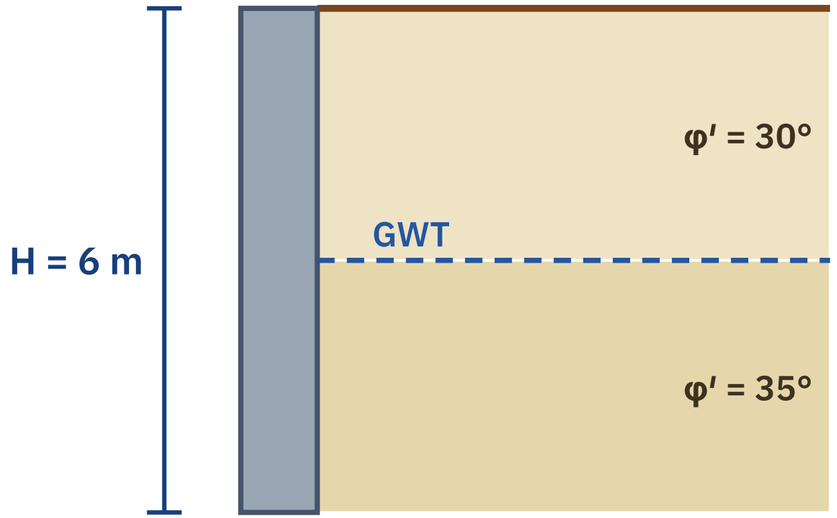
Geotechnical lecture presentation · Lateral earth pressure

Rankine lateral earth pressure

Lecture: active and passive earth pressure acting on a frictionless vertical wall; cohesionless and cohesive fill, surcharge, groundwater and layered soil; a worked example for each topic.

- Active and passive states
- $K_a = \tan^2(45° - \varphi'/2)$
- Surcharge and groundwater
- Layered fill
- Tension crack



Introduction

What will we learn in this lecture?

- with the Mohr circle of the active and passive states, **why** $\sigma'_a = K_a\sigma'_o - 2c'\sqrt{K_a}$
- To calculate the K_a and K_p coefficients from φ'; to compare them with the at-rest coefficient K_0
- To find the **force** and the **height of action** from the pressure triangle in a cohesionless fill
- Seeing how surcharge, groundwater and layer boundaries change the diagram
- in c'–φ' and $\varphi = 0$ soil, to separate the **tension zone** and the force with / without a crack
- Computing passive resistance and knowing how much the wall must move

LECTURE FLOW

Each topic is covered in **three steps**:

1 · **Theory**: what is the rule, why is it so?

2 · **Problem statement**: given and required

3 · **Solution**: step by step, with numbers

The forces are per unit length of wall (kN/m); the pressures are in kPa, all stresses are effective.

Plastic equilibrium and Mohr circle

THEORY

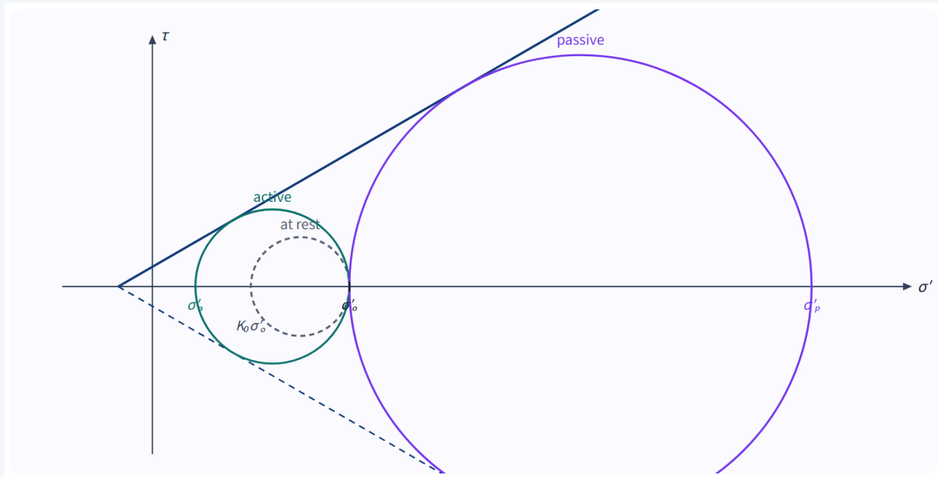
Rankine (1857) examined a soil mass every point of which is on the verge of failure. If a vertical, frictionless wall **moves away from the soil**, the horizontal stress decreases from the at-rest value $K_0\sigma'_o$ and the Mohr circle touches the failure envelope: **active state**. If the wall **is pushed into the soil**, the horizontal stress rises above σ'_o: **passive state**.

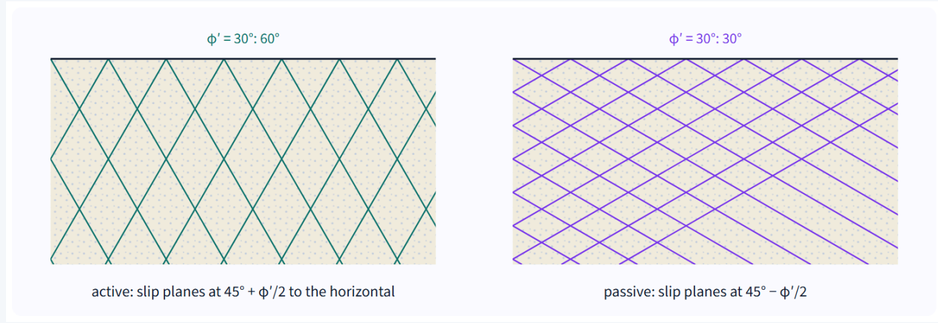
$$\sigma'_a = \sigma'_o \tan^2\left(45^\circ - \frac{\varphi'}{2}\right) - 2c' \tan\left(45^\circ - \frac{\varphi'}{2}\right)$$

$$\sigma'_p = \sigma'_o \tan^2\left(45^\circ + \frac{\varphi'}{2}\right) + 2c' \tan\left(45^\circ + \frac{\varphi'}{2}\right)$$

σ'_o is the vertical effective stress (confining pressure); behind the wall the major principal stress is vertical (in the active case) or horizontal (in the passive case).

Slip planes make an angle of 45° + φ′/2 with the horizontal in the active case, and 45° − φ′/2 in the passive case.





K_a and K_p coefficients

THEORY

From the geometry of Mohr's circle two coefficients are defined; they are reciprocals of each other:

$$K_a = \tan^2\left(45^\circ - \frac{\varphi'}{2}\right) = \frac{1-\sin\varphi'}{1+\sin\varphi'} \qquad K_p = \tan^2\left(45^\circ + \frac{\varphi'}{2}\right) = \frac{1}{K_a}$$

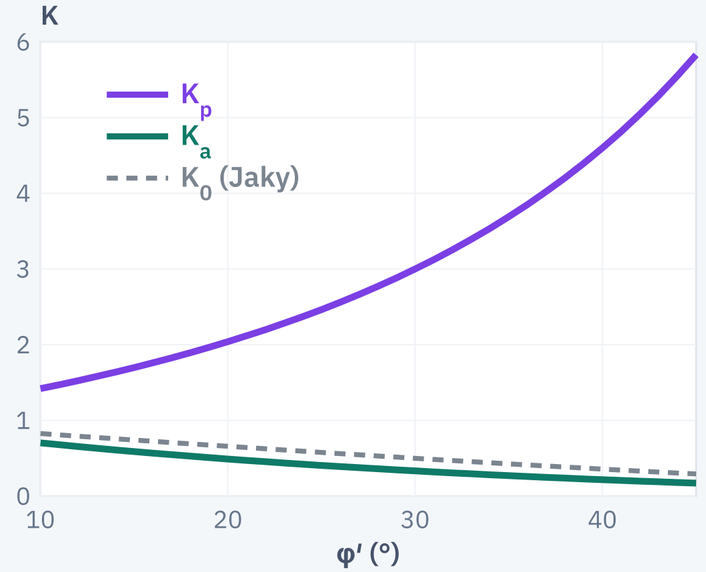
$$\sigma'_a = K_a\sigma'_o - 2c'\sqrt{K_a} \qquad \sigma'_p = K_p\sigma'_o + 2c'\sqrt{K_p}$$

φ′	25°	30°	35°	40°
K_a	0.406	0.333	0.271	0.217
K_p	2.464	3.000	3.690	4.599
K_0 (Jaky)	0.577	0.500	0.426	0.357

$K_a < K_0 < K_p$: the at-rest pressure before the wall moves lies between the two limits.

K_p grows rapidly with φ′: at φ′ = 40° the passive is more than 20 times the active.

K_a, K_p and K_0 – φ′



Problem statement

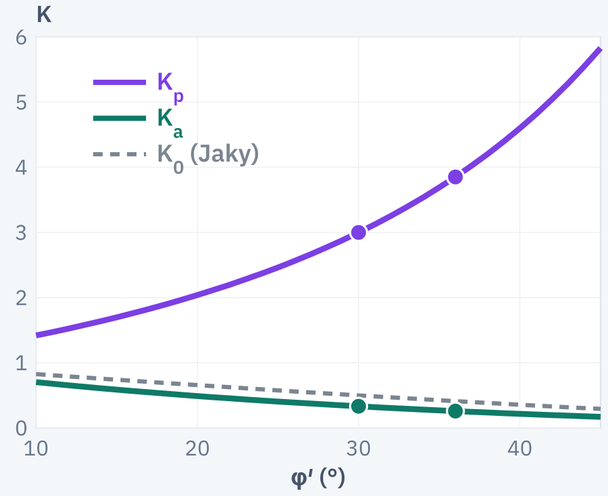
EXAMPLE

Given

Soil	**cohesionless sand, $c' = 0$; two cases: $\varphi' = 36^\circ$ and $\varphi' = 30^\circ$**
Wall	**vertical, frictionless; backfill surface horizontal**

REQUIRED

K_a, K_p and **K_0** according to Jaky; verify the ordering of the three.



Solution

SOLUTION

1 φ′ = 36°

$$K_a = \tan^2(45^\circ - 18^\circ) = \tan^2 27^\circ = \mathbf{0.2596} \qquad K_p = \tan^2 63^\circ = \frac{1}{K_a} = \mathbf{3.852}$$

2 φ′ = 30°

$$K_a = \frac{1 - \sin 30^\circ}{1 + \sin 30^\circ} = \frac{0.5}{1.5} = \mathbf{0.3333} \qquad K_p = \frac{1 + \sin 30^\circ}{1 - \sin 30^\circ} = \mathbf{3}$$

3 At-rest coefficient (Jaky): $K_0 = 1 - \sin\varphi'$

$$\varphi' = 36^\circ:\ K_0 = 1 - 0.5878 = \mathbf{0.4122} \qquad \varphi' = 30^\circ:\ K_0 = 1 - 0.5 = \mathbf{0.50}$$

In both soils **$K_a < K_0 < K_p$**; $K_a \cdot K_p = 1$. As φ′ increases from 30° to 36°, K_a goes from 0.333 → 0.260 and K_p from 3.00 → 3.85.

Check the solution in GeoTerva ↗

Pressure triangle, force and height of action

THEORY

For c′ = 0 and an embankment with a horizontal surface, the pressure increases **linearly** with depth; the diagram is triangular. The force per unit length of the wall is the area of the triangle, and its point of application is the centroid (H/3 above the base):

$$\sigma'_a = K_a \gamma z \qquad P_a = \tfrac{1}{2} K_a \gamma H^2 \qquad \bar{z} = \tfrac{H}{3}$$

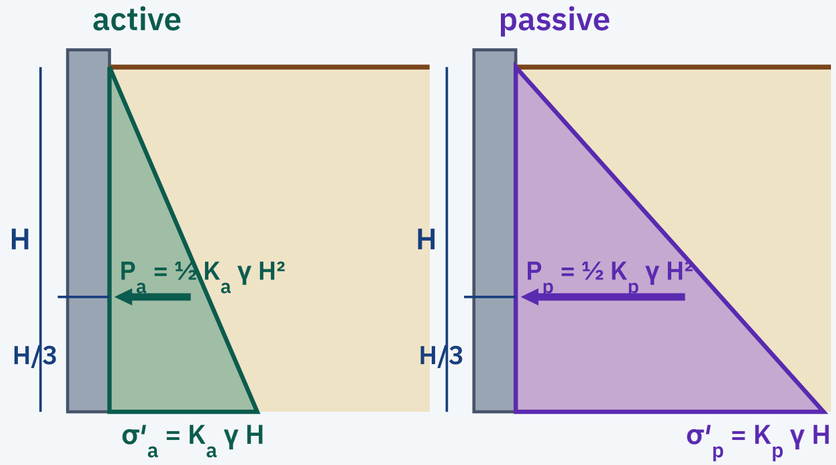
$$\sigma'_p = K_p \gamma z \qquad P_p = \tfrac{1}{2} K_p \gamma H^2 \qquad \bar{z} = \tfrac{H}{3}$$

The force grows with **H²**: doubling the wall height quadruples the force.

The force is perpendicular to the wall and horizontal (frictionless wall, δ′ = 0).

Units: γ kN/m³, H in m gives P in kN/m.

TWO LIMIT STATES



Problem statement

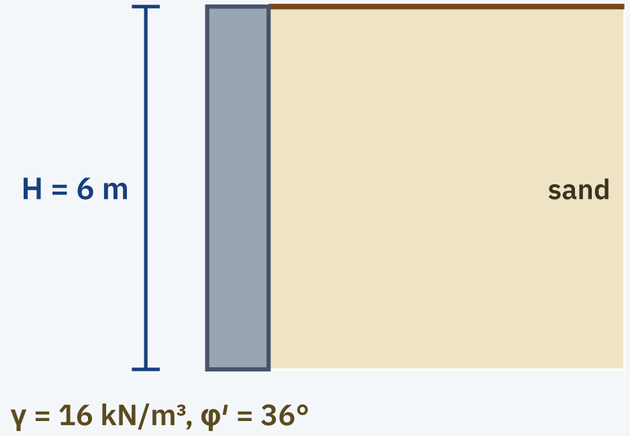
EXAMPLE

REQUIRED

Active and **passive** forces P_a, P_p and their heights of application; also the at-rest force P_0.

Given

Wall	$H = 6$ **m, vertical, frictionless; fill surface horizontal**
Soil	**dry sand:** $\gamma = 16\ \mathrm{kN/m^3},\ \varphi' = 36^\circ,\ c' = 0$



Solution

SOLUTION

1 Coefficients (Example 1): $K_a = 0.2596$, $K_p = 3.852$

$$\sigma'_a(6) = K_a \gamma H = 0.2596(16)(6) = \mathbf{24.92}\ \text{kPa}$$

2 Active force (area of the triangle)

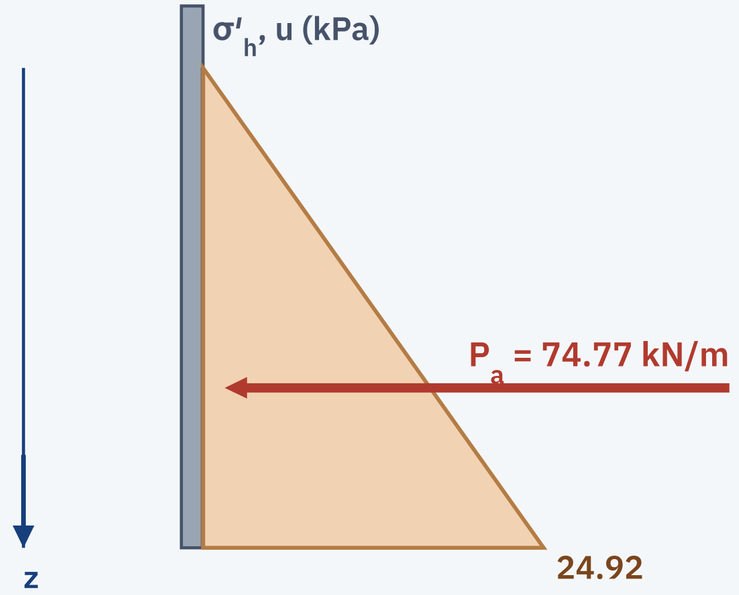
$$P_a = \tfrac{1}{2}\sigma'_a(6)\, H = \tfrac{1}{2}(24.92)(6) = \mathbf{74.77}\ \text{kN/m}$$

$$\bar{z} = \tfrac{6}{3} = \mathbf{2.0\ m}$$

3 Passive force

$$P_p = \tfrac{1}{2} K_p \gamma H^2 = \tfrac{1}{2}(3.852)(16)(36) = \mathbf{1{,}109.3}\ \text{kN/m}$$

$$\bar{z} = \tfrac{6}{3} = \mathbf{2.0\ m}$$



P_a = **74.77 kN/m**, P_p = **1,109.3 kN/m**, both 2.0 m above the base. The passive resistance is **14.8 times** the active thrust; the at-rest P_0 = 118.72 kN/m lies in between.

Check the solution in GeoTerva ↗

Two effects that change the diagram

THEORY

Uniform surcharge q adds the same pressure at every depth: a rectangle is added. **Below the groundwater table**, effective stress is computed with $\gamma' = \gamma_{sat} - \gamma_w$, and in addition the water pressure $u = \gamma_w(z - H_1)$ is added **at its full value**:

$$P_a = K_a q H + \tfrac{1}{2} K_a \gamma H_1^2 + K_a \gamma H_1 H_2 + \tfrac{1}{2} \left(K_a \gamma' + \gamma_w\right) H_2^2$$

Component	Force	Arm (from base)
Surcharge (rectangular)	$K_a\, q\, H$	$H/2$
Upper triangle	$\tfrac{1}{2} K_a\, \gamma\, H_1^2$	$H_2 + H_1/3$
Lower rectangle	$K_a\, \gamma\, H_1\, H_2$	$H_2/2$
Lower triangle (effective)	$\tfrac{1}{2} K_a\, \gamma'\, H_2^2$	$H_2/3$
Water pressure	$\tfrac{1}{2} \gamma_w\, H_2^2$	$H_2/3$

Taking the moment of the components about the base point gives the height of the resultant: $\bar{z} = \Sigma P_i z_i / \Sigma P_i$.

The passive force is found with the same components using K_p; the water pressure is the same.

WHY IS WATER SO INFLUENTIAL?

The water pressure **does not depend on the friction angle**: it is multiplied by 1 instead of K_a. Since $\gamma' \approx \gamma_{sat}/2$ in the submerged zone, the effective earth pressure decreases, but the water pressure more than compensates for it.

Problem statement

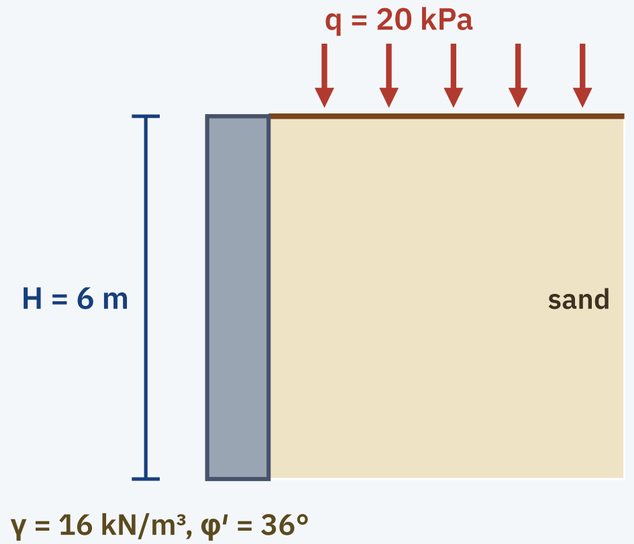
EXAMPLE

REQUIRED

P_a and $\bar{z}$; effect of surcharge.

Given

Wall and soil	**The wall in Example 2: $H = 6$ m, $\gamma = 16\ \mathrm{kN/m^3}$, $\varphi' = 36^\circ$, dry**
Surcharge	**uniformly distributed $q = 20$ kPa on the backfill surface**



Solution

SOLUTION

1 Pressure: $K_a q$ at the surface, $K_a q + K_a \gamma H$ at the base

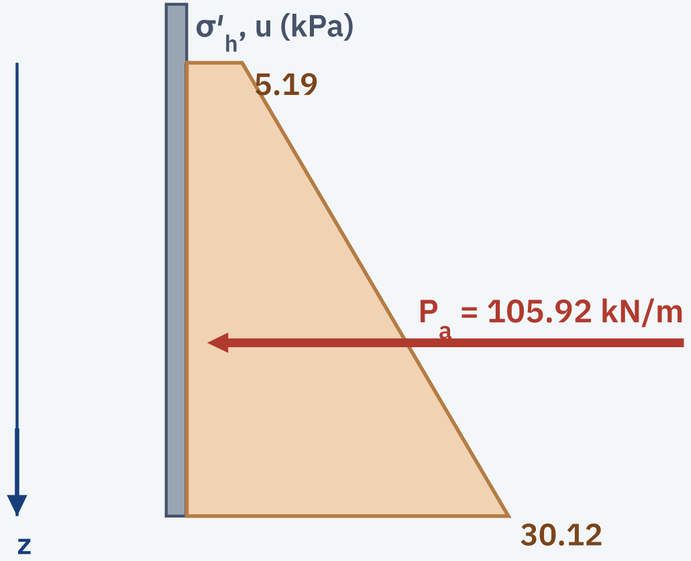
$$\sigma'_a(0) = 0.2596(20) = 5.19 \text{ kPa}$$
$$\sigma'_a(6) = 5.19 + 24.92 = \mathbf{30.12} \text{ kPa}$$

2 Forces: rectangle (arm 3.0 m) + triangle (arm 2.0 m)

$$P_q = K_a q H = 5.19(6) = 31.15 \text{ kN/m}$$
$$P_\gamma = \tfrac{1}{2} K_a \gamma H^2 = 74.77 \text{ kN/m}$$

3 Resultant and height of action

$$P_a = 31.15 + 74.77 = \mathbf{105.92} \text{ kN/m}$$
$$\bar{z} = \frac{31.15(3) + 74.77(2)}{105.92} = \mathbf{2.29} \text{ m}$$



The surcharge force increased it by 31.15 kN/m (42%); the point of application rose from **2.00 m to 2.29 m** (the moment arm of the rectangle is H/2).

Check the solution in GeoTerva ↗

Problem statement

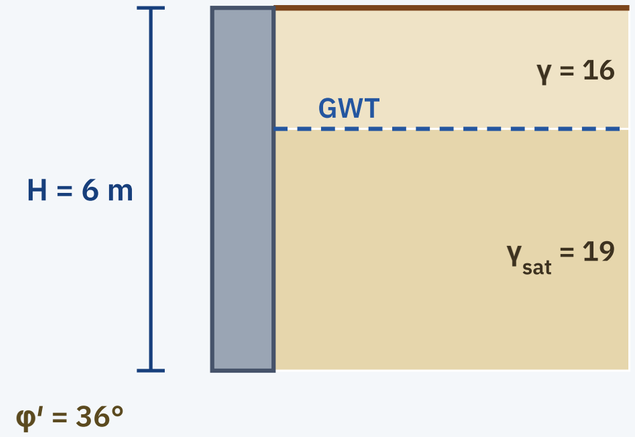
EXAMPLE

Given

Wall	$H = 6$ m, vertical; sand fill with horizontal surface, no surcharge
Soil	top $\gamma = 16\ \mathrm{kN/m^3}$ (dry); groundwater level at 2 m depth; bottom $\gamma_{sat} = 19\ \mathrm{kN/m^3}$; $\varphi' = 36^\circ$

REQUIRED

The **total force** from effective earth pressure and water pressure and its height of action; the effect of water.



Solution

SOLUTION

1 Effective stresses (z = 2 and 6 m)

$$\sigma'_o(2) = 16(2) = 32 \text{ kPa}$$
$$\sigma'_o(6) = 32 + 4(19 - 9.81) = 68.76 \text{ kPa}$$
$$\sigma'_a(6) = K_a \sigma'_o(6) = \mathbf{17.85} \text{ kPa}$$

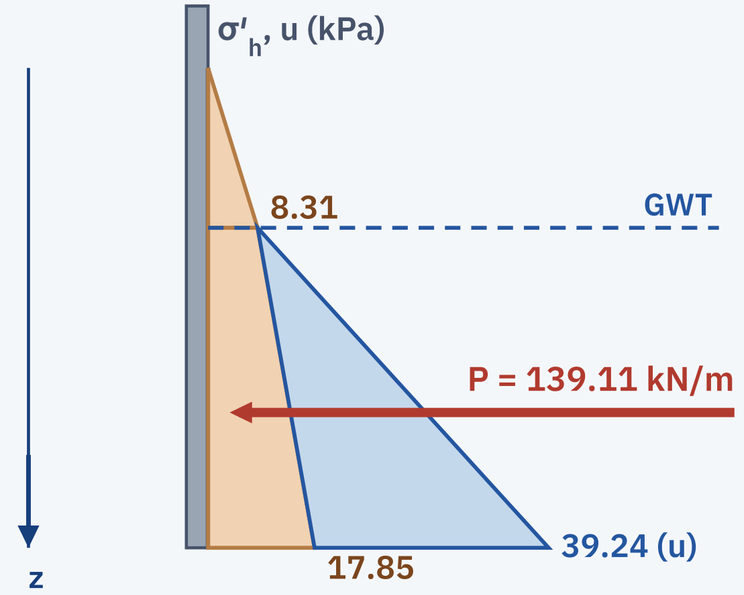
2 Water pressure at the base: u = γ_w(6 − 2)

$$u(6) = 9.81(4) = \mathbf{39.24} \text{ kPa}$$

3 Forces: upper triangle · lower rectangle · lower triangle · water

$$P_a = 8.31 + 33.23 + 19.09 = 60.63 \text{ kN/m (soil)}$$
$$P_w = \tfrac{1}{2}(39.24)(4) = 78.48 \text{ kN/m}$$

Total = 60.63 + 78.48 = **139.11 kN/m, z̄ = 1.69 m**. The force of the dry wall was 74.77 kN/m: the water force increased it to **1.9 times**.



Check the solution in GeoTerva ↗

Each layer uses its own K value

THEORY

If the fill consists of multiple layers, the **vertical effective stress σ'_o is continuous** (it does not jump at a layer boundary); however, since the horizontal stress $\sigma'_a = K_i\sigma'_o$ uses its own K_i value in each layer, **the diagram jumps at the boundary where φ' changes**:

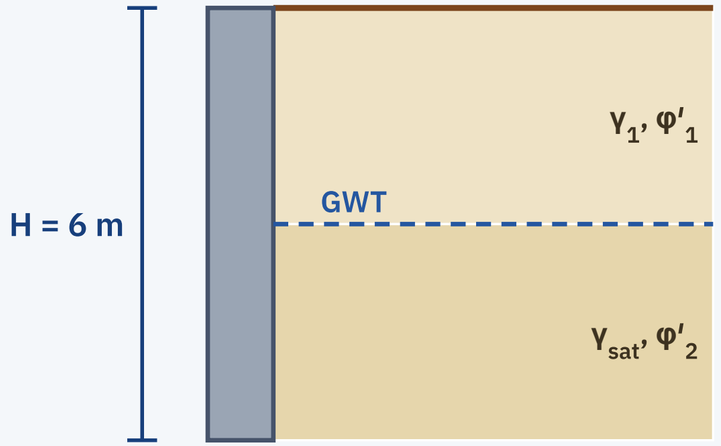
$$\sigma'_a = K_{a,i}\,\sigma'_o(z) \qquad \sigma'_o(z) = q + \sum \gamma_i h_i \;\; (\gamma' \text{ in submerged zone})$$

At the boundary two values are read: the $K_{a,1}\sigma'_o$ value of the upper layer and the $K_{a,2}\sigma'_o$ value of the lower. If the lower layer's φ' is large, the pressure **drops** downward.

The groundwater level is treated like a layer boundary: γ' begins, u is added.

The force is found by summing the areas of each segment (triangle / rectangle), and the line of action is found by taking moments.

LAYERED FILL AND WATER



Problem statement

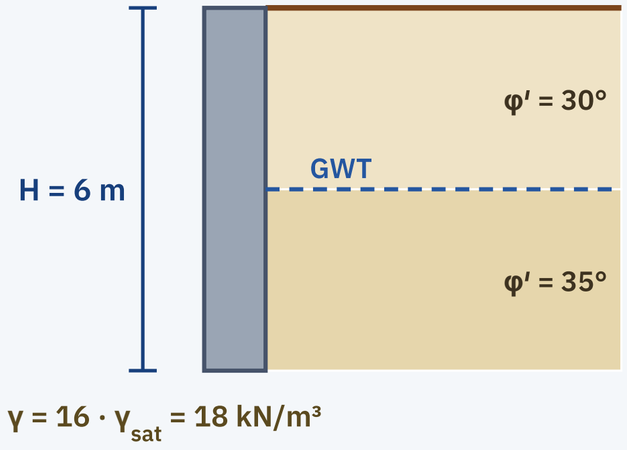
EXAMPLE

Given

Wall	$H = 6$ m, vertical, frictionless; horizontal surface; no surcharge
Upper layer (0–3 m)	sand: $\gamma = 16\ \mathrm{kN/m^3}$, $\varphi' = 30^\circ$
Lower layer (3–6 m)	sand: $\gamma_{sat} = 18\ \mathrm{kN/m^3}$, $\varphi' = 35^\circ$
Groundwater level	At 3 m depth (at the layer boundary)

REQUIRED

Total **force** (soil + water) and **height of action**. The example that opens in the module is this wall.



Solution (1/2)

SOLUTION

1 Coefficients

$$K_{a,1} = \tfrac{1}{3} = \mathbf{0.3333} \qquad K_{a,2} = \tan^2 27.5^\circ = \mathbf{0.2710}$$

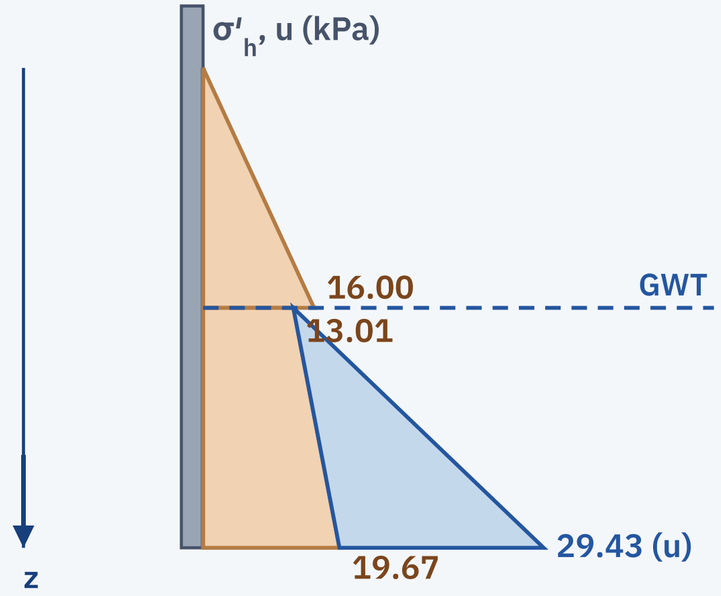
2 at 3 m depth (boundary): σ′$_o$ = 16(3) = 48 kPa

$$\sigma'_a = 0.3333(48) = \mathbf{16.00}\ \text{kPa (top)}$$
$$\sigma'_a = 0.2710(48) = \mathbf{13.01}\ \text{kPa (bottom)}$$

3 At 6 m depth (base)

$$\sigma'_o = 48 + 3(18 - 9.81) = 72.57\ \text{kPa} \qquad u = 9.81(3) = \mathbf{29.43}$$
$$\sigma'_a = 0.2710(72.57) = \mathbf{19.67}\ \text{kPa}$$

At the boundary the diagram jumps from 16.00 → 13.01 kPa (change of φ′); σ′$_o$ remains continuous.



Solution (2/2)

SOLUTION

4 Forces: upper triangle · lower rectangle · lower triangle · water

$$P = \tfrac{1}{2}(3)(16.00) + 3(13.01) + \tfrac{1}{2}(3)(6.66) + \tfrac{1}{2}(3)(29.43)$$
$$= 24.00 + 39.02 + 9.99 + 44.14 = \mathbf{117.15}\ \mathrm{kN/m}$$

5 Height of application: moment about the base point (arms 4; 1.5; 1; 1 m)

$$\bar{z} = \frac{24.00(4) + 39.02(1.5) + 9.99(1) + 44.14(1)}{117.15} = \mathbf{1.78}\ \mathrm{m}$$

The total force is **117.15 kN/m**, **1.78 m** above the base; the soil contributes 73.01 kN/m and the water 44.14 kN/m. Water accounts for about 38% and is the largest component of the force.

Check the solution in GeoTerva ↗

Tension zone and tension cracks

THEORY

In c′–φ′ soil the active pressure is **negative** at the top (the soil tends to pull the wall); the depth at which the pressure is zero:

$$z_0 = \frac{2c'}{\gamma\sqrt{K_a}} - \frac{q}{\gamma} \qquad \varphi = 0:\ z_0 = \frac{2c_u}{\gamma}$$

The soil cannot sustain tension: over time **tension cracks** open down to depth z_0. The force is only the positive part of the diagram:

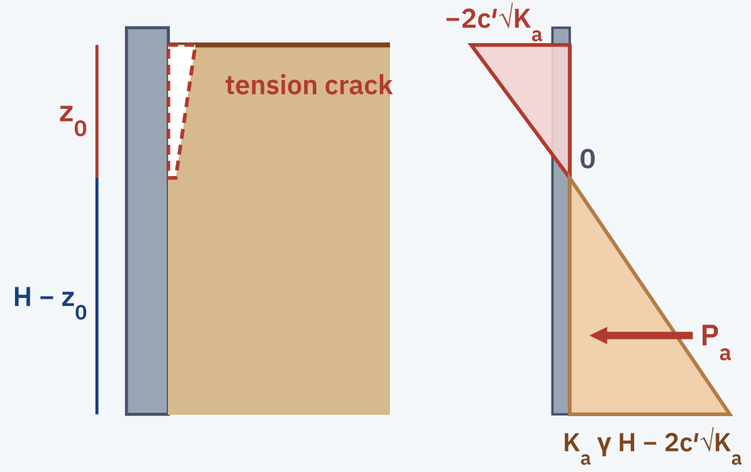
$$P_a = \tfrac{1}{2}\left[K_a(q+\gamma H) - 2c'\sqrt{K_a}\right](H - z_0)$$

Before cracking, the entire diagram is counted (smaller force): $P_a = ½K_a\gamma H^2 - 2c'\sqrt{K_a}\,H + K_a qH$.

> In design, the cracked (larger) force governs; if the crack fills with water, the hydrostatic force $\gamma_w z_0^2/2$ is added to it.

> The height of action is the centroid of the positive triangle: $(H - z_0)/3$.

TENSION ZONE



Negative pressure: at depth z_0 below the top, there is no contact with the wall.

Problem statement

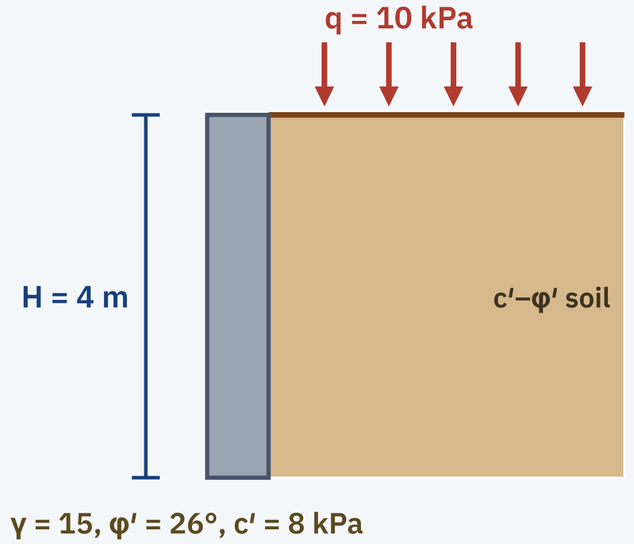
EXAMPLE

Given

Wall	$H = 4$ **m, vertical, frictionless; horizontal surface**
Soil	$\gamma = 15\ \mathrm{kN/m^3},\ \varphi' = 26^\circ,\ c' = 8$ **kPa**
Surcharge	$q = 10$ **kPa**

REQUIRED

Tension depth z_0, the active force with a crack and its height of action; comparison with the force without a crack.



Solution (1/2)

SOLUTION

1 Coefficient: $K_a = \tan^2(45° - 13°)$

$$K_a = \tan^2 32^\circ = \mathbf{0.3905} \qquad \sqrt{K_a} = 0.6249$$

$$2c'\sqrt{K_a} = 2(8)(0.6249) = 10.00\ \text{kPa}$$

2 Pressure at top and base

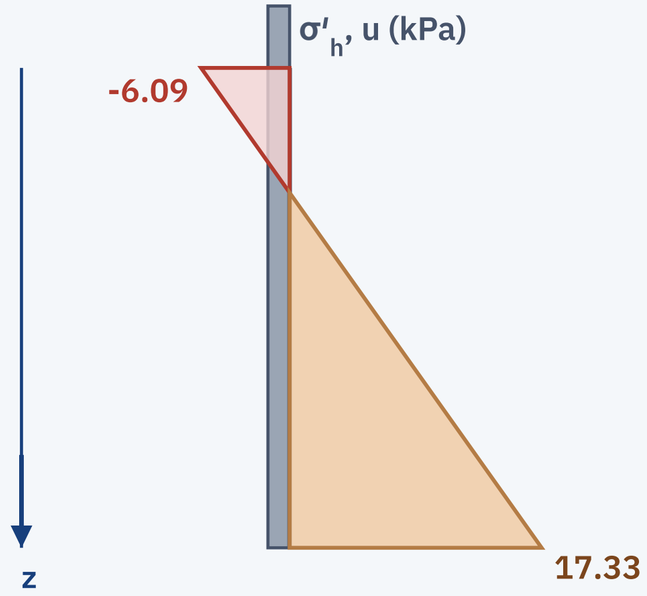
$$\sigma'_a(0) = 0.3905(10) - 10.00 = -\mathbf{6.09}\ \text{kPa (tension)}$$

$$\sigma'_a(4) = 0.3905(10 + 15 \cdot 4) - 10.00 = \mathbf{17.33}\ \text{kPa}$$

3 Tension depth (where the pressure is zero)

$$z_0 = \frac{2(8)}{15(0.6249)} - \frac{10}{15}$$

$$= 1.707 - 0.667 = \mathbf{1.04}\ \text{m}$$



Solution (2/2)

SOLUTION

4 Cracked force (positive triangle only)

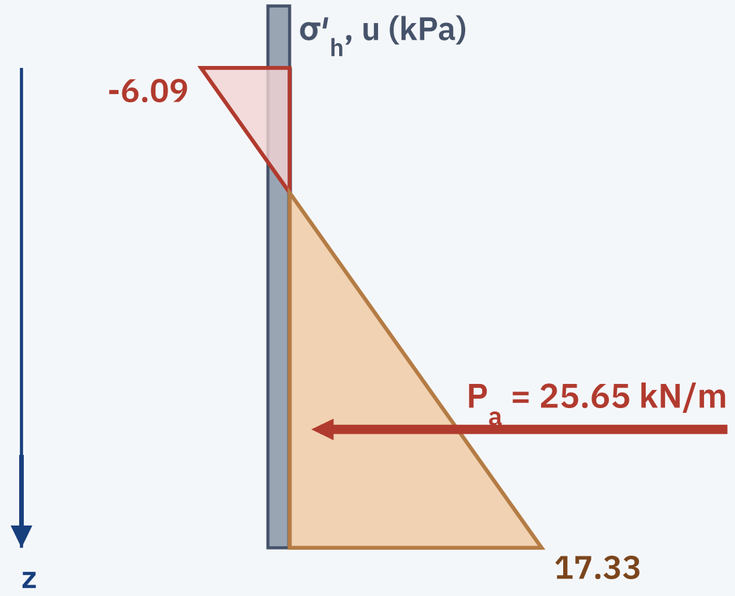
$$P_a = \tfrac{1}{2}(17.33)(4 - 1.04) = \mathbf{25.65}\ \mathrm{kN/m}$$

$$\bar{z} = \frac{4 - 1.04}{3} = \mathbf{0.99}\ \mathrm{m}$$

5 Comparison: uncracked (including the negative zone)

$$P_a = \tfrac{1}{2}(-6.09 + 17.33)(4) = 22.48\ \mathrm{kN/m}$$

The force with a crack is **25.65 kN/m**, 14% greater than the force without a crack; the cracked value is the safe side.



Check the solution in GeoTerva ↗

Problem statement

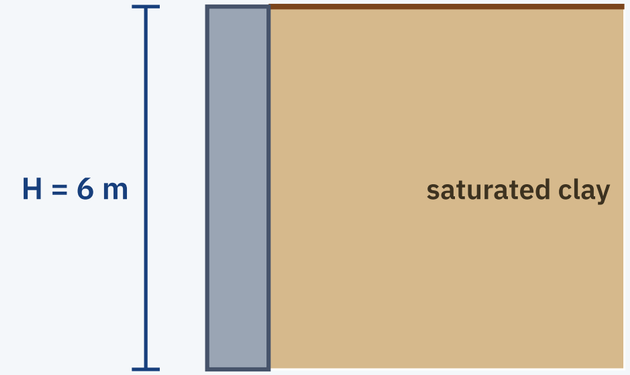
EXAMPLE

Given

Wall	$H = 6$ **m, vertical; horizontal surface; no surcharge**
Soil	**saturated clay, undrained:** $\gamma = 18\ \mathrm{kN/m^3},\ \varphi = 0,\ c_u = 25$ **kPa**

REQUIRED

z_0, active force with and without a crack; passive force; height H_c that can be cut vertically without a wall.



Solution (1/2)

SOLUTION

1 For φ = 0, $K_a = K_p = 1$: tension depth and base pressure

$$\sigma_a = \gamma z - 2c_u = 18z - 50 \text{ kPa}$$

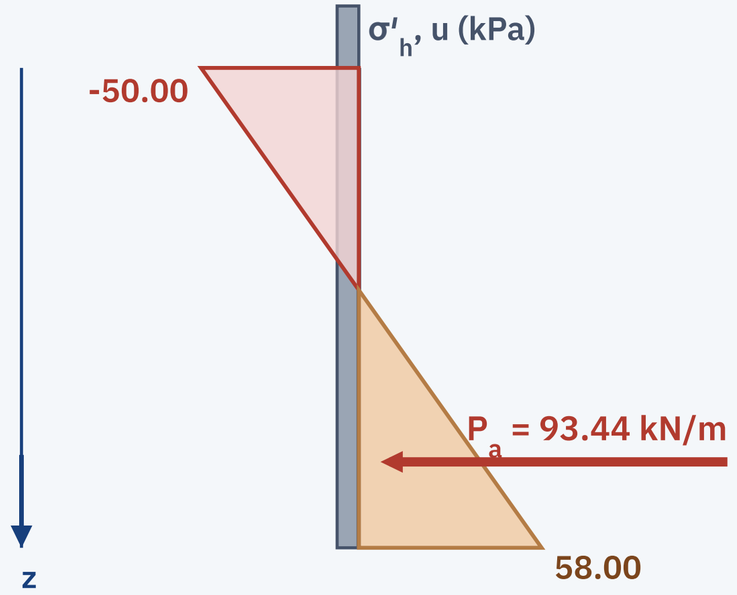
$$z_0 = \frac{2c_u}{\gamma} = \frac{50}{18} = \mathbf{2.78} \text{ m}$$

$$\sigma_a(6) = 108 - 50 = \mathbf{58} \text{ kPa}$$

2 Active force with crack

$$P_a = \tfrac{1}{2}(58)(6 - 2.78) = \mathbf{93.44} \text{ kN/m}$$

$$\bar{z} = \frac{6 - 2.78}{3} = 1.07 \text{ m}$$



Solution (2/2)

SOLUTION

3 Active force and passive force without cracks

$$P_a = \tfrac{1}{2}\gamma H^2 - 2c_u H = 324 - 300 = \mathbf{24}\ \mathrm{kN/m}$$

$$P_p = \tfrac{1}{2}\gamma H^2 + 2c_u H = 324 + 300 = \mathbf{624}\ \mathrm{kN/m}$$

4 Height that can be cut vertically without a wall (P_a = 0 without cracks)

$$\tfrac{1}{2}\gamma H_c^2 - 2c_u H_c = 0 \ \Rightarrow\ H_c = \frac{4c_u}{\gamma} = \frac{4(25)}{18} = \mathbf{5.56}\ \mathrm{m}$$

The force with a crack (93.44 kN/m) is **3.9 times** the force without a crack (24 kN/m): in cohesive soil, assuming a crack governs the result. Since H = 6 m is greater than H_c = 5.56 m, even the force without a crack is positive.

Check the solution in GeoTerva ↗

Cohesion increases passive resistance

THEORY

In the passive case cohesion adds resistance **at every depth**; there is no tension zone and no crack. The pressure at the top is not zero:

$$\sigma'_p(z) = K_p\,(q + \gamma z) + 2c'\sqrt{K_p}$$

$$P_p = \tfrac{1}{2}K_p\gamma H^2 + K_p q H + 2c'\sqrt{K_p}\,H \qquad \varphi = 0:\ P_p = \tfrac{1}{2}\gamma H^2 + 2c_u H$$

The pressure diagram is **trapezoidal**: cohesion and surcharge add a rectangle, γz adds a triangle.

The height of application is found by taking moments (cohesion contribution at H/2).

Passive resistance depends on the wall moving sufficiently; the full value is not used in design, it is reduced by a factor.

ACTIVE – PASSIVE COMPARISON

	Active	Passive
Coefficient	$K_a < 1$	$K_p > 1$
Cohesion	**reduces** the pressure ($-2c'\sqrt{K_a}$)	**increases** the resistance ($+2c'\sqrt{K_p}$)
Tension zone	exists (z_0)	none
Slip plane	45° + φ′/2	45° – φ′/2
Required movement	small	large

Problem statement

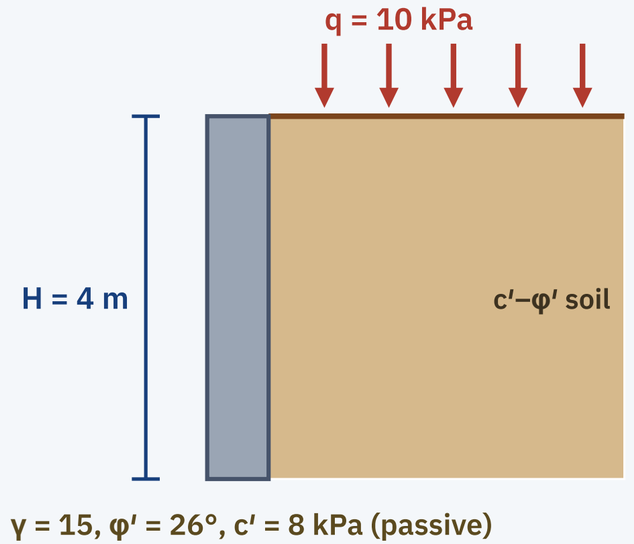
EXAMPLE

Given

Wall and soil	**Wall and soil from Example 6:** $H = 4$ **m,** $\gamma = 15\ \mathrm{kN/m^3}$, $\varphi' = 26°$, $c' = 8$ **kPa**
Surcharge	$q = 10$ **kPa (on the passive side)**

REQUIRED

Passive force P_p and its height of action.



Solution

SOLUTION

1 Coefficient: $K_p = \tan^2(45° + 13°)$

$$K_p = \tan^2 58^\circ = \mathbf{2.561} \qquad 2c'\sqrt{K_p} = 2(8)(1.600) = 25.61\ \text{kPa}$$

2 Pressure at top and base

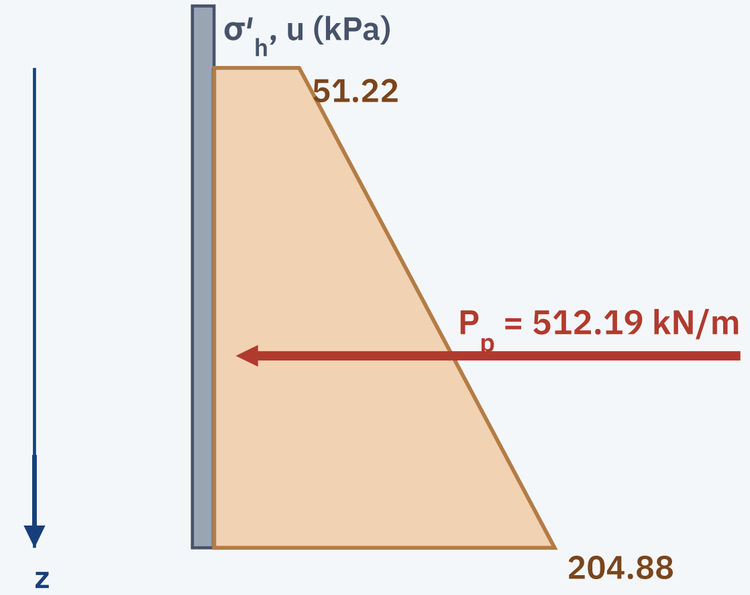
$$\sigma'_p(0) = 2.561(10) + 25.61 = \mathbf{51.22}\ \text{kPa}$$

$$\sigma'_p(4) = 2.561(10 + 60) + 25.61 = \mathbf{204.88}\ \text{kPa}$$

3 Area of the trapezoid and centroid

$$P_p = \tfrac{1}{2}(51.22 + 204.88)(4) = \mathbf{512.2}\ \text{kN/m}$$

$$\bar{z} = \frac{51.22(4)(2) + \tfrac{1}{2}(153.66)(4)(\tfrac{4}{3})}{512.2} = \mathbf{1.60}\ \text{m}$$



Passive resistance **512.2 kN/m**, 1.60 m above the base; about **20 times** the cracked active force of the same wall.

Check the solution in GeoTerva ↗

How much movement is required to develop the active and passive states?

THEORY

To reach the Rankine states, the wall must move away from the soil (active) or toward the soil (passive). **The movement required for passive is much greater than that for active**; relative to the height H:

Soil	Active $\Delta L_a/H$	Passive $\Delta L_p/H$	active for H = 6 m	passive for H = 6 m
Loose sand	0.001–0.002	0.01	6–12 mm	60 mm
Dense sand	0.0005–0.001	0.005	3–6 mm	30 mm
Soft clay	0.02	0.04	120 mm	240 mm
Stiff clay	0.01	0.02	60 mm	120 mm

If the movement does not reach these values, the pressure remains greater than K_a and less than K_p; if the wall is fully restrained, the at-rest pressure K_0 develops.

For a wall rotating about its base, these ratios apply to the top movement.

Scope of the Rankine solution

THEORY

The wall: vertical and smooth ($\delta' = 0$); the pressure is horizontal and perpendicular to the wall. In reality wall friction reduces the active force and increases the passive force; Rankine is slightly on the safe side for active and on the conservative (safe) side for passive.

Embankment: horizontal surface, each layer homogeneous; slip surfaces are planar. For inclined embankment and inclined wall, see the Rankine (inclined embankment) module.

Stresses: effective stress is fundamental; water pressure is added separately, and for clay the undrained ($\varphi = 0$) solution can also be used with total stress.

Surcharge: a uniformly distributed load; strip, point and line load modules are treated separately.

Earthquake: Rankine is the static solution; for earthquakes the Mononobe–Okabe and seismic passive modules are used.

Summary

Key points

States: active (wall moves away) $\sigma'_a = K_a\sigma'_o - 2c'\sqrt{K_a}$; passive (wall is pushed) $\sigma'_p = K_p\sigma'_o + 2c'\sqrt{K_p}$

Coefficients: $K_a = \tan^2(45° - \varphi'/2)$, $K_p = 1/K_a$; $K_a < K_0 = 1 - \sin\varphi' < K_p$

Cohesionless fill: $P = \frac{1}{2}K\gamma H^2$, at $H/3$ from the base; the force increases with H^2

Surcharge adds a rectangular block ($K\,q\,H$, arm $H/2$); **water** adds the full $u = \gamma_w(z - H_1)$ independent of φ' and multiplies the force many times over

In layered soils σ'_o is continuous, σ'_a jumps at the boundary where φ' changes; the force is found by dividing into parts, taking moments about $\bar{z}$

In **c′–φ′ soil** $z_0 = 2c'/(\gamma\sqrt{K_a}) - q/\gamma$; with a tension crack the force is only the positive triangle, which is greater than the force without a crack

Passive increases with cohesion and there is no tension zone; but the wall must move **much more** than for active

References

Das, B.M. (2018). Principles of Geotechnical Engineering, 9th ed. Cengage Learning.

Rankine, W.M.J. (1857). On the stability of loose earth. Philosophical Transactions of the Royal Society of London, 147, 9–27.

NOTE

All numerical examples have been produced with the module's own calculation engine; the module gives the same values. The module opens with the two-layer wall of Example 5.

GeoTerva

Online geotechnical analysis

From theory to practice

Enter the layers, surcharge and groundwater level of your own wall in GeoTerva; the module gives the pressure diagram, the force and the height of action together.

Open the module →

Theory page →

Open on your phone
The example modules need no registration.

If you would like to use them in your lectures: info@geoterva.com