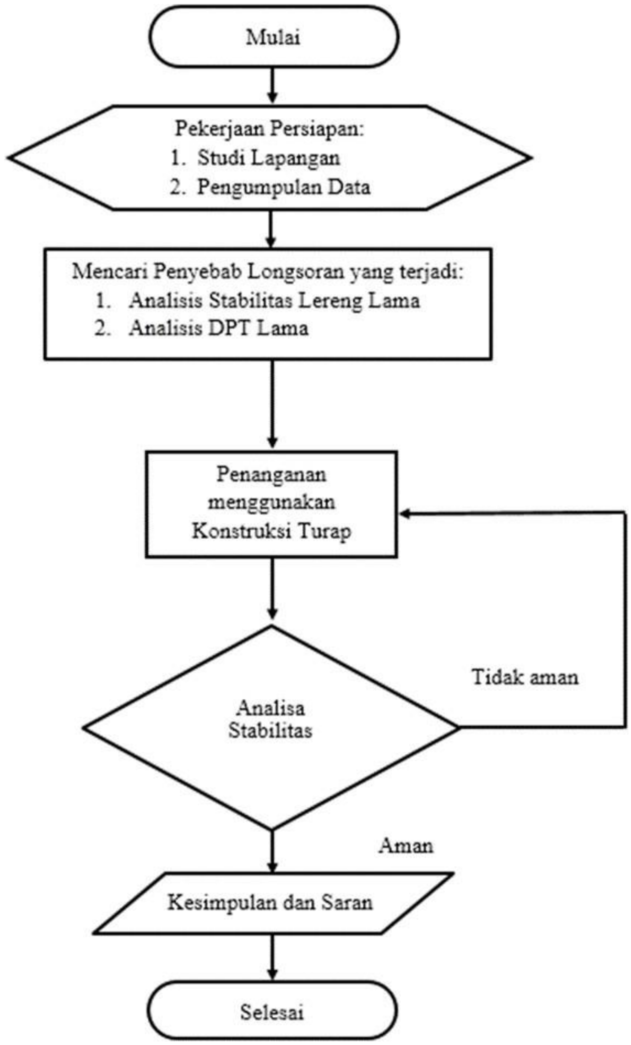


Figure 1 diagrams the flow

4. RESULTS AND DISCUSSION

Calculation of Soil Parameters:

Laboratory results for soil parameters

Table 1 Test Results in the Laboratory

Bor No.	*Depth* (m)	*Sample*	Kadar Air ω (%)	Berat Isi Tanah γ (gr/cm³)	Berat Jenis Tanah (Gs)	*Grain Distribution* Clay <0.002 mm (%)	Silt & Clay 0.002 - 0.05 mm (%)	Fine Sand 0.05 - 0.2 mm (%)	Medium Sand 0.2 - 0.6 mm (%)	Course Sand 0.6 - 2 mm (%)	Gravel >2 mm (%)	*Plasticity Test* LL (%)	PL (%)	PI (%)	Klasifikasi USCS
BH-1	-07,50 m s.d -08,00 m	UDS	39,122	1,729	2,693	35,055	30,588	12,065	15,345	1,727	5,220	60,650	33,392	27,258	OH & MH
	-11,50 m s.d -12,00 m	DS	19,198	1,756	2,704	40,956	35,365	8,037	11,798	2,357	1,487	55,350	32,288	23,062	OH & MH

Bor No.	Depth (m)	*Sample*	*Unconfined Compression Test* qu (kg/cm²)	ε (%)	St	Direct Shear Test c (kg/cm²)	ϕ (°)	Consolidation Cc	Cs	Cv (cm²/sec)
BH-1	-07,50 m s.d -08,00 m	UDS	1,883	12,618	1,245	0,336	15,802	0,282	0,043	0,00036
	-11,50 m s.d -12,00 m	DS	-	-	-	0,527	13,501	-	-	-

Sondir test results

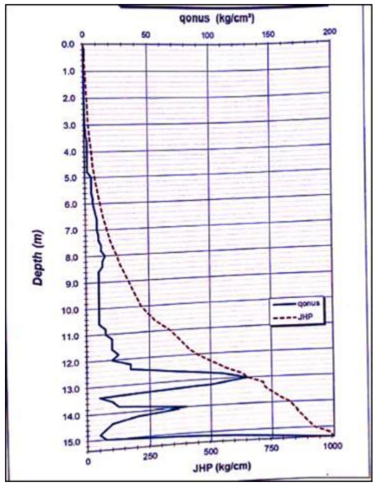


Figure 3 Sondir Graph

Sondir Data Correlation Result

Correlation to get the value of Cohesion, Angle of Shear, and weight of soil using a table of correlation values of the results of the NSPT test and soil physical properties according to Bowles (1988). The result is as follows.

Table 2 Results of sondir data correlation

Kedalaman	Jenis Tanah	Cu (kN/m2)	γ (kN/m3)	ϕ (˚)
0,2 - 8,0	Lempung Sangat Lunak	10	15	0
8,0 - 12,2	Lempung Lunak	12,5	16	0
12,2 - 13,2	Lensa Pasir	75	20	0
13,2 - 15,0	Pasir Lepas	30	18	0
15,00 -	Tanah Keras	0	24	40

Calculation of Initial Condition Slope Stability Using Geoslope/W 2018

It was found that the safety factor (SF) = 0.764 < 1.50, which means the slope is unstable and can experience a landslide.

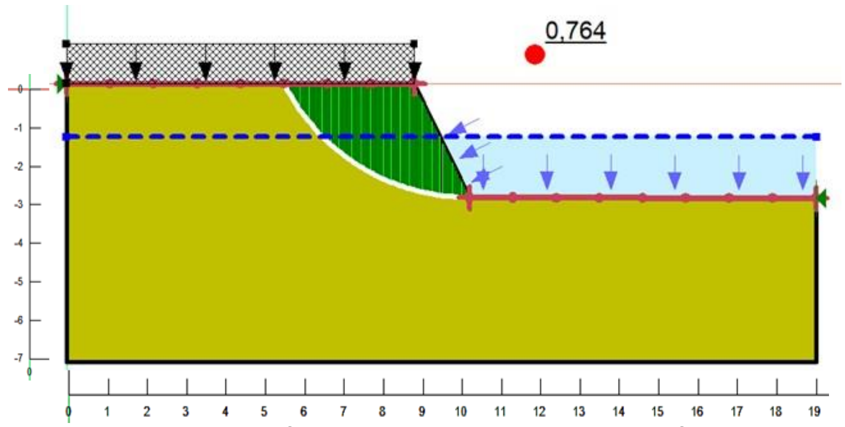


Figure 4 Analysis of Slope Stability Conditions Before Landslide

Analysis of Existing Soil Bearing Capacity

The first step in this stage is to calculate the *Hk* of the subgrade, as follows:

$$Hk = \frac{Cu.Nc}{\gamma.SF}$$

Cu = 10 kN/m2 ; γ = 15 kN/m3 ; Nc = 5,14 ; SF = 1,5

Hk = (10. 5,14)/ (15.1,5)

= 2,28 m < = 2,5 m

The critical height = 2.28 is obtained, which is smaller than the existing embankment, which is 2.5 m high, which means that the subgrade has the possibility to experience soil bearing capacity failure caused by the existing embankment. Furthermore, the bearing capacity of the subgrade is calculated to determine whether it is safe or not to be given a 2.5 m high soil pile.

Known :

H_{timb} = 2,5 m ; γ_{timb} = 17 kN/m3 ; Cu = 10 kN/m2 ; Nc ; 5,14

- The bearing capacity of the subgrade

qu = Cu. Nc

= 10 . 5,14

= 51,4 kN/m2

- Stockpile and traffic loads

Self weight of embankment (q1) :

$$q1 = \gamma \,.\, H$$
$$= 17 \,.\, 2{,}5 = 42{,}5 \text{ kN/m2}$$

Traffic weight (q2) :

$$q2 \quad = q \,.\, (\text{Htim} + \text{Traffic Equivalent Load})$$
$$= 20 \,.\, (2{,}5 + 0{,}8) = 66 \text{ kN/m2}$$

Q =108,5 kN/m2 > qu = 51,4 kN/m2 (NOT ELIGIBLE)

Because the length of the galam is 5 m, to determine the JHP value, it can be seen from the sondir data at a depth of 5 m, which is 51 kN/m

Kgalam = 3,14 * 0,1 = 0,314 m

Δq = (n. Kgalam . JHP)/ SF

= 16 . 0,314 . 51 / 5

= 51,29 kN/m2

q = q subgrade + Δq

= 51,4 + 51,29 = 102,69 kN/m2 < q tot = 108,5 kN/m2 (NOT ELIGIBLE)

It turned out that after adding cerucuk galam as an increase in carrying capacity, it was still not enough because the q value was still below the total q value. Which means that with the addition of the cerucuk galam, the soil is still unable to withstand the load generated by the embankment and results in failure of the bearing capacity.

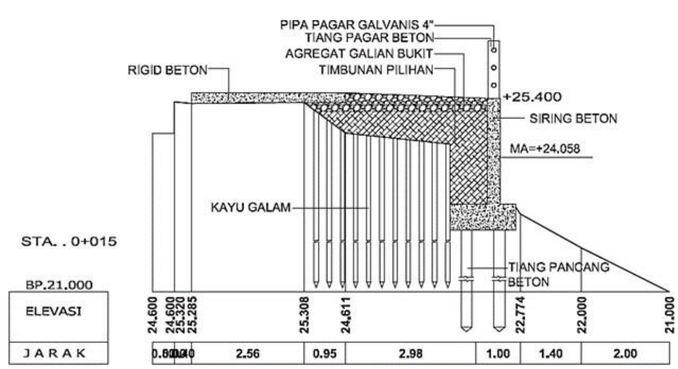


Figure 5 Design of existing cerucukgalam wood (Source: Dokumen Shop Drawing CV.Takabeya Jaya Utama)

Existing Land Subsidence Analysis

The calculation of the decrease that will be calculated is before and after the presence of cerucuk galam, which is as follows.

- Before there was a cerucuk galam

Take the example calculation (Layer 1):

The thickness of the layer under consideration (Hi) = 8 m

Embankment height (Htimb) = 2.5 m

γ timb = 17 kN/m3

To determine the values of e and cv use the soil parameter correlation table (Biarez & favre)

e = 2,38

Cc = 0,7

Cv = 31,4 m2/th

Tv 90% = 0,848

To determine the value of the influence factor (I) used the curve below

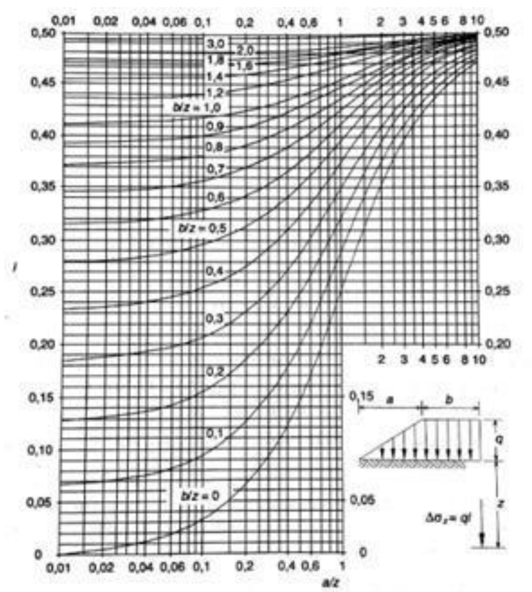


Figure 6 Influence Factors of Decrease in the Angle of the Trapezoid

a. Po $= \gamma'. Hi$

$= 15\text{-}10 . 8$

$= 40$ kN/m2

b. Δp = I . po

= 0,42 . 40

= 16,8 kN/m2

c. Sc $= \frac{H}{1+e}\ (\text{Cc} \log (\frac{\Delta p+po}{po}))$

$= \frac{8}{1+2{,}38}\ (0{,}7 \log (\frac{16{,}8+40}{40}))$

= 0,25 m

The next calculation is made a table

Table 3 Calculation of Sc before the existence of a cerucuk galam

No	Hi (m)	Zi (m)	y (kN/m3)	y' (kN/m3)	po (kN/m2)	e	Cc	I	Δp (kN/m2)	Δp+po (kN/m2)	ΔHi=Sc (m)
1	8	4	15	5	40	2,38	0,7	0,42	16,8	57	0,252312
2	4,2	10,1	16	6	73	1,7	0,41	0,35	25,62	99	0,083124
3	1	12,7	20	10	132	0,69	0,05	0,326	43,032	175	0,003626
4	1,8	14,1	24	14	210	1,08	0,02	0,308	64,68	275	0,002018
5	1	15,5	40	30	480	0,2	0	0,293	140,64	621	0
										Sc Tot =	0,34108

d. T $= \frac{Tv\ x\ H.H}{Cv}$

$= \frac{0{,}848\ x\ 15{,}5 . 15{,}5}{31{,}4}$

= 6,49 year

e. Decrease /year = 0.341/6.49

= 52.254 mm/year > 30 mm/year (NOT ELIGIBLE)

- After there is a cerucuk galam

Total galam (n) = 16 pieces/m2

Qult = (JHP.K)/SF

= (51. 0,314)/5

= 3,206 kN/tiang

Qtot = n.Qult

= 16. 0,314

= 51,29 kN/m2

The burden received by galam (pvu) = (2,5 . 17)/ 51,29 = 0.83 kN/m2

a. Po $= \gamma'. Hi$

$= 15\text{-}10 . 2$

= 10 kN/m2

b. Δp = Po . I

= 10 . 0,5

= 5 kN/m2

Sc $= \frac{H}{1+e} \left(Cc \log \left(\frac{\Delta p + po}{po} \right) \right)$

$= \frac{2}{1+2{,}38} \left(0{,}7 \log \left(\frac{5+10}{10} \right) \right)$

= 0,0143 m

The next calculation is made a table

Table 4 Calculation of Sc After the Existence of cerucuk

No	Hi (m)	Zi (m)	y (kN/m3)	y' (kN/m3)	po (kN/m2)	e	Cc	pvu (kN/m2)	Δp (kN/m2)	pvu + po (kN/m2)	ΔHi = Sc (m)
1	2	1	15	5	10	2,38	0,7	0,828598	5,00	11	0,014319867
2	4,2	4,1	16	6	37	1,7	0,41	0,828598	17,11	38	0,006101863
3	1	6,7	20	10	72	0,69	0,05	0,828598	31,68	73	0,044801244
4	1,8	8,1	24	14	126	1,08	0,02	0,828598	50,90	127	4,92689E-05
5	1	9,5	40	30	300	0,2	0	0,828598	114,00	301	0
										Sc Tot =	0,065272243

c. T $= \frac{Tv\ x\ H.H}{Cv}$

$= \frac{0{,}848\ x\ 15{,}5 .15{,}5}{31{,}4}$

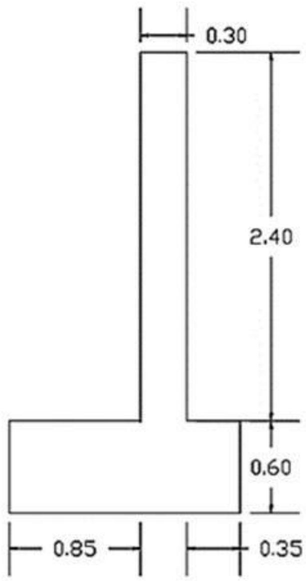
= 6,49 year

d. Decrease /year = 0.065/6.49

= 10.06 mm/year < 30 mm/year (QUICKLY)

Analysis of Existing Cantilever Type Retaining Wall

An analysis of the retaining wall was carried out with the water level at a height of 1.66 m above the base of the retaining wall.



Tekanan tanah aktif total, Pa (kN)	Jarak dari 0 (m)	Momen ke-0 (Kn.m)
0,5 x 20,1 x 1,34 = 13,47	1,99	28,8
20,1 x 1,66 = 33,37	0,83	27,69
0,5 x (28,4 – 20,1) x 1,66 = 6,89	0,55	3,79
∑Pa = 53,72		**∑M = 60,28**

NO	Berat W (Kn)	Jarak Dari 0 (m)	Momen ke 0 (kN.m)
1	0,85 . 1,34 . 15 = 17,085	1,075	18,37
2	0,85 . 1,06 . 15 = 13,515	1,075	14,53
3	0,30 . 2,40 . 24 = 17,280	0,5	8,64
4	1,50 . 0,60 . 24 = 21,600	0,75	16,20
5	1,06 . 0,35 . 10 = 3,710	0,175	0,65
	Total berat = 73,19		**Jumlah Momen ke 0 = 58,38**

Stability control

- **Roll**

  SF = Mt tot/ Mg tot

  = 58,38/60,28 = 0,97 < 1,5 (NOT ELIGIBLE)

- **Sliding**

  SF = (c_a . B + Pp)/P tot

  = (10 . 1,50 + 11. 2,3)/ 53,72

  = 0,75 < 1,5 (NOT ELIGIBLE)

- **Soil bearing capacity**

A minipile of 20 meters will be used with dimensions of 20/20 cm

Using the Meyerhofs equation (1956)

$Q_{ult} = 40.N_b.A_p + 0,2.N.A_s$

Nb (Nspt value at the base of the pile) = 54

Ap (cross-sectional area of the pile) = 0.04 m2

As (Area of the pile blanket) = 16 m2

N (Average Nspt value along the pile) = 24.25

Qult = 40.54.0,04 + 0,2.24,25.16

= 164,00 kN/m2

SF = (164,00 . 2) / 161,795 = 2,027 < 3(NOT ELIGIBLE)

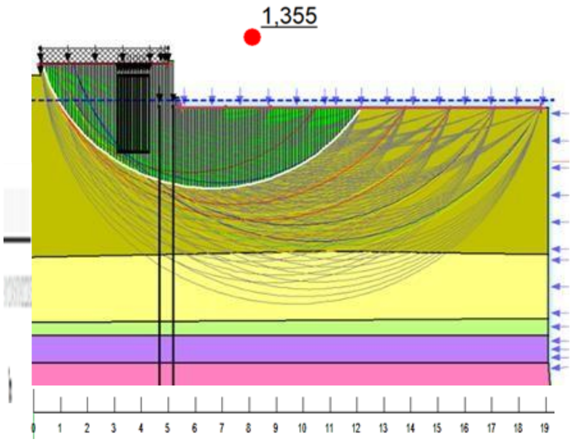


Figure 8 Stability of existing slope

Cantilever Sheet Pile Planning

a. Calculation of earth pressure coefficient

The coefficient of active and passive earth pressure is obtained using the Rankine formula, namely:

1. Coefficient of active earth pressure

$Ka = \tan^2 (45 - \frac{\phi}{2})$

$Ka1 = \tan^2 (45 - \frac{0}{2}) = 1$

2. Coefficient of passive earth pressure

$Kp = \tan^2 (45 + \frac{\phi}{2})$

$Kp1 = \tan^2 (45 + \frac{\phi}{2}) = 1$

Table The results of the calculation of the active earth pressure coefficient and passive earth pressure coefficient

Jenis Tanah	Cu (kN/m2)	ɣ (kN/m3)	ϕ (˚)	Ka	Kp
Lempung Sangat Lunak	10	15	0	1	1
Lempung Lunak	12,5	16	0	1	1
Lensa Pasir	75	20	0	1	1
Pasir Lepas	30	18	0	1	1
Tanah Keras	0	24	40	0,22	4,6

b. Calculation of earth stress

Active

- point 1

$W = (\gamma \,.\, Z) + q$

$= 17 \,.\, 0 + 20 = 20$ kN/m2

$\sigma h = W \,.\, Ka1 – 2\, Cu \sqrt{Ka1}$

$= 20 \,.\, 1 – (2 \,.\, 12{,}5 \,.\, \sqrt{1}) = -5$ kN/m2

Passive

- point 3,5

$W = (\gamma 1 \,.\, Z) + q$

$= (5 \,.\, 0) + 0$

$= 0$

$\Sigma h3{,}5 = W \,.\, Ka1 + 2\, Cu1 \sqrt{Kp1}$

$= (0 \,.\, 1) + (2 \,.\, 10 \,.\, 1)$

$= 20$ kN/m2

After calculating up to point 8, the soil stress will be obtained as below.

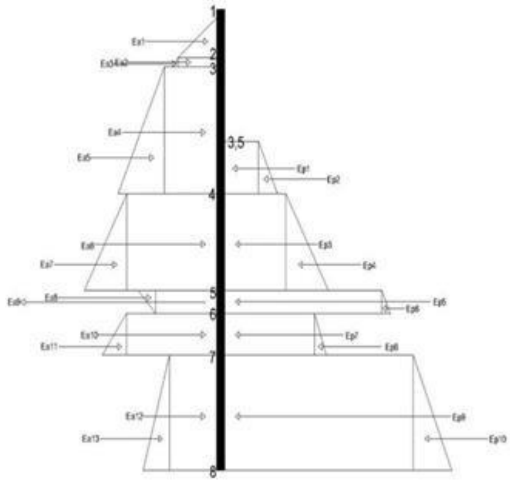


Figure 9 Lateral Earth Stress and Pressure Diagram

c. Calculation of Active and Passive Earth Pressure

$$\frac{hc}{2{,}1-hc} = \frac{5}{30{,}7}$$

30,7hc = 10,5 - 5hc

Hc = 0,294 m

2,1 – hc = 1,806 m

Za1 = 1,806 m

$$Ea1 = ((\,{}^{1}/_{2}\,.\,(q + (\gamma tim\,.\,Ztim))\,.\,Ka - 2\,.\,Cu\,\sqrt{Ka})\,.\,Za1$$

$$= ((\,{}^{1}/_{2}\,.\,(20 + (17\,.\,2{,}1))\,.\,1 - 2\,.\,12{,}5\,.\,\sqrt{1})\,.\,1{,}806$$

$$= 5{,}1471 \text{ kN/m}$$

Table. active earth pressure calculation

	Gaya		Jarak ke Titik 8	Momen
Tekanan Tanah Aktif	Ea1 =	5,1471	13,6 + Do	70 + 5,1471Do
	Ea2 =	12,28	12,7 + Do	155,956 + 12,28Do
	Ea3 =	0,56	12,63 + Do	7,0728 + 0,56Do
	Ea4 =	211,75	9,75 + Do	2064,56 + 211,75Do
	Ea5 =	75,625	8,833 +Do	667,99 + 75,625Do
	Ea6 =	256,2	4,9 +Do	1255,38 + 256,2Do
	Ea7 =	52,92	4,2 +Do	222,264 + 52,92Do
	Ea8 =	-38,8	2,3 + Do	(-89,24 - 38,8Do)
	Ea9 =	5	2,4667 + Do	12,3335 + 5Do
	Ep10 =	110,16	0,9 + Do	99,144 + 110,16Do
	Ep11 =	12,96	0,6 + Do	7,776 + 12,96Do
	Ep12 =	29,062Do	0,5Do	14,531Do^2
	Ep13 =	1,54Do^2	0,33Do	0,5082^3
Tekanan Tanah Pasif	Ep1 =	45,4	8,135 + Do	369,329 + 45,4Do
	Ep2 =	12,88225	7,757 + Do	99,93 + 12,88225Do
	Ep3 =	152,67	4,9 +Do	748,084 + 152,67Do
	Ep4 =	52,92	4,2 +Do	222,264 + 52,92Do
	Ep5 =	186,55	2,3 + Do	429,065 + 186,55Do
	Ep6 =	5	2,133 + Do	10,665 + 5Do
	Ep7 =	191,79	0,9 + Do	172,611 + 191,79Do
	Ep8 =	12,96	0,6 + Do	7,775 + 12,96Do
	Ep9 =	280,37Do	0,5Do	140,185Do^2
	Ep10 =	32,2Do^2	0,33Do	10,626Do^3

d. Calculation of sheet pile depth

$\sum$MDo = 0

$\sum$MDo = $-10{,}118$ Do^3– 125,65Do^2 + 43,63Do + 2413,52

Do = 3,9513 m

D = SF x Do = 1,5 x 3,9513 = 5,927 ≈ 6 m

Total length of sheet pile = 6 + 15 = 21 m

e. Maximum Moment Calculation

Mx = $-10{,}118$ Do^3– 125,65Do^2 + 43,63Do + 2413,52

Mx/Dx = 0

Mx/Dx = -30,35x^2- 251,306x + 43,63

x = 0,171 m

Mmaks = $-10{,}118(0{,}171\ )$ ^{3}– 125,65$(0{,}171)^2$ – 43,63(0,171)

+ 2413,52

= 2417,26 kNm

f. Sheet Pile Profile Planning

Steel sheet pile with Larsen profile with t = 210 MN is used, then we get

$$W = \frac{Mtotal}{\sigma t} = \frac{2417{,}26}{210 \text{ x } 10\text{^}3} = m^3 = 11510\ cm^3$$

Where W is the Widestands Moment.

From the larssen sheet pile profile table, the LF606 n larseen profile is used with W = 17810 cm^3 > W = 11510 cm^3 So that the sheet pile is declared safe.

Table 9 Profile of larseen sheet pile

LARSSEN-Stahlpfähle LF
LARSSEN LF steel piles

	Lamellen anzahl[1] *No. of plates*[1]	Widerstands-moment *Section modulus* W_y	W_z	Flächenträg-heitsmoment *Moment of inertia* I_y	I_z	Eigen-last *Weight*	Abmessungen *Dimensions* B	H	t	s	Umfang[2] *Circum-ference*[2] Abwicklung[3] / Umriss Total[3] / Outline	Fläche *Area* Stahlquerschnitt *Steel cross section*	eingeschl.[4] / Umriss[4] *Included*[4] / *Outline*[4]	Trägheits-radius *Radius of gyration* i_y
		cm³	cm³	cm⁴	cm⁴	kg/m	mm	mm	mm	mm	cm	cm²	cm²	cm
LF 24	0	13870	**13530**	827100	**827000**	**438**	1222	1165	15,6	10,0	428	555	9610	38,6
	5	22920	20780	1400000	1269000	634		1185			378	805	10980	41,7
LF 605	0	15530	**15010**	1030400	**1030200**	**418**	1373	1309	12,5	9,0	468	530	12590	44,1
	5	25770	23150	1748000	1590000	614		1329			425	780	13890	47,3
LF 605 K	0	16090	**15560**	**1066800**	1068000	**434**	1373	1309	12,2	10,0	468	552	12590	44,0
	5	26430	23730	1792000	1629000	630		1329			425	802	13890	47,3
LF 25	0	16530	**16130**	986100	**985300**	**515**	1222	1165	20,0	11,5	428	655	9610	38,8
	5	25660	23510	1571000	1436000	711		1185			378	905	10980	41,7
LF 716	0	16650	**16270**	1231000	**1231000**	**400**	1514	1442	10,2	9,5	493	509	15600	49,2
	5	28090	25380	2116000	192100	596		1462			468	759	16780	52,8
LF 606 n	0	17810	**17270**	**1195000**	1196000	**471**	1385	1321	14,4	9,2	478	600	12740	44,6
	5	28220	25620	1937000	1774000	667		1341			428	850	14140	47,7
LF 628	0	18940	**18320**	**1287000**	1288000	**497**	1406	1339	16,3	9,8	480	633	12910	45,1
	5	29400	26760	2044000	1881000	693		1359			435	883	14530	48,1
LF 607 n	0	21720	**21070**	**1476000**	1477000	**570**	1402	1336	19,0	10,6	485	725	12910	45,1
	5	32360	29660	2252000	2079000	766		1356			434	975	14460	46,2
LF 720	0	21770	**21150**	**1699000**	1700000	**482**	1608	1531	12,0	10,0	524	614	17710	52,6
	5	34160	31010	2717000	2493000	678		1531			497	864	18990	56,1

Overall Stability

Calculation of overall stability using the Geoslope/W 2018 software

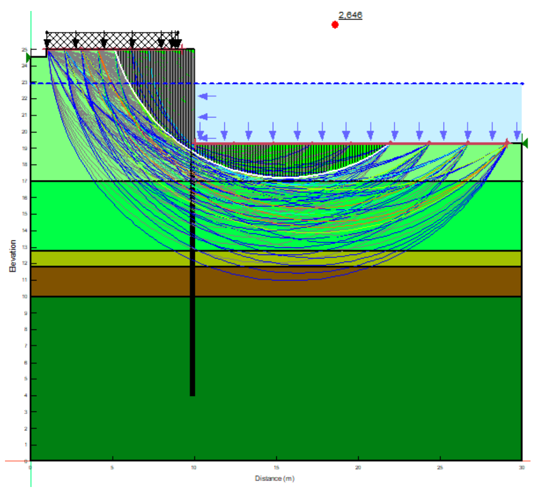


Figure 10 Slope stability with cantilevered sheet pile design

5. CONCLUSION

1. In the condition before the retaining wall was built, the slope stability in the area had a safety rating of 0.764 < 1.5. With this safety factor, the road experienced landslides so that a cantilever type retaining wall was built (existing) but the slopes still experienced landslides caused by several factors, namely:
   - The design of the existing embankment as high as 2.5 meters causes the bearing capacity of the subgrade to be unable to accept the load even though a cerucukgalam has been installed where qizin = 102.69 kN/m2 < qwork = 108.5 kN/m2
   - The safety rating on the cantilever type retaining wall (existing) does not meet the safety requirements, namely: Rolling stability = 0.97 < 2 ; Shear stability = 0.75 < 2 ; Pile bearing capacity = 2.027 < 3.

- Slope stability after the existing retaining wall was built, it was found that SF = 1.355 < 1.5, which value is still not safe, and there is a distance of 0.9 meters between the piles of the retaining wall which causes very soft clay to flow through between the piles.

2. Redesigned the cantilever sheet pile type retaining wall that meets the safety requirements. sheet pile used in the design of this final project is steel sheet pile with LF606 n larseen profile.
3. Calculation of the overall stability of the cantilever sheet pile type retaining wall using the help of the Geoslope/W 2018 software obtained a safety number (SF) of 2.646.

BIBLIOGRAPHY

Bowles, J.E. 1979. *Foundation Analysis and Design Volume 2 Fourth Edition.* Jakarta: Erlangga.

Chalid, Fachriyan. Kamaludin Lubis. 2017. Design Analysis of Sheet Piles for the Pier Construction Project in Belawan International Container Terminal, JCEBT (*Journal of Civil Enggineering, Building and Tranportation)*

Christady, Hary*, 2002, Foundation Techniques 1 , PT Beta Offset Publisher, Jakarta*

Das, B.M. *Principles of Foundation Engineering* 8*th*Edition*,* 2016, Publishimg Cengage Learning

Das, B.M. 1995. *Soil Mechanics (Principles of Geotechnical Engineering) Volume 1 Translated by : Noor E.M. and Indrasurya B.M.* Jakarta: Erlangga.

Hardiyatmo, H C. 2010. Foundation Analysis and Planning Part II.Yogyakarta: Gadjah Mada University Press Hardiyatmo, H C. 2010. Foundation Analysis and Planning Part II.Yogyakarta: Gadjah Mada University Press

Simatupang, Pintor Tua, 2008, Cantilever Sheet Sheet Type Module, Mercu Buana University, Jakarta

Sorodarsono, Suyono. Kazuto Nakazawa (ed.). 1990. *Soil Mechanics and Foundation Engineering.* Jakarta Pradnya Paramita

Yuliet, Rina. Abdul Hakim. Yones Ramanugraha. 2014. “Study of Stability of Concrete Sheet Piles. *Journal of Stability Study of Concrete Sheet Piles on the banks of the Anai River, Padang Pariaman Regency. Padang*.