

G-2

TDRSA Access Ramp Stability Analysis



TDRSA Access Ramp Stability Calculations

1. Purpose

Evaluate the stability of TDRSA Access Ramp and underlying geosynthetic liner components due to vehicle loading.

2. Methodology

Calculate the Factor of Safety of liner stability using a two-dimension infinite slope analysis where factor of safety FS is evaluated by:

$$FS = \left(\frac{\text{Resisting Forces}}{\text{Driving Forces}} \right)$$

Two conditions will be analyzed: the ramp with static conditions, and the ramp with a loaded vehicle. The analysis does not consider the side width strength of the liner components. As such, the calculated FS is conservative. The minimum design Factor of Safety for this analysis was chosen as $FS=1.1$ based on engineering practice and consequence of failure.

3. Conditions/Assumptions

The TDRSA Access Ramp will be constructed adjacent to the 3:1 (H:V) sideslope of the TDRSA at a 10% slope. Figure 1 in this appendix shows a cross sectional view of the ramp and the loading conditions. Variables are identified on page 5 of this appendix.

4. Factor of Safety for Static Conditions

Resisting Force Calculation

Resisting Force in Block A, F_{RA} :

$$F_{RA} = W_{AR} \tan \phi$$

$$W_{AR} = W_A \cos \beta$$

$$F_{RA} = W_A \cos \beta \tan \phi$$

Therefore:

And
$$F_A = W_A \sin \beta - W_A \cos \beta \tan \phi$$

Resisting Force in Block B, F_{RB}

$$F_{RB} = W_{BR} \tan \phi$$

$$W_{BR} = W_B + F_A \cos \beta$$



$$W_{BR} = W_B + (W_A \sin \beta - W_A \cos \beta \tan \phi) \cos \beta$$

$$F_{RB} = [W_B + (W_A \sin \beta - W_A \cos \beta \tan \phi) \cos \beta] \tan \phi$$

Driving Force Calculation:

$$F_D = W_A \sin \beta$$

Weight of Block A Calculation:

Block A has been divided as illustrated in Figure 1 into two components, A1 and A2. Weight of Block A is sum of the component weights:

$$W_A = W_{A1} + W_{A2}$$

For the portion A1:

$$W_{A1} = \gamma h L$$

γ = unit weight of sand = 115 pcf

h = 3ft. (Figure 1)

L = 45 (Figure 1)

$$W_{A1} = 115 \text{ pcf} \times 3 \text{ ft} \times 45 = 15,525 \text{ lb/ft}$$

For the portion A2:

$$W_{A2} = \frac{\gamma h L}{2} = \frac{15 \text{ pcf} \times 14.2 \text{ ft} \times 43 \text{ ft}}{2} = 35,109.5 \frac{\text{lb}}{\text{ft}}$$

Total weight of Block A:

$$W_A = 15,525 \text{ lb/ft} + 35,109.5 \text{ lb/ft} = 50,634.5 \text{ lb/ft}$$

Weight of Block B Calculation:

$$W_B = \frac{\gamma h L}{2} = \frac{115 \text{ pcf} \times 14.2 \text{ ft} \times 107 \text{ ft}}{2} = 87,365.5 \frac{\text{lb}}{\text{ft}}$$

**Factor of Safety Formula Development:**

$$FS = \left(\frac{\text{Resisting Forces}}{\text{Driving Forces}} \right)$$

Shown in Figure 1:

$$FS = \left(\frac{F_{RA} + F_{RB}}{F_D} \right)$$

Substituting terms developed above:

$$FS = \frac{W_A \cos \beta \tan \phi + [W_B + (W_A \sin \beta - W_A \cos \beta \tan \phi) \cos \beta] \tan \phi}{W_A \sin \beta}$$

$$\beta = 18.4^\circ \quad \cos 18.4^\circ = 0.949 \quad \sin 18.4^\circ = 0.316$$

From TDRSA Liner Stability Analysis, Appendix G-1:

$$\phi = 18^\circ \quad \tan 18^\circ = 0.325$$

Then

$$FS = \frac{50,634.5(0.949)(0.325) + [87,365.5 + (50,634.5(0.316) - 50,634.5(0.949)(0.316))(0.949)](0.325)}{50,634.5(0.316)}$$

$$FS = 2.8$$

5. Factor of Safety for Ramp with Loaded Vehicle**Vehicle Assumptions**

Add vehicle weight to Block A only

Maximum vehicle weight will be 50 tonnes. Weight of vehicle W_v is converted into English units:

$$W_v = 50 \text{ tonnes} \times 2205 \text{ lb / tonne} = 110,250 \text{ lb}$$

Assume 100 psi tire contact pressure and tire width = 2 ft

Calculate contact pressure W_g :

$$W_g = 100 \text{ psi} / 2 \text{ ft} \times 144 \text{ in}^2 / \text{ft}^2 = 7,200 \text{ lb / ft}$$



Calculate Factor of Safety:

$$FS = \frac{(W_A + W_g) \cos \beta \tan \phi + [W_B + (W_A \sin \beta - W_A \cos \beta \tan \phi) \cos \beta] \tan \phi}{(W_A + W_g) \sin \beta}$$

Substitute values:

$$FS = \frac{(50,634.5 + 7200)(0.949)(0.325) + [87,365.5 + (50,634.5(0.316) - 50,634.5(0.949)(0.325))(0.949)](0.325)}{(50,634.5 + 7200)(0.316)}$$

$$FS = 2.5$$

6. Conclusions

The proposed ramp will have Factors of Safety *FS* of 2.8 and 2.5 for static and vehicle loading conditions, respectively. Both values exceed the minimum Factor of Safety for evaluation of 1.1. Based upon these results the ramp and underlying geosynthetic components will be stable.

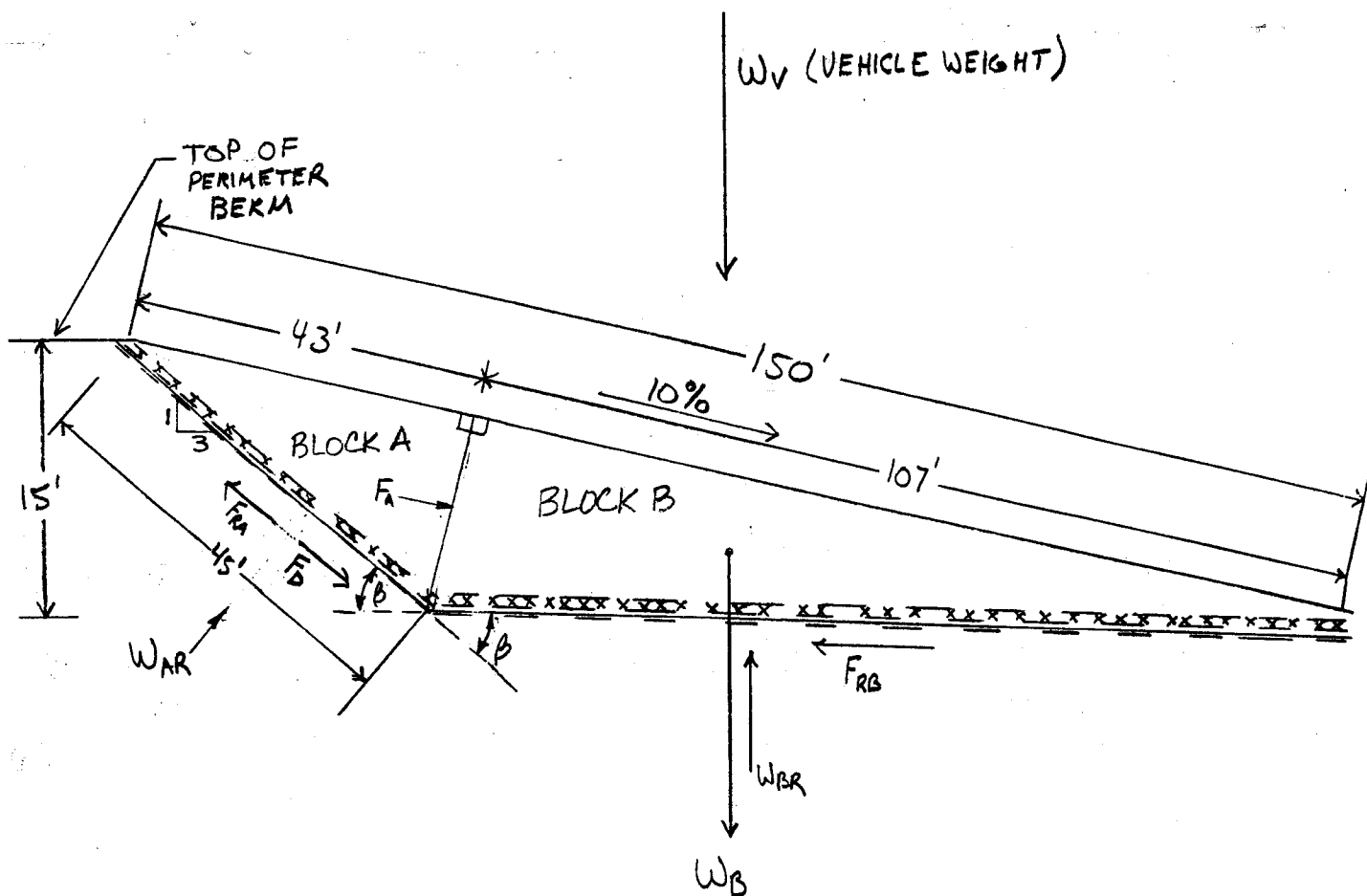
Variable Identification

Variable	Description
β	Angle of TDRSA slope to horizontal, (degrees)
ϕ	Liner system interfacial friction angle, (degrees)
γ	Unit weight of a material, (lb/ft ³ , pcf)
A1	Portion of Block A, identified on Figure 1
A2	Portion of Block A, identified on Figure 1
F_A	Force Block A exerts on Block B, (lb/ft, note 1)
F_D	Driving force of Block A, (lb/ft, note 1)
F_{RA}	Resisting force – Block A, (lb/ft, note 1)
F_{RB}	Resisting force – Block B, (lb/ft, note 1)
FS	Factor of Safety, (unitless)
W_A	Weight of Block A, (lb/ft, note 1)
W_B	Weight of Block B, (lb/ft, note 1)
W_{AR}	Resisting force against weight of Block A perpendicular to the face, (lb/ft, note 1)
W_{BR}	Resisting force against weight of Block B perpendicular to the face, (lb/ft, note 1)
W_g	Contact weight of the vehicle, (lb/ft, note 1)
W_v	Weight of the vehicle, (lb/ft, note 1)

Note 1: Forces and weights in this calculation were performed as unit forces and weights per width of the TDRSA ramp. This is reflected in the units for these variables.

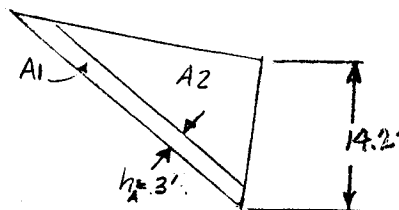


FIGURE 1
TDRSA ACCESS RAMP CROSS-SECTION
FORCE DIAGRAM



$$\beta = 18.4^\circ = 3:1 (H:V)$$

$$FS = \frac{F_{RA} + F_{RB}}{F_D}$$



BLOCK A COMPONENTS
(FOR CALCULATION)