Slope Stability

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Exercise 1 - Solution

BLOCK STABILITY ANALYSIS

Assess the stability of the block ABCD in Fig. 1 considering the different proposed conditions. The block has a width of 1 meter. The characteristics of the slip surface AB and of the vertical joint BC are provided for each condition.

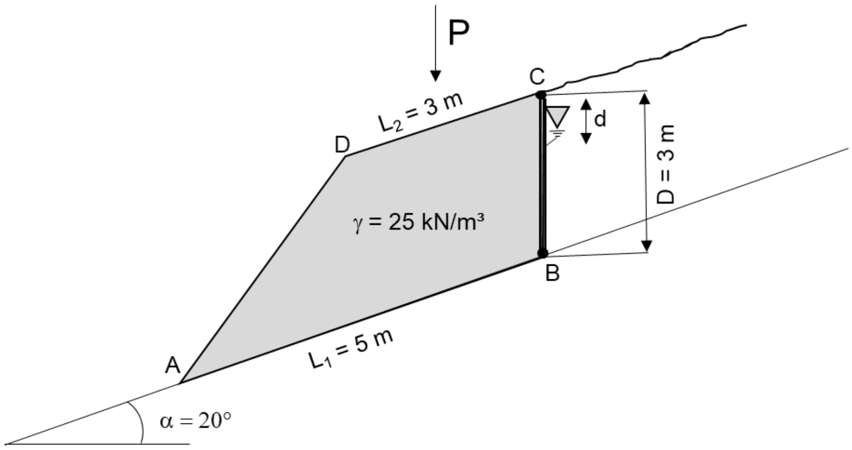


Fig. 1 Block geometry.

Considering the size and weight of the block, the weight of the block can be computed:

W = 281.9 kN

Absence of water in the vertical joint and slip surface

1. Compute F considering the given shear strength parameters.

By imposing the translational equilibrium of the block, the forces parallel and perpendicular to the slip surface can be computed as follows:

$$T = W\sin\alpha$$
$$N = W\cos\alpha$$

Then, the safety factor can be computed as:

$$F = \frac{T_f}{T} = \frac{c'L_1}{W\sin\alpha} + \frac{W\cos\alpha\tan\varphi'}{W\sin\alpha} = \frac{c'L_1}{W\sin\alpha} + \frac{\tan\varphi'}{\tan\alpha}$$

a. $c' = 0$, $\varphi' = 22°$;
Result: F = 1.11

b. $c' = 10$ kPa, $\varphi' = 22°$;
Result: F = 1.63

c. $c' = 0$, $\varphi' = 19°$;
Result: F = 0.95

d. $c' = 10$ kPa, $\varphi' = 19°$.
Result: F = 1.46

2. For the cases 1.a and 1.b, assess the effects of an additional vertical load (P) on the block stability.

a. $c' = 0$, $\varphi' = 22°$;

$$F = \frac{T_f}{T} = \frac{\tan\varphi'}{\tan\alpha}$$

Result: No influence

b. $c' = 10$ kPa, $\varphi' = 22°$;

$$F = \frac{T_f}{T} = \frac{c'L_1}{(W+P)\sin\alpha} + \frac{\tan\varphi'}{\tan\alpha} < \frac{c'L_1}{(W)\sin\alpha} + \frac{\tan\varphi'}{\tan\alpha}$$

Result: Lower factor of safety with respect to the case in which no load is applied.

3. For the case 1.b, compute the maximum value of P for which $F \geq 1.3$.

$$F = \frac{c'L}{(W+P)\sin\alpha} + \frac{\tan\varphi'}{\tan\alpha} \geq 1.3$$

Result: P ≤ 487.7 kN

Presence of water in the vertical joint and slip surface

1. Assuming $c' = 10$ kPa and $\varphi' = 22°$, plot F as a function of the water level depth d in the vertical joint and assess the minimum d for which $F \geq 1.3$, for the following cases:

a. Drainage at the toe (A) is allowed (triangular distribution of the water pressure along L_1);

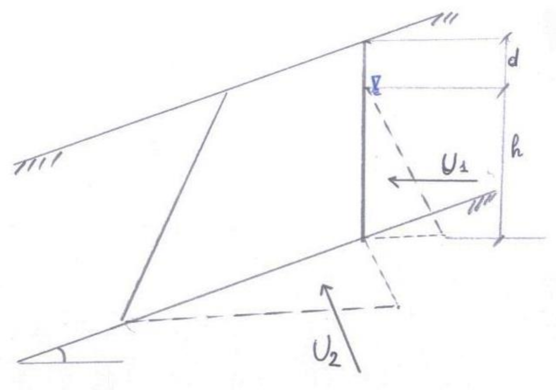


Fig. 2 Water pressure distributions when the drainage at the toe A is allowed.

Defining:

d = depth of the water level

h = CB – d   (see Fig. 1)

The forces due to water pressure acting on the slip surface and on the discontinuity can be computed as a function of h:

$$U_1 = \gamma_w \frac{h^2}{2}$$

$$U_2 = \gamma_w \frac{h \cdot AB}{2}$$

with AB=L_1

Thus:

$$F = \frac{T_f}{T} = \frac{c' L_1 + \left(W \cos\alpha - U_2 - U_1 \sin\alpha\right)\tan\varphi'}{W \sin\alpha + U_1 \cos\alpha}$$ is a function of h (see appendix)

Result: d = 1.45 m

b. Drainage at the toe (A) is prevented (hydrostatic distribution through all the discontinuities).

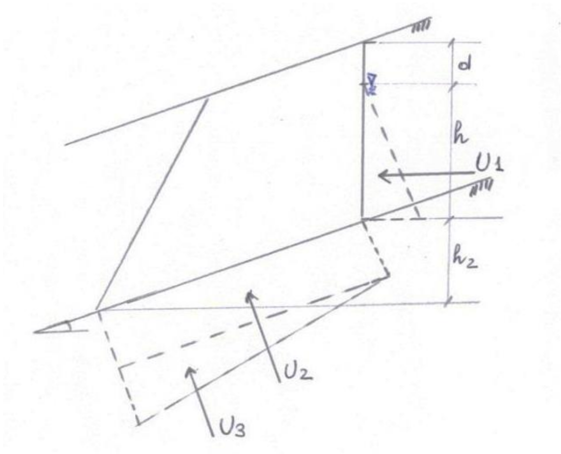


Fig. 3 Water pressure distributions when the drainage at the toe A is not allowed.

Defining:

d = depth of the water level

h = CB – d (see Fig. 1)

h_2= ABsinα (see Fig. 1)

The forces due to water pressure acting on the slip surface and on the discontinuity can be computed as a function of h:

$$U_1 = \gamma_w \frac{h^2}{2}$$

$$U_2 = \gamma_w \cdot h \cdot AB$$

$$U_3 = \gamma_w \frac{h_2 \cdot AB}{2}$$

with AB=L_1

It follows:

$$F = \frac{T_f}{T} = \frac{c'L_1 + \left(W\cos\alpha - U_2 - U_3 - U_1 \sin\alpha\right)\tan\varphi'}{W\sin\alpha + U_1\cos\alpha}$$ is a function of h (see appendix)

Result: h_2=1.71 m; U_3=41.9 kN; d = 2.40 m

Appendix

The detailed tables used to reply to questions 4.a and 4.b are given in this Appendix. In addition, a graph summarizing how the safety factor varies with the depth d is shown in a figure. The safety factor limit threshold of 1.3 is also represented in the same graph.

4.a Effect of water – The drainage at the toe A is allowed

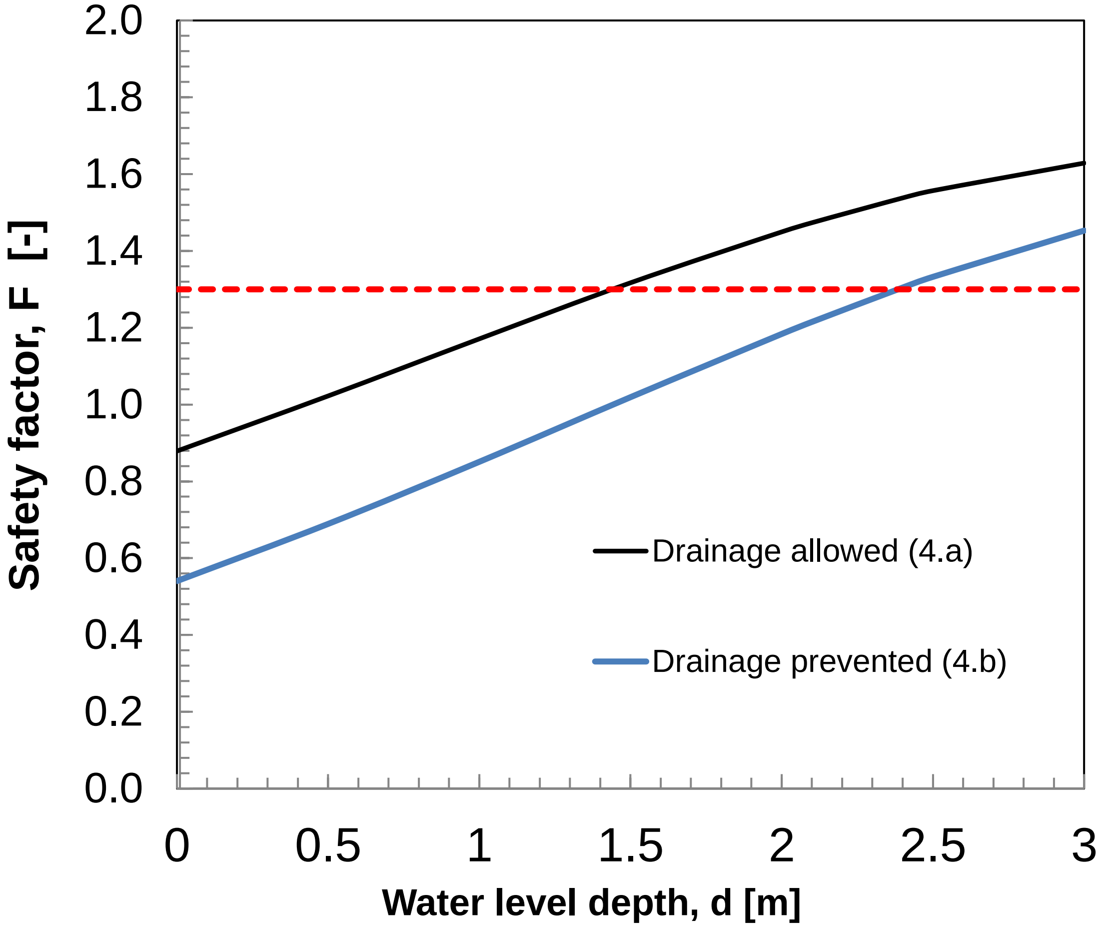
φ'	22	°	0.38397	rad
c'	10	kPa		
W cosα	264.9	kN		
W sinα	96.2	kN		
γ_w	9.81	kN/m^3		

d [m]	h [m]	U_1 [kN]	U_2 [kN]	F
0	3	44.15	73.58	0.88
0.25	2.75	37.09	67.44	0.95
0.50	2.5	30.66	61.31	1.02
0.75	2.25	24.83	55.18	1.10
1.00	2	19.62	49.05	1.17
1.25	1.75	15.02	42.92	1.24
1.50	1.5	11.04	36.79	1.32
1.75	1.25	7.66	30.66	1.39
2.00	1	4.91	24.53	1.45
2.25	0.75	2.76	18.39	1.51
2.50	0.5	1.23	12.26	1.56
2.75	0.25	0.31	6.13	1.60
3.00	0	0.00	0.00	1.63

4.b effect of water - The drainage at the toe A is prevented

φ'	22	°	0.38397	rad
c'	10	kPa		
W cosα	264.9	kN		
W sinα	96.2	kN		
γ_w	9.81	kN/m^3		
h_2	1.71			
U_3	41.94	kN		

d [m]	h [m]	U_1 [kN]	U_2 [kN]	U_3 [kN]	F
0	3	44.15	147.15	41.94	0.54
0.25	2.75	37.09	134.89	41.94	0.61
0.5	2.5	30.66	122.63	41.94	0.69
0.75	2.25	24.83	110.36	41.94	0.77
1	2	19.62	98.10	41.94	0.85
1.25	1.75	15.02	85.84	41.94	0.93
1.5	1.5	11.04	73.58	41.94	1.02
1.75	1.25	7.66	61.31	41.94	1.10
2	1	4.91	49.05	41.94	1.18
2.25	0.75	2.76	36.79	41.94	1.26
2.5	0.5	1.23	24.53	41.94	1.33
2.75	0.25	0.31	12.26	41.94	1.40
3	0	0.00	0.00	41.94	1.45


2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Safety factor, F [-]
0
0.5
1
1.5
2
2.5
3
Water level depth, d [m]
Drainage allowed (4.a)
Drainage prevented (4.b)