Design of MSE Wall with geotextile reinforcement for temporary mitigation of landslide in Padang Panjang – Sicincin road section (STA 64+100)

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Abstract. The Padang Panjang - Sicincin roads section was cut off due to a flash flood on Saturday, 11 May 2024. This caused a landslide in the area resulting in the national road access being cut off, and traffic flow was forced to be diverted to several alternative routes. The study aims to obtain the total length of geotextile at any depth (L), the vertical spacing of the layers (S_v), and the lap length (l_1) in MSE wall heights at STA 64 + 100. The computation method for external and internal stability (pull out and break), uses the Load Resistance Factor Design (LRFD). From the calculation results for the effective height (H_e) of the MSE wall of 8 m, the reinforcement length is 6 m, the embedment depth is 0.6 m, the vertical spacing (S_v) is 0.8 m from the internal stability, and the fold length (l_1) is 1 m. The design results obtained MSE wall dimensions that are safe for external and internal stability. These dimensions can be used for temporary landslide handling but not long-term. For long-term stability, adding facing elements like secant piles, cantilever walls, and other forms is recommended to avoid erosion due to river water flow.

1 Introduction

The main road section on the Padang Panjang – Sicincin city was cut off due to flash floods that caused landslides on the area's road slopes, so traffic flow was forced to be diverted to several alternative routes. From the results of the field visit, information was obtained that STA 64-100 was one of the road sections that experienced landslides, so the STA 64+100 road section was selected for this study, as shown in Fig. 1. The design of the MSE wall associated with the geotextile as the reinforcement was carried out to temporarily mitigate landslides on the Padang Panjang - Sicincin boundary at (STA 64+100). The design results of the optimal MSE wall dimensions can be used as a reference for designing landslide mitigation in other areas under the same conditions.

The MSE walls consist of a face cover and steel or geosynthetic reinforcements tied to the face cover and installed in layers in a granular soil embankment that quickly drains water. The combination of reinforcement and granular soil embankment produces an internally stable composite structure [1]

The MSE walls are an alternative to conventional retaining walls, such as gravity retaining walls and cantilever walls, which are widely used for road construction. MSE walls are prone to landslides and retain soil on slopes close to vertical to minimize the width of the road embankment area, especially on high embankments

Fig. 1. Landslide location in Padang Panjang-Sicincin Road section (STA64+100) [2]

This study can provide information on the design of MSE walls by the Indonesian National Standard (SNI) 8460-2017. Other researchers have used SNI 8460-2017 to design MSE walls [3]. Research on the design of MSE walls with Geotextile reinforcement has been widely conducted, but many still need to refer to SNI 8460-2017; this can be seen from the references used by researchers [4-7]. After the publication of SNI 8460-2017, there are still researchers who have not used SNI 8460-2017 for the

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design of MSE walls [8], and there are researchers who use other standards from outside Indonesia, such as the FHWA standard [9]. Research on slope landslides and handling of slope landslides with Retaining Walls without geotextiles has been conducted by the research team since 2012 and has been published in several national journals [10-13].

The primary purpose of using reinforcement is to increase the stability of steep slopes for slope improvement and to increase the stability of the surface. Fig. 2 shows three failure modes in reinforced slopes, namely internal, external, and combined failure.

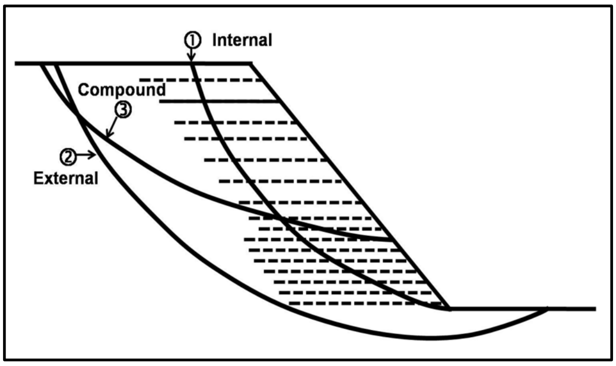

Fig. 2. Failure modes for reinforced soil slopes (FHWA) **[**14]

2 Research methods

2.1 Field survey

The field survey was carried out to describe the area experiencing the landslide and to measure the geometry of the existing slope.

2.2 Data sources

The secondary data obtained is information about the dominant material used for the MSE wall, namely, 100 kN woven geotextile, sand, and gravel mixture as material backfill taken from the Sicincin quarry area and compacted with a relative compaction of 96.86% (γ_r = 23.6 kN/m^3).

2.3 Analysis of MSE Walls

2.3.1 Establish project requirements

In this section, the geometry of the MSE wall is determined, including the effective height of the MSE wall, the length of the MSE wall, service life, type of reinforcement, earthquakes, and the presence of groundwater. According to SNI 8460 2017, the required reinforcement length is $L \geq 0.7\ H_e$, where H_e is the effective height of the MSE wall. Regardless of the effective height, L must be ≥ 2.5 m (Fig. 3). The length of the reinforcement must be the same for the entire height of the wall except for certain things, such as adding length and reducing the length of the reinforcement. The minimum reinforcement length also increases due to the work of external loads and the softness of the foundation soil. The vertical spacing for MSE walls with geotextile reinforcement is 0.2 m – 1.25 m. This spacing can change with depth.

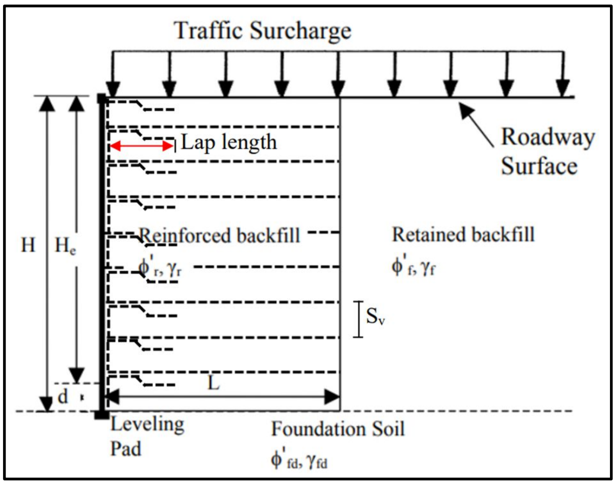

Fig. 3. The parameters for analysis of an MSE wall [14]

2.3.2 Evaluate project parameters

The soil parameters of shear strength and unit weight of embankment on reinforcement, embankment parameters behind reinforcement, and foundation soil parameters are required for MSE wall design requirements. The bearing resistance factor of the foundation for consideration of service limit and consideration of strength limit is assumed to be 359 kN/m^2 and 502 kN/m^2, respectively. Traffic and off-road load (q) are determined based on the road class I [2].

2.3.3 Estimate the depth of embedment and length of reinforcement

The facing element in this study is a flexible facing element made of geosynthetic material. The geosynthetic facing element is installed by bending the geosynthetic 180° and returning it to the back to form a sloped surface. The minimum embedment of the facing element (d) for the slope in front of the horizontal wall is $H_e/20 > 0.35$ m [2, 14].

2.3.4 Estimate unfactored loads

The computation of the stability of the MSE wall is carried out by considering the mass of the MSE wall as a rigid body. The active earth pressure coefficient can be calculated as follows:

$$K_a = \tan^2\left(45 - \frac{f_f'}{2}\right) \tag{1}$$

The vertical forces:

$$V_1 = g_r HL \tag{2}$$

$$V_s = q_t\ L \tag{3}$$

The horizontal forces:

$$F_1 = \frac{1}{2} K_{af}\, g_f\, H^2 \quad (4)$$

$$F_2 = K_{af}\, q\, H \quad (5)$$

The components of the forces acting on the MSE wall can be seen in Fig. 4.

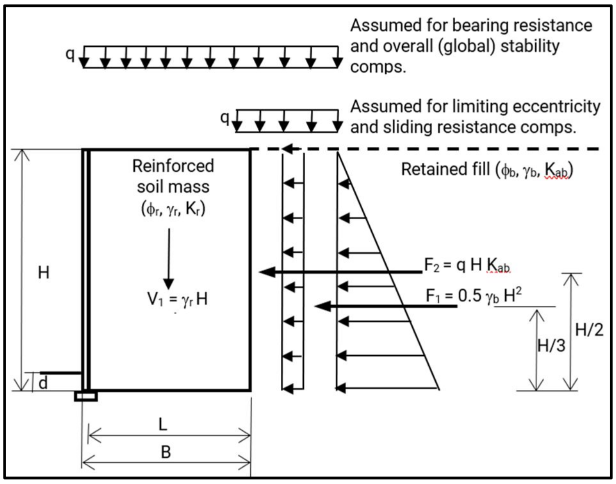

Fig. 4. Components of forces and moments for external stability [2, 14]

2.3.5 Load factors

Table 1 shows the load factors, and Table 2 shows the resistance factors used in the LRFD method.

Table 1. The load factors [14]

Load combination	Load factors		
	EV	EH	LL
Strength I (max.)	1.35	1.5	1.75
Strength I (min.)	1	0.9	1.75
Service I	1	1	1

Table 2. The resistance factors [14]

Item	Resistance factors
Sliding (ϕ_s)	1
Bearing (ϕ_b)	0.65
Tensile (ϕ_t)	0.65
Pullout (ϕ_p)	0.9

2.3.6 Evaluate the external stability

In the LRFD method, the soil load is symbolized by EV and EH, while the live load is symbolized as LL. The forces acting can be used to calculate the external stability of the MSE wall.

2.3.7 Evaluate internal stability

Internal failure of MSE walls can occur in two different failure modes, but both cause significant movements in the MSE wall structure, leading to the collapse of the wall structure. The two internal failure modes are:

1. Failure of the reinforcement material, namely excessive elongation or breaking of the reinforcement, due to high tensile forces on the reinforcement. (FS break > 1.5)
2. Failure due to removing reinforcement from the embankment due to the high tensile force on the reinforcement (FS pullout > 1.5).

3 Results and discussion

The following project requirements were set for designing the MSE wall:

- Height of wall, H_e = 8 m
- Length of wall = 20 m
- Design life = 75 years
- Type reinforcement = geotextile woven
- No seismic considerations
- No groundwater influence

Soil parameters used in MSE wall analysis:

- Reinforced backfill, $\phi'_r = 43^o$, $\gamma_r = 23.6$ kN/m^3
- Retained backfill, $\phi'_f = 43^o$, $\gamma_f = 23.6$ kN/m^3
- Parameters of soil, $\phi'_{fd} = 43^o$, $\gamma_{fd} = 23.6$ kN/m^3
- Live load surcharge = 10 kN/m^2 (Table 1)
- Traffic surcharge = 15 kN/m^2 (Table 1)

Minimum embedment depth (d) = $H_e/20$; for this design, assume d = 0.6 m; thus, H = H_e + d = 8.6 m. The minimum initial length is assumed to be 0.7 H or 6 m.

Based on equation (1), the lateral earth pressure coefficient is:

$$K_{ar} = \tan^2\left(45 - \frac{34^o}{2}\right) = 0.189 \quad (6)$$

$$K_{af} = \tan^2\left(45 - \frac{30^o}{2}\right) = 0.189 \quad (7)$$

Calculate V_1 using equation (2) and V_s using equation (3). The results of the calculation of vertical forces and moments can be seen in Table 3.

Table 3. Unfactored vertical forces and moments

	Force (kN/m)	Moment arm (m)	Moment (kN.m)	LRFD load type
V_1	1,218	3	3,653	EV
V_s	150	3	450	LL

Calculate F_1 using equation (4) and F_2 using equation (5). The results of the calculation of horizontal forces and moments can be seen in Table 4

Table 4. Unfactored horizontal forces and moments

	Force (kN/m)	Moment arm (m)	Moment (kN.m)	LRFD load type
F_1	165	2.87	473	EH
F_2	41	4.30	175	LL

Table 5, Table 6, and Table 7 show the computation of external stability (sliding resistance, overturning/limiting eccentricity, and bearing capacity resistance).

Table 5. Computations of sliding resistance

Item	Strength I (max)	Strength I (min)
Lateral load (H_m), kN/m	319	220
Vertical load (V_1), kN/m	1,644	1,218
Nominal sliding resistance (V_{Nm}), kN/m	1,533	1,136
Sliding resistance (V_{Fm}), kN/m	1,533	1,136
Is $V_{Fm} > H_m$?	YES	YES
Capacity Demand Ratio (CDR)	4.8	5.2
Minimum sliding resistance (V_{Fmin}), kN/m	1,136	
Maximum lateral load (Hmmax), kN/m	319	
Is $V_F$min > Hmmax	YES	
Critical Capacity Demand Ratio (CDR_{critis})	3.56	

Table 6. Computations of limiting eccentricity

Item	Strength I (max)	Strength I (min)
Total vertical load (V_A), kN/m	1,644	1,218
Resisting moments (M_{RA}), kN-m/m	4,932	3,653
Overturning moments (M), kN-m/m	1,015	732
Net moment (M_A), kN-m/m	3,917	2,922
Location of the resultant force (a), m	2.38	2.40
Eccentricity (e_L), m	0.63	0.61
Limiting eccentricity (e), m	1.5	1.5
Is $e_L \leq e$?	Yes	Yes
Calculated e_L/L	0.10	0.10
Maximum overturning moments (M_{OA-C}), kN-m/m	1,015	
Minimum resisting moments (M_{RA-C}), kN-m/m	3,653	
Critical net moments (M_{A-C}), kN-m/m	2,638	
Minimum vertical force (V_{AC}), kN/m	1,218	
Location of the resultant force (a), m	2.17	
Eccentricity from center of wall base: (e_L), m	0.844	
Limiting eccentricity, (e), m	1.51	
Is $e_L \leq e$?	Yes	
Effective width of base (B'), m	4.33	
Calculated e_L/L	0.14	

Table 7. Computations of bearing resistance.

Item	Strength I (max)	Strength I (min)	Service I
Vertical load (ΣV), kN/m	1,906	1,480	1,368
Resisting moments (M_{RA}), kN-m/m	5,719	4,441	4,103
Overturning Moments (M_{OA}), kN-m/m	1,015	732	648
Net moment (M_A), kN-m/m	4,704	3,709	3,455
Eccentricity (e_L), m	0.54	0.50	0.48
Limiting eccentricity (e), m	1.51	1.51	1.00
Is $e_L \leq e$?	YES	YES	YES
Effective width of base (B'), m	4.93	5.01	5.05
Bearing stress (σ_V), kN/m^2	386	295	271
Bearing resistance (q_{nf-str} for strength or q_{nf-ser} for service), (kN/m^2)	502	359	359
Is $\sigma_V < q_{nf-str}$ or q_{nf-ser}?	YES	YES	YES
Capacity Demand Ratio (CDR)	1.30	1.22	1.33
Minimum resisting moments (M_{RA-C}), kN-m/m	4,441		
Maximum overturning moments (M_{OA-C}), kN-m/m	1,015		
Net moment (M_{A-C}), kN-m/m	3,425		
Minimum vertical force (ΣV_C), kN/m	1,480		
Eccentricity (e_L), m	0.7		
Limiting eccentricity (e), m	1.51		
Is eL ≤ e?	YES		
Critical Capacity Demand Ratio (CDR_{critis})	1.57		

The results of external stability calculations in Table 5, Table 6, and Table 7 show that the MSE wall designed with a total height of H = 8.6 m and a reinforcement length of 6 m based on critical values has a capacity demand ratio of 3.56 for shear, 1.57 for bearing capacity respectively. This value is greater than the minimum standard, which is > 1. This shows that the MSE Wall has qualified external stability. For internal stability, the safety factor against pulling out (FS_P) = 1.5, and the safety factor against breaking or breaking (FS_B) = 1.5. Based on these values, the calculation results obtained a vertical spacing (Sv) of 0.8 m; this value is by SNI requirements, which is in the range of 0.2 m - 1.25 m. If divided by the height of the MSE wall, the number of layers of geotextile is 8.6 / 0.8 ≈ 10 layers of geotextile. For the lap length from the calculation results, the value obtained is $l_l = 0.1$ m < 1 m, so a fold length of 1 m is used as the minimum requirement.

4 Conclusion

From the design results for an effective height of 8 m, the embedment depth (d) is 6 m, so the total wall height is (H) 8.6 m. With these dimensions, the MSE wall is safe for external stability. The vertical spacing (S_v) is 0.8 m, and the lap length (l_l) is 1 m, which is safe for internal stability. These dimensions can be used for temporary landslide handling but not long-term stability. For long-term stability, adding facing elements like secant piles, cantilever walls, and other forms are recommended to avoid erosion due to river water flow.

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