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SOIL MECHANICS/GEOTECHNICAL ENGINEERING I

EARTH PRESSURE

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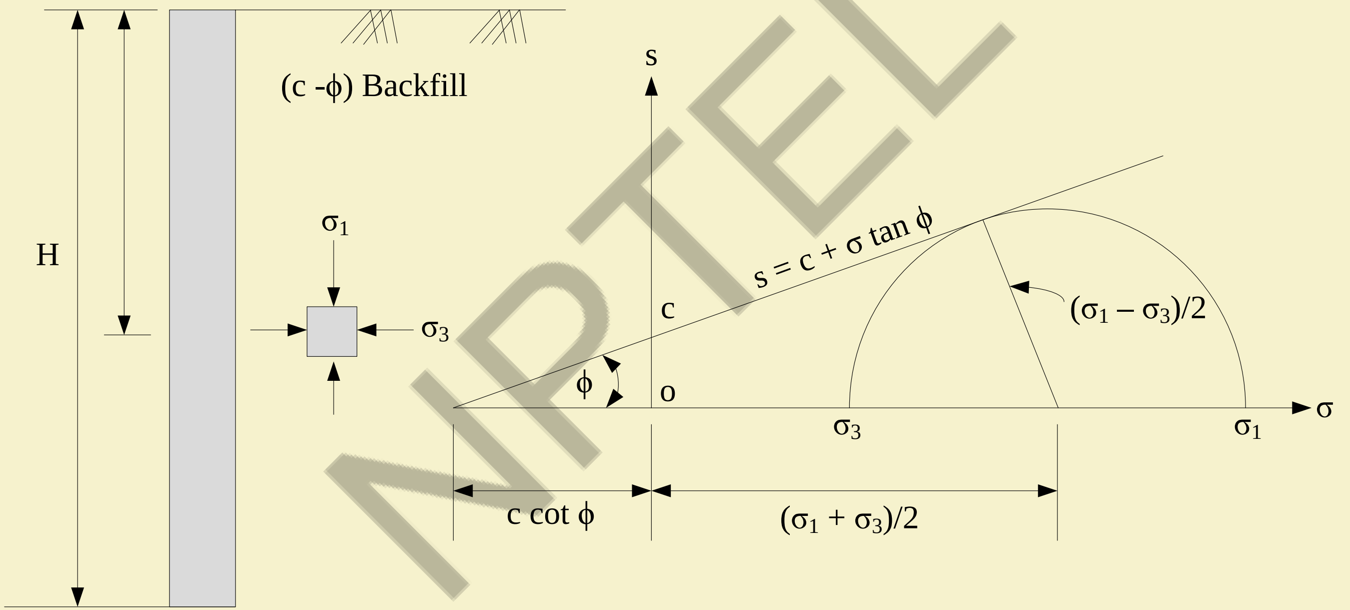
Lateral earth pressure in partially cohesive soils: active case



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EARTH PRESSURE

Active case

$$\sin\phi = \frac{(\sigma_1 - \sigma_3)/2}{(\sigma_1 + \sigma_3)/2 + c\cot\phi} = \frac{\sigma_1 - \sigma_3}{\sigma_1 + \sigma_3 + 2c\cot\phi}$$

$$\sigma_3 = \sigma_1 \frac{1 - \sin\phi}{1 + \sin\phi} - 2c\sqrt{\frac{1 - \sin\phi}{1 + \sin\phi}} = \sigma_1 k_a - 2c\sqrt{k_a}$$

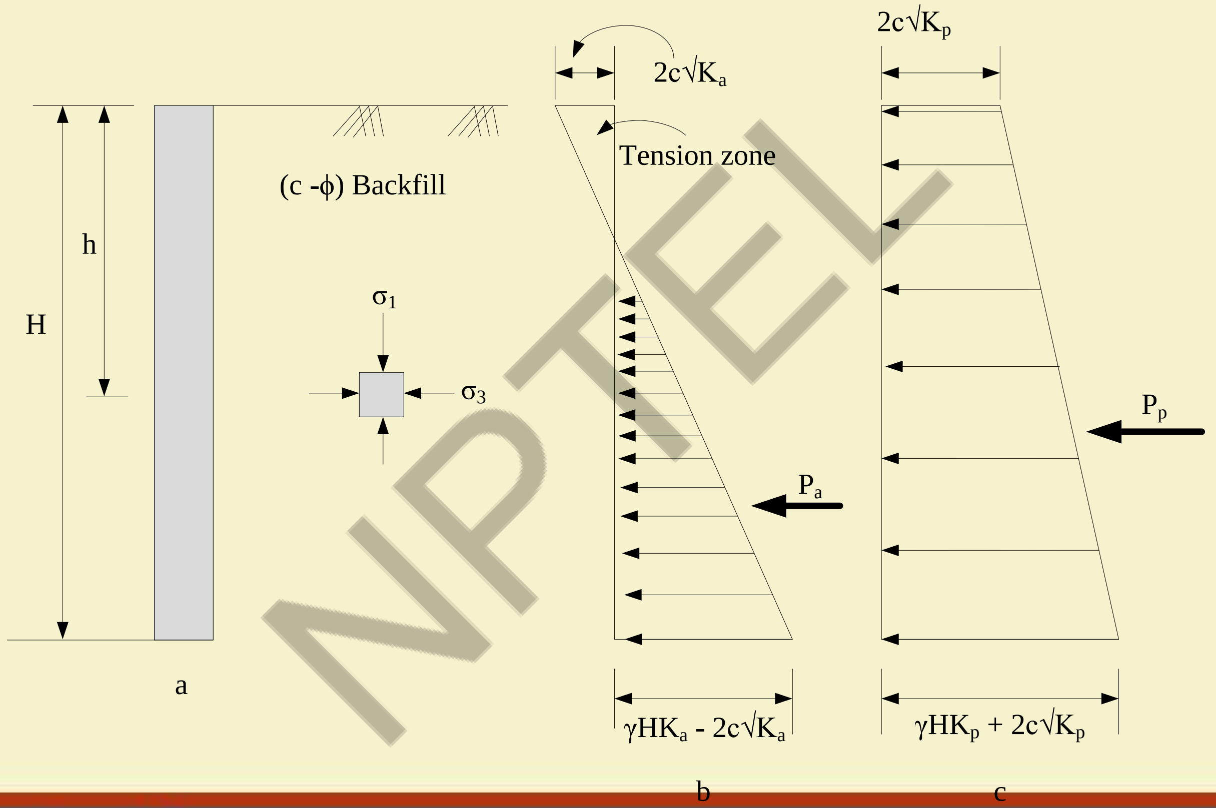
EARTH PRESSURE

Passive case

$$\sin\emptyset = \frac{\sigma_3 - \sigma_1}{\sigma_3 + \sigma_1 + 2c\cot\emptyset}$$

$$\sigma_3 = \sigma_1 \frac{1+\sin\emptyset}{1-\sin\emptyset} + 2c\sqrt{\frac{1+\sin\emptyset}{1-\sin\emptyset}} = \sigma_1 k_p + 2c\sqrt{k_p}$$

EARTH PRESSURE



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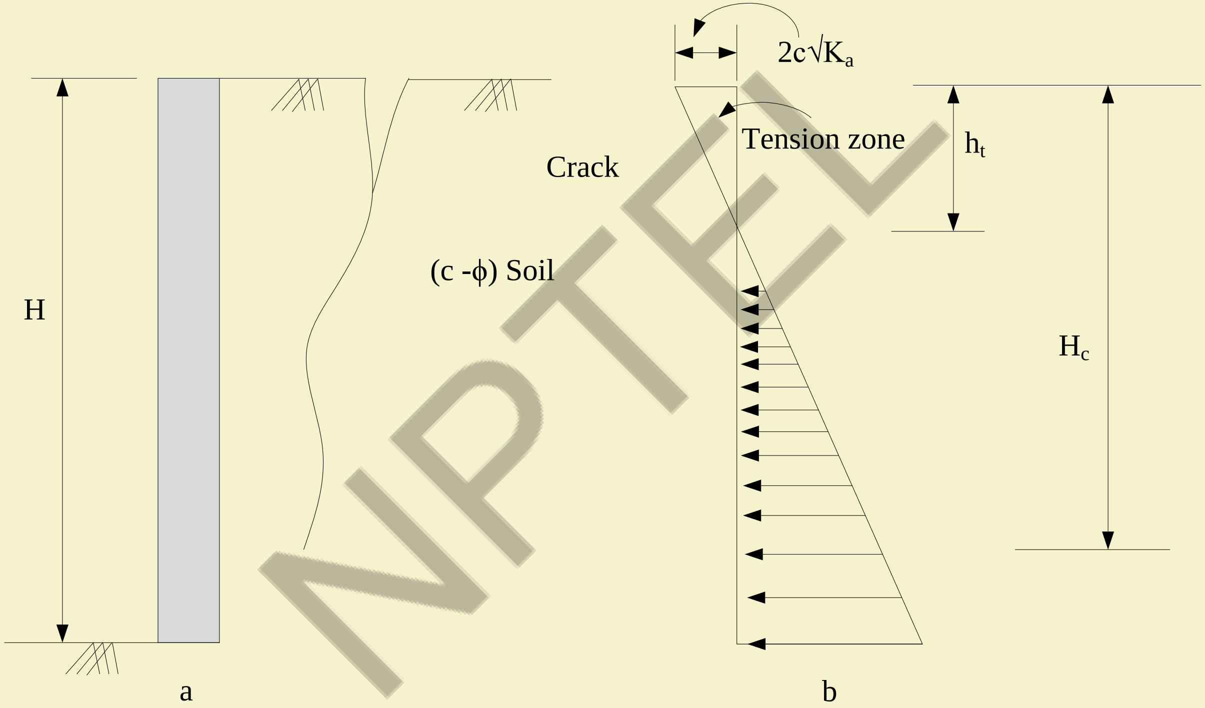

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EARTH PRESSURE

Unsupported cuts in c-ϕ soil

$$\sigma_3 = \sigma_1 \frac{1 - sin\emptyset}{1 + sin\emptyset} - 2c\sqrt{\frac{1 - sin\emptyset}{1 + sin\emptyset}} = \sigma_1 k_a - 2c\sqrt{k_a}$$

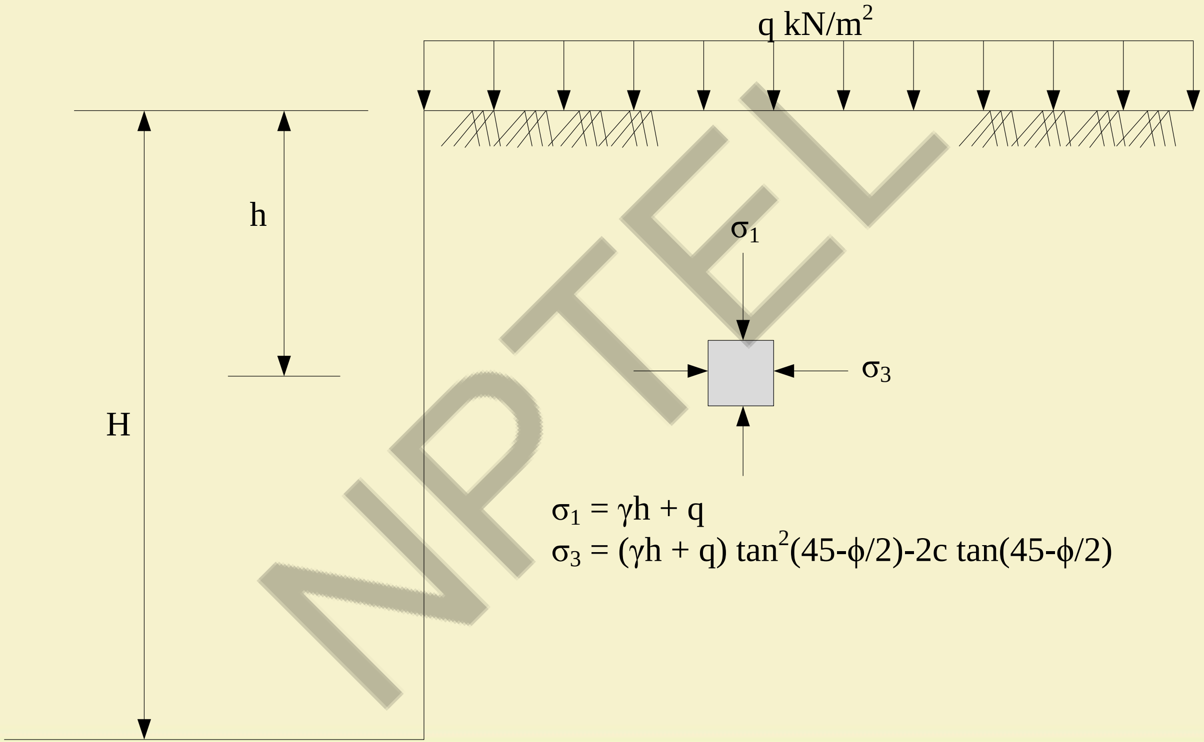
At ground surface h=0 and $\sigma_3 = -2c\sqrt{k_a}$ Tension

The theoretical depth of the crack ht can be determined by recognising that at the bottom of the crack σ3 = o

$$0 = \gamma h_t k_a - 2c\sqrt{k_a}$$

$$h_t = \frac{2c}{\gamma\sqrt{k_a}}$$

EARTH PRESSURE



$$\sigma_1 = \gamma h + q$$

$$\sigma_3 = (\gamma h + q)\tan^2(45-\phi/2) - 2c\tan(45-\phi/2)$$

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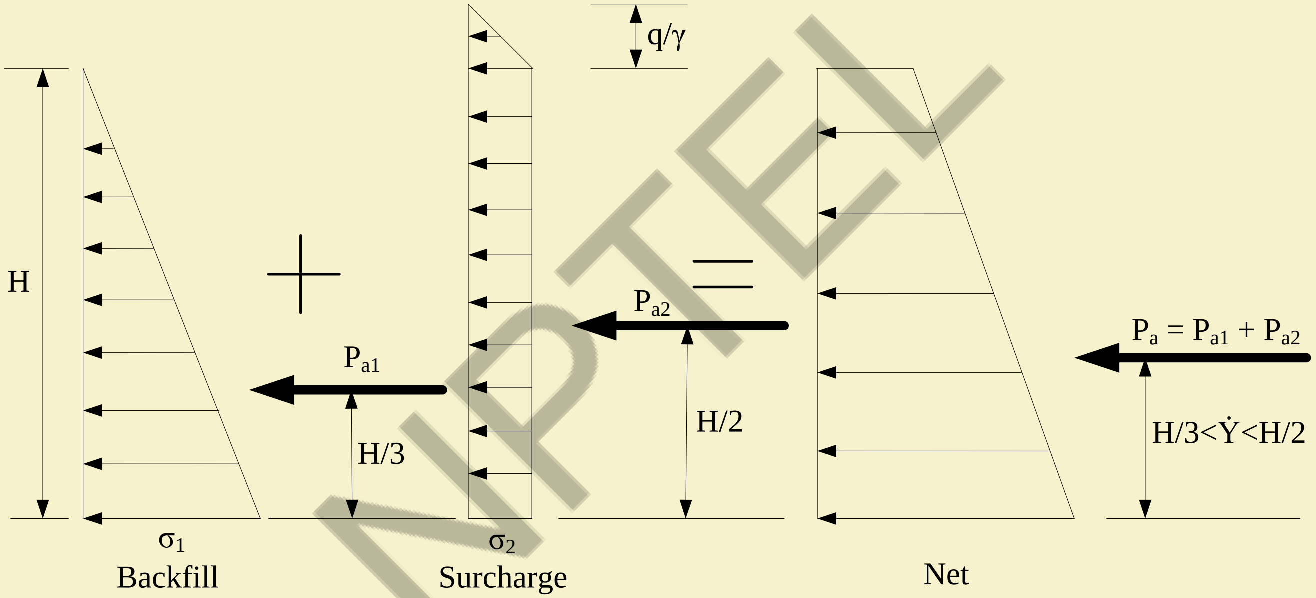

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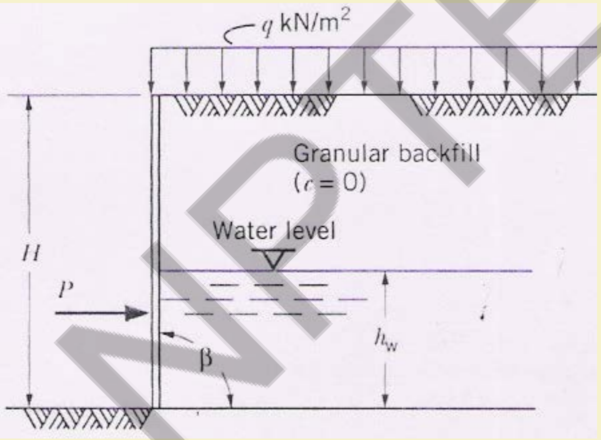
EARTH PRESSURE

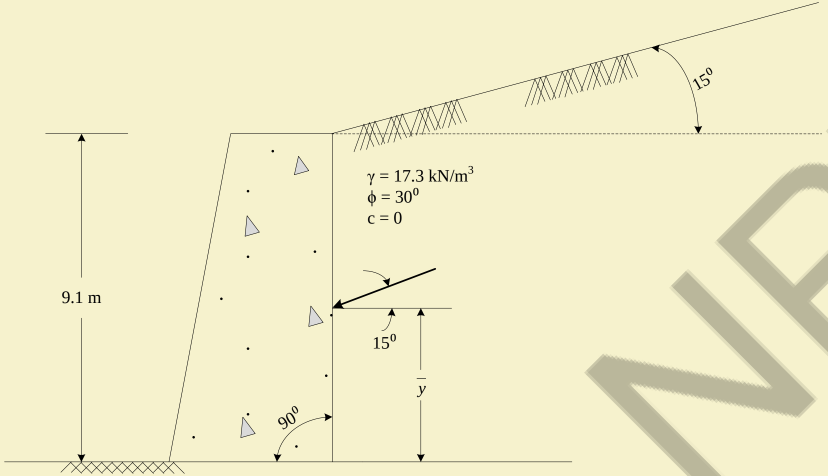
A smooth unyielding wall of height 2.5 m retains a dense cohesionless soil having unit weight 18. 4 kN/m3 and angle of internal friction of 37 deg with no lateral movement of soil. Draw the lateral earth pressure diagram against the wall and determine the total lateral force acting on the wall.

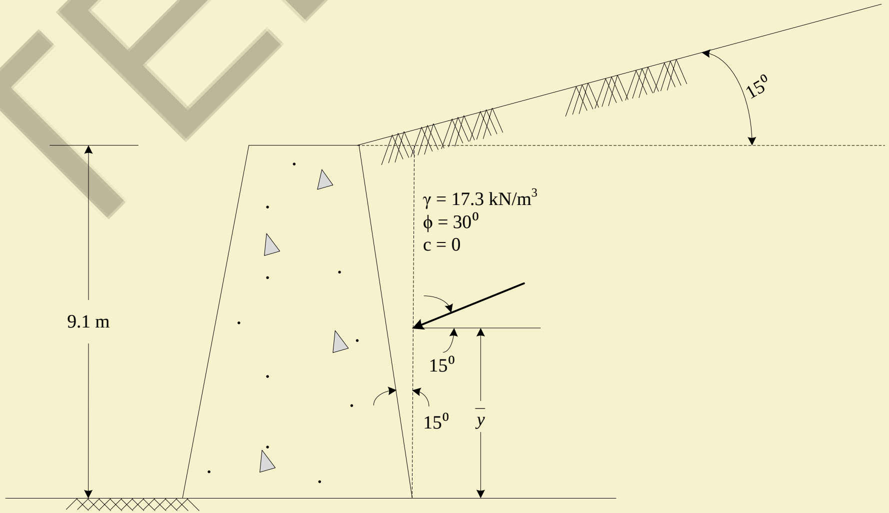
EARTH PRESSURE

For the earth retaining structure shown in Fig Q. 4(a), determine the total active thrust on the wall. Given: H = 5 m, Φ = 30^0, β = 90^0, h_w = 2.0 m, γ = 18 kN/m^3, and q = 250 kN/m^2.



What is the total active earth pressure per meter of wall for the wall shown in the Figure (a) and (b)





EARTH PRESSURE

A retaining wall 6 m high supports two layers of soil each having thickness of 3 m. The properties of the layers are:

Upper layer: $c' = 0.0$, $\phi' = 30^o$, $\gamma_{bulk} = 18.0\ kN/m^3$,

Lower layer: $c' = 10.0\ kPa$, $\phi' = 18^o$, $\gamma_{sat} = 19.0\ kN/m^3$

EARTH PRESSURE

A retaining wall with smooth vertical back is 6.0 m high and retains a two-layered soil backfill with the following properties:

0 to 4.0 m depth: $c' = 10.0$ kN/m^2, $\phi' = 10.0$, and $\gamma = 18.0$ kN/m^3

4 to 6.0 m depth: $c' = 0.0$, $\phi' = 30^\circ$ and $\gamma_{sat} = 22.0$ kN/m^3

Location of water table is at 4.0 m from the ground surface

Calculate the total active thrust on the wall if the horizontal backfill carries a uniform surcharge load of 30 kN/m^2. Also calculate the line of action of the lateral force from the base of the wall.

EARTH PRESSURE

- A retaining wall with smooth vertical back is 8.0 m high and retains a two-layered soil backfill with the following properties:

0 to 4.0 m depth (from the top of the wall): $c' = 0.0$ kN/m^2, $\phi' = 35^0$, and $\gamma = 19.0$ kN/m^3

4 to 8.0 m depth (from the top of the wall): $c' = 10.0$ kN/m^2, $\phi' = 10.0$, and $\gamma = 18.0$ kN/m^3

Location of water table is at a depth of 6.0 m from the top of the wall.

Calculate the total active thrust on the wall if the horizontal backfill carries a uniform surcharge load of 30 kN/m^2. Also calculate the line of action of the lateral force from the base of the wall.

EARTH PRESSURE

A retaining wall with smooth vertical back is 8.0 m high and retains cohesionless soil backfill. Location of water table is at a depth of 3.0 m from the top of the wall. Calculate the total active thrust on the wall if the horizontal backfill carries a uniform surcharge load of 30 kN/m^2. Also calculate the line of action of the lateral force from the base of the wall

EARTH PRESSURE

A retaining wall with smooth vertical back is 8.0 m high and retains a two-layered soil backfill with the following properties:

0 to 4.0 m depth (from the top of the wall): $c' = 0.0$ kN/m^2, $\phi' = 30^0$, and $\gamma = 18.0$ kN/m^3

4 to 8.0 m depth (from the top of the wall): $c' = 0.0$ kN/m^2, $\phi' = 35^o$, and $\gamma = 19.0$ kN/m^3

Location of water table is at a depth much below the base of the wall.

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EARTH PRESSURE

A retaining wall with smooth vertical back is 8.0 m high and retains a two-layered soil backfill with the following properties:

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4 to 8.0 m depth (from the top of the wall): $c' = 0.0$ kN/m^2, $\phi' = 35^o$, and $\gamma = 19.0$ kN/m^3

Location of water table is at a depth much below the base of the wall. Determine the earth pressure diagram against the wall and determine the total active thrust and point of application

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A retaining wall 6 m high supports two layers of soil each having thickness of 3 m. The properties of the layers are:

Upper layer: $c' = 0.0$, $\phi' = 30^o$, $\gamma_{bulk} = 18.0\ kN/m^3$,

Lower layer: $c' = 10.0\ kPa$, $\phi' = 18^o$, $\gamma_{bulk} = 19.0\ kN/m^3$

Determine the total lateral thrust and its line of action above the base of the wall.

A retaining wall with smooth vertical back is 8.0 m high and retains cohesionless soil backfill. Location of water table is at a depth of 3.0 m from the top of the wall. Calculate the total active thrust on the wall if the horizontal backfill carries a uniform surcharge load of 30 kN/m^2. Also calculate the line of action of the lateral force from the base of the wall

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EARTH PRESSURE

Determine using Coulomb's theory the total active thrust on a vertical retaining wall 5 m high if the soil retained has a horizontal surface level with the top of the wall and has the following properties: ϕ = 36 deg, ϒ= 19 kN/m3. Assume δ=0.5ϕ

$$P_a = \frac{1}{2}\gamma h^2 \left[\frac{cosec\beta \sin(\beta - \emptyset)}{\sqrt{\sin(\beta+\delta)} + \sqrt{\frac{\sin(\emptyset+\delta)\sin(\emptyset - i)}{\sin(\beta - i)}}} \right]^2 = \frac{1}{2}\gamma h^2 k_a$$

i= 0.0, β=90, δ= 18

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EARTH PRESSURE

A retaining wall 4 m supports a backfill with horizontal top. The wall is pushed towards the fill. Compute the total force acting on the wall. The properties of the fill are: c= 25 kN/m2, Ø= 20 and ϒ 18 kN/m3.

EARTH PRESSURE

Determine the maximum unsupported depth of a vertical cut in natural soil deposit with cohesion of 30 kPa, angle of internal friction of 20 deg, and unit weight of 18.0 kN/m3

EARTH PRESSURE

A vertical cut in a purely cohesive soil failed when the depth of cut reached to a depth of 5.1 m. What is the expected value of the cohesion of the soil? Assume unit weight of soil as 20 kN/m3.

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SOIL MECHANICS/GEOTECHNICAL ENGINEERING I

STABILITY OF SLOPES

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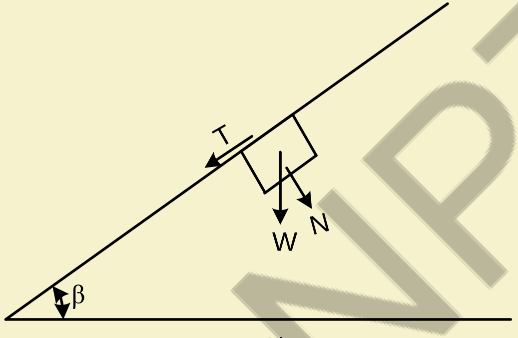
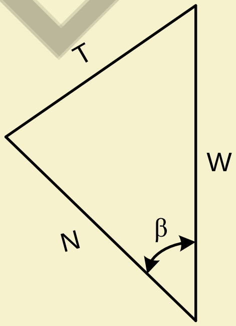
Introduction: Gravel and sand are referred to as granular soils and normally exhibit only a frictional component of strength. A potential slip surface in a slope of granular material will be planar and the analysis of the slope is relatively simple. However most soils exhibit both cohesive and frictional strength and pure granular soils are fairly infrequent. Nevertheless a study of granular soils is a useful introduction to the later case where both cohesive and frictional strength exists.

SLOPE STABILITY

Figure in the previous slide illustrates an embankment of granular material with an angle of shearing resistance Ø and with its surface sloping at an angle β to the horizontal.



Slope



Triangle of forces

SLOPE STABILITY

Consider an element of the embankment of weight W

Force parallel to the slope = $W sin\beta$

Force perpendicular to the slope = $W\ cos\beta$

For stability, sliding force = Resisting Force / FS

i. e., $$W\ sin\beta = \frac{W\ cos\beta\ tan\varphi}{F}$$

Or, $$F = \frac{tan\emptyset}{tan\beta}$$

For limiting equilibrium (F = 1), i. e., Ø= β

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Important observations

From this it is seen that (a) the weight of a material does not affect the stability of the slope, (b) the safe angle for the slope is the same whether the soil is dry or submerged and (c) the embankment can be of any height.

Failure of a submerged sand slope can occur, however, if the water level of the retained water falls rapidly while the water level in this slope lags behind. Since seepage forces are set up in this situation

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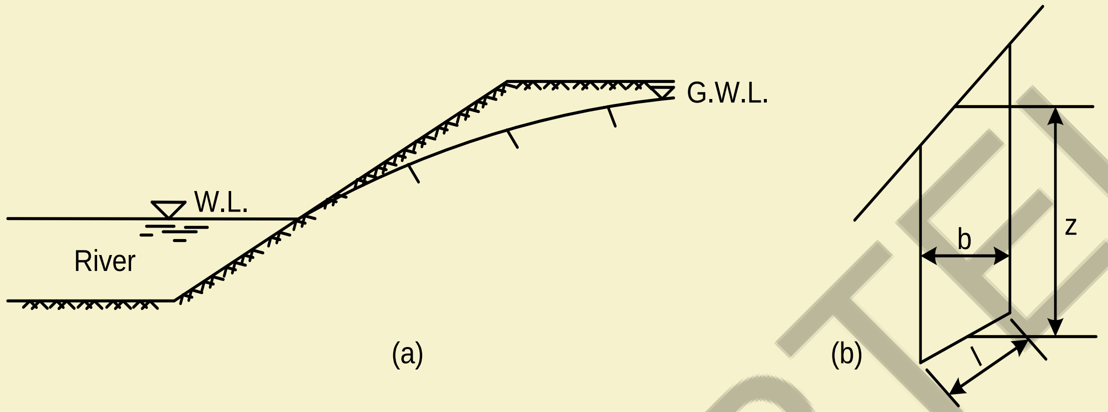
Seepage Forces in a Granular Slope Subjected to Rapid Drawdown:

As shown in the Figure the water level of the river has dropped suddenly due to tidal effects. The permeability of the soil in the slope is such that the water in it cannot follow the water level changes as rapidly as the river, with the result that seepage occurs from the high water level in the slope to the lower water level of the river. A flow net can be drawn for this condition and the excess hydraulic head for any point within the slope can be determined.

SLOPE STABILITY



Assume that a potential failure plane, parallel to the slopes surface, occurs at a depth z and consider an element within the slope of weight W. Let the excess pore water pressure induced by seepage be u at the mid point of the base of the element.;

SLOPE STABILITY

Normal reaction N = $W\ cos\beta$

Normal stress, $\sigma = \dfrac{W\ cos\beta}{l} = \dfrac{W\ cos^2\beta}{b}$ $\quad since, l = \dfrac{b}{cos\beta}$

Normal effective stress, $\sigma' = \dfrac{Wcos^2\beta}{b} - u = \dfrac{\gamma zbcos^2\beta}{b} - u = \gamma zcos^2\beta - u$

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SLOPE STABILITY

Tangential Force = $W sin\beta$

Tangential shear stress, $\tau = \frac{W\ sin\beta}{l} = \gamma z\ sin\beta\ cos\beta$

Ultimate shear strength of soil= $\sigma'\ tan\emptyset = \tau F$

Hence, $\gamma z\ sin\beta\ cos\beta = (\gamma z\ cos^2\beta - u)\frac{tan\emptyset}{F}$

Or, $F = \left(\frac{cos\beta}{sin\beta} - \frac{u}{\gamma z\ sin\beta\ cos\beta}\right) tan\emptyset = \left(1 - \frac{u}{\gamma z cos^2\beta}\right)\frac{tan\emptyset}{tan\beta}$

This expression may be written as: $F = \left(1 - \frac{r_u}{cos^2\beta}\right)\frac{tan\emptyset}{tan\beta}$

Where $r_u = \frac{u}{\gamma z}$

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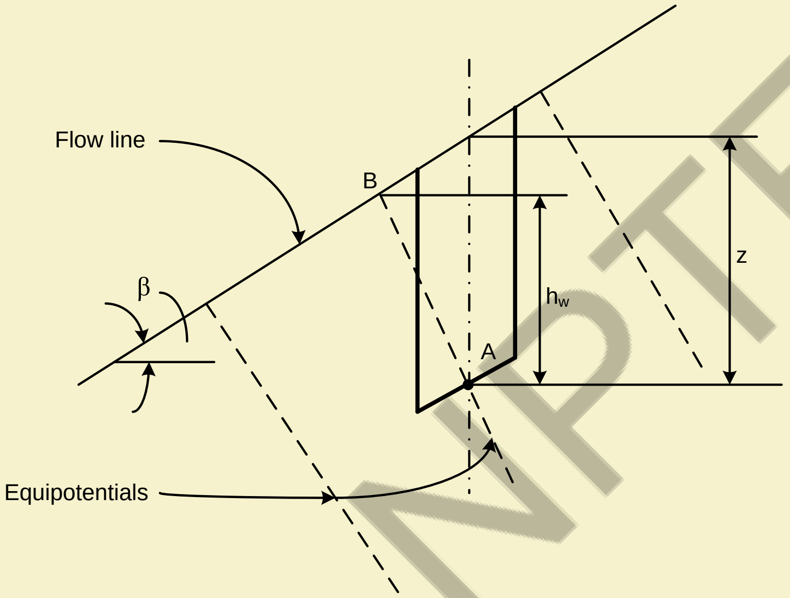
Flow Parallel to and at the Surface



SLOPE STABILITY

If we consider the same element as before, the excess pore water head, at the center of the base of the element, is represented by the height hw in the Figure. In the Figure AB = z cosβ and hw = AB cos β. Hence, hw = $z\cos^2\beta$. So the excess pore water pressure at the base of the element = $\gamma_w z\cos^2\beta$

Hence,

$$r_u = \frac{u}{\gamma z} = \frac{\gamma_w z\cos^2\beta}{\gamma z} = \frac{\gamma_w}{\gamma}\cos^2\beta$$

The equation for F becomes,

$$F = \left(1 - \frac{\gamma_w}{\gamma}\right)\frac{\tan\phi}{\tan\beta} = \left(\frac{\gamma - \gamma_w}{\gamma}\right)\frac{\tan\phi}{\tan\beta} = \frac{\gamma'}{\gamma}\frac{\tan\phi}{\tan\beta}$$

SLOPE STABILITY

A granular soil has a saturated unit weight of 18.0 kN/m3 and an angle of shearing resistance of 30 deg. A slope is to be made of this material. If the factor of safety is to be 1.25, determine the safe angle of the slope (i) when the slope is dry or saturated and (ii) if seepage occurs at and parallel to the surface of the slope.

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