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NPTEL ONLINE CERTIFICATION COURSES

NPTEL

SOIL MECHANICS/GEOTECHNICAL ENGINEERING I

EARTH PRESSURE

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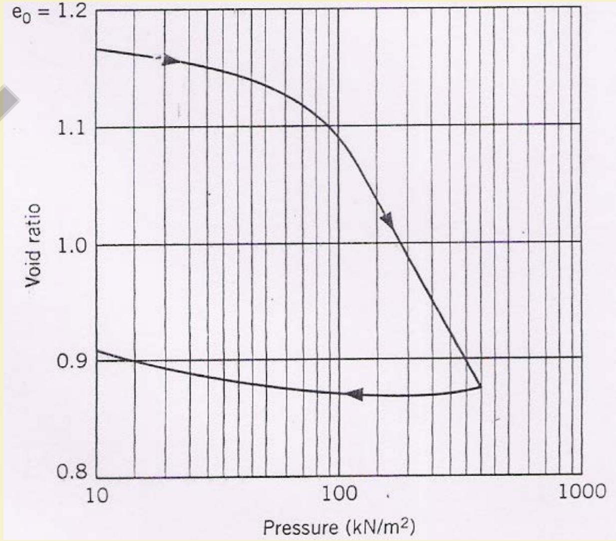
COMPRESSIBILITY OF SOILS

The coordinates of two points on the virgin compression line are: σ'_1= 400 kPa, e_1=0.8; σ'_2 = 800 kPa, e_2 = 0.75. In the field, a 3.0 m thick normally consolidated layer of this soil subjected to construction load and the average effective vertical stress increased from 250 kPa to 450 kPa. Determine: (i) compression index and initial void ratio of the clay layer (ii) the consolidation settlement, (ii) the load increment to cause a 25 mm final consolidation settlement and the corresponding void ratio

COMPRESSIBILITY OF SOILS

Assume that the e-logp relationship shown in Figure represents the laboratory results of a one-dimensional consolidation test. The clay stratum from which the test sample was extracted was 3.5 m thick, totally saturated.

How much additional effective pressure can the clay withstand if the ultimate expected settlement is not to exceed 120 mm? Assume $\sigma_0 = \sigma_{pc}$ (normally consolidated).



COMPRESSIBILITY OF SOILS

A compressible clay layer is expected to have a total settlement of 150 mm under a given loading. It settles by 30 mm in two months after the application of load increment. How many months will be required to settle 75 mm? How much will it settle in 18 months? (Assume double drainage in the clay layer)

COMPRESSIBILITY OF SOIL: Secondary compression

As was pointed out earlier additional deformation can occur in clays for a considerable period of time after the completion of primary consolidation settlement. This occur at a much slower rate, at a very small seepage velocity, and presumably under zero excess pore pressure.

The amount of secondary compression can be estimated by maintaining a constant load on a clay long enough past the point of primary consolidation to establish a relationship between secondary deformation and time.

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COMPRESSIBILITY OF SOILS

$$C_\alpha = \frac{\varepsilon_1 - \varepsilon_2}{\log\left(t_2/t_1\right)}$$

Some common values of C_α

Over consolidated clays	**0.0005-0.0015**
Normally consolidated clays	0.005-0.03
Organic soils, peat	0.04-0.1

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Retaining wall

Types of earth retaining structure:

Externally stabilised system – soil is not a fundamental part of system.

Gravity wall – typically small true gravity retaining wall, crib wall, Gabion and cantilevered.

Insitu wall – Either cantilevered, braced or tie back sheet pile wall, shoulder pile

EARTH PRESSURE

Internally stabilised system – Soil is a fundamental part of the system. Example: Reinforced earth soil nailing.

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Earth Pressure

Why study earth pressure?

Design of foundation wall (basement), safe excavation during construction and design of earth retaining structure.

Earth pressure type:

Earth pressure at rest (K_0 condition)

Active earth pressure

Passive earth pressure

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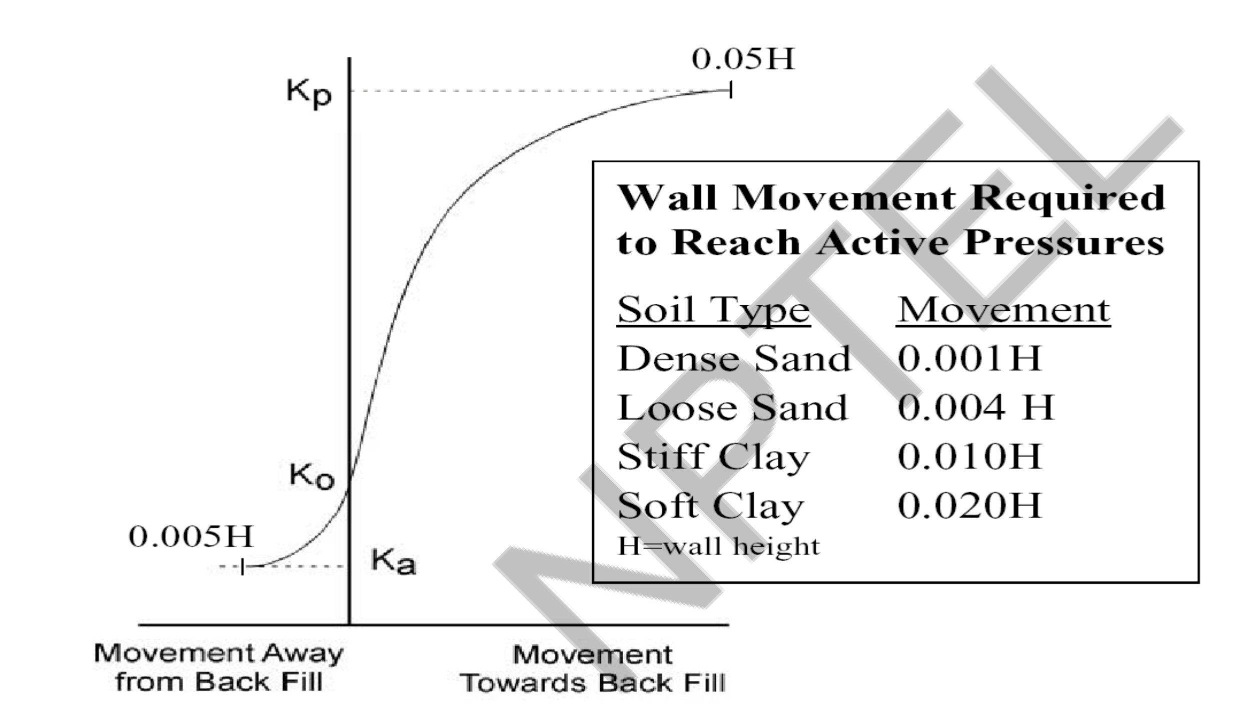
EARTH PRESSURE



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ACTIVE CASE	PASSIVE CASE
Wall moves out	Wall moves in
Shear stress on failure plane reduces	Shear stress on failure plane increases
Lateral pressure reduces	Lateral pressure increases
Minimum lateral stress achieves when soil fails and full strength is mobilised	Maximum lateral stress achieves when soil fails and full strength is mobilised

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EARTH PRESSURE

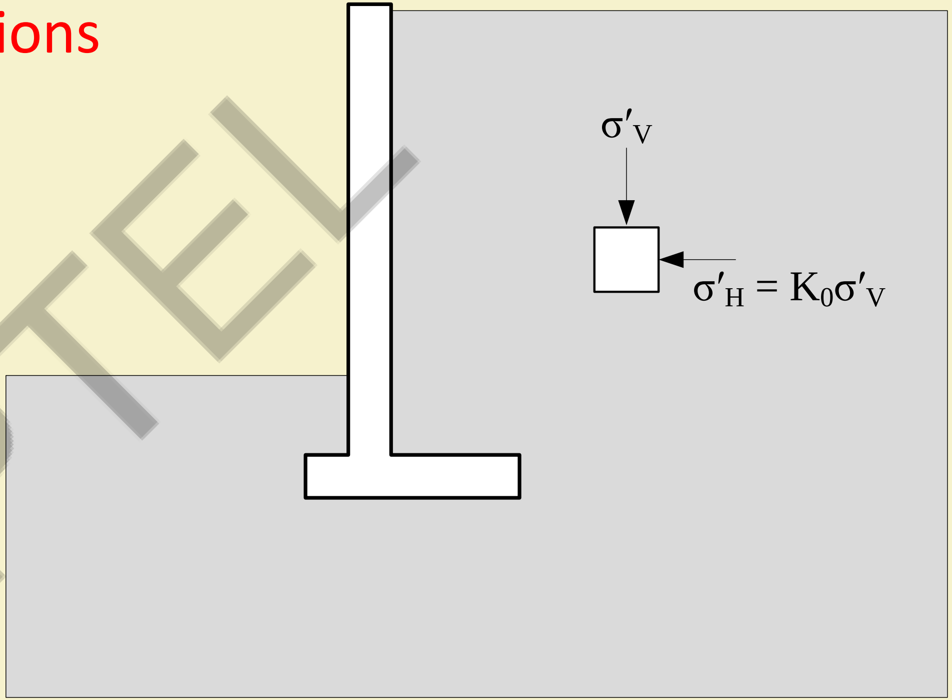
Lateral pressure at rest: assumptions

Rigid and unyielding wall

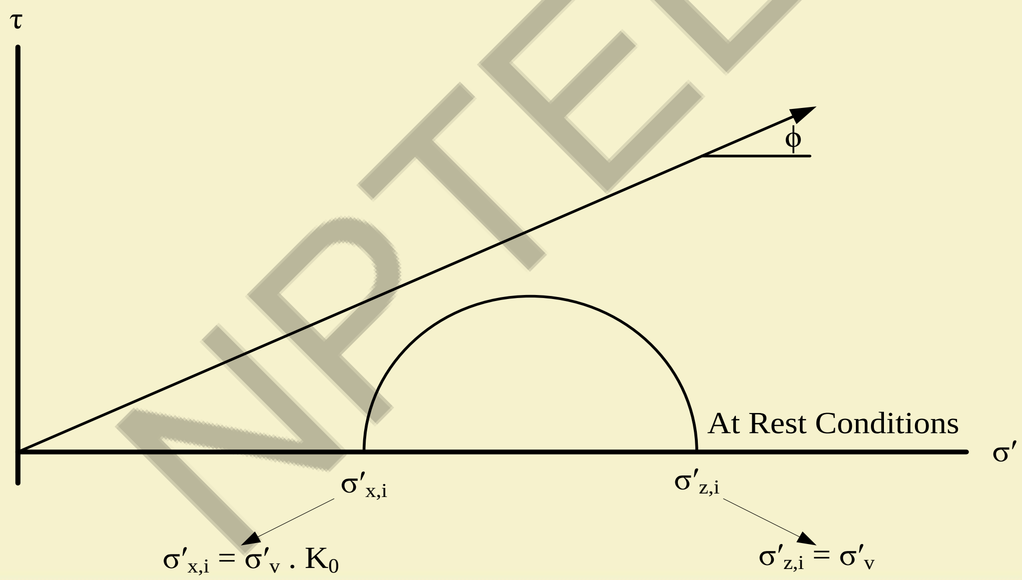
Frictionless

$$k_0 = \frac{\sigma_h'}{\sigma_v'}$$

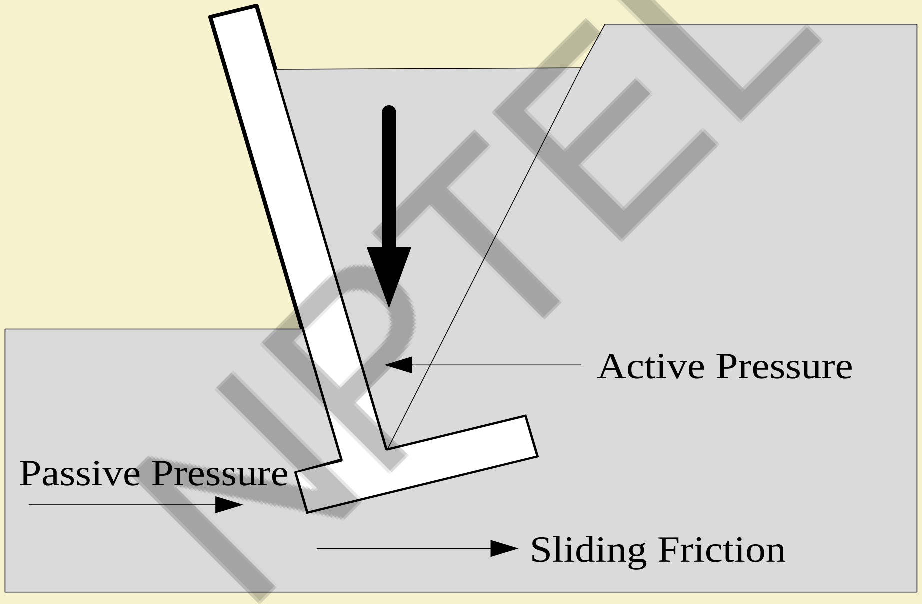
$$k_0 = (1 - sin\emptyset')$$



Mohr circle at rest condition

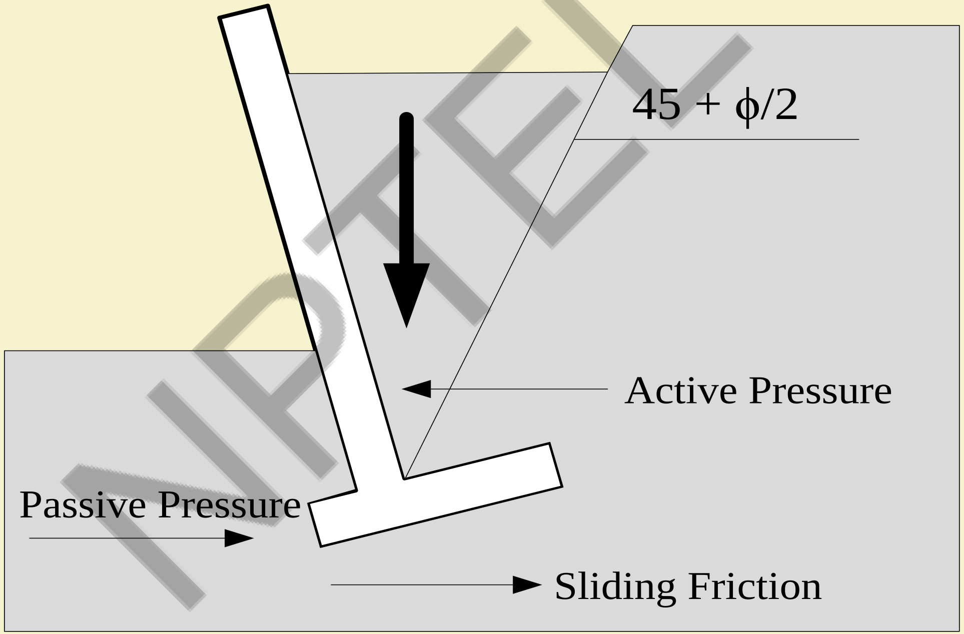


Lateral earth pressure



EARTH PRESSURE

Active earth pressure



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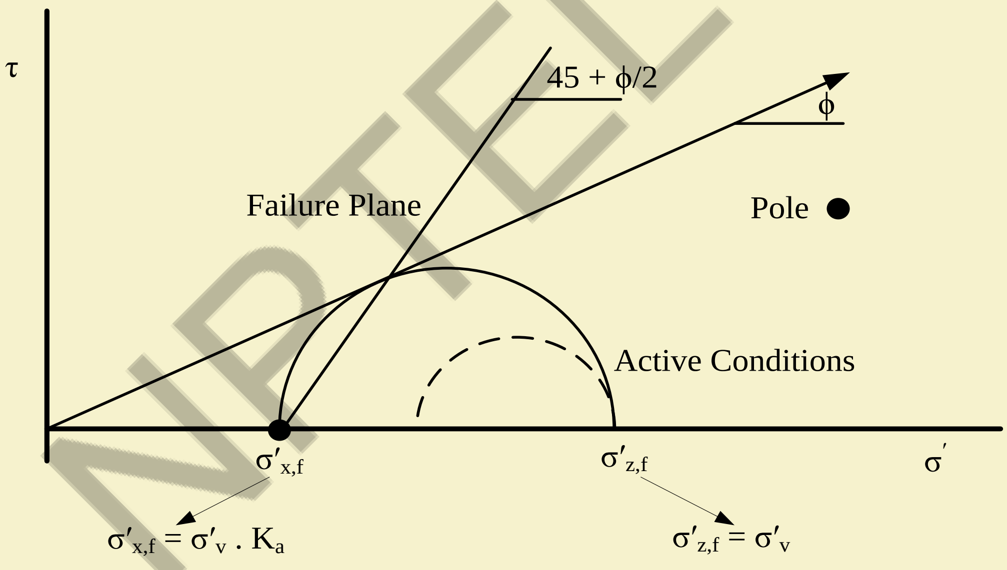
Mohr circle for active earth pressure condition



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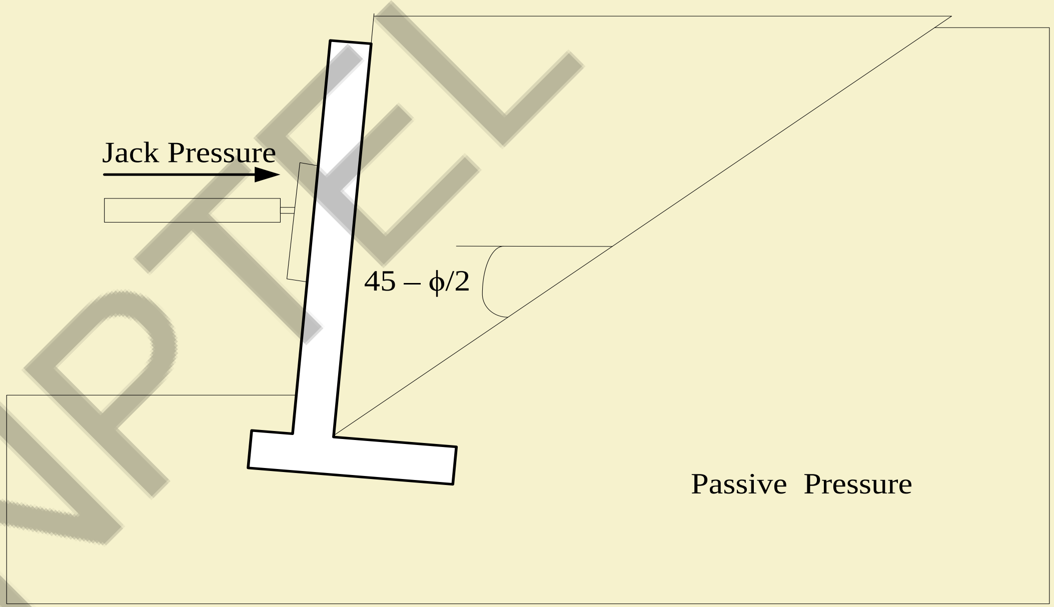
Passive earth pressure



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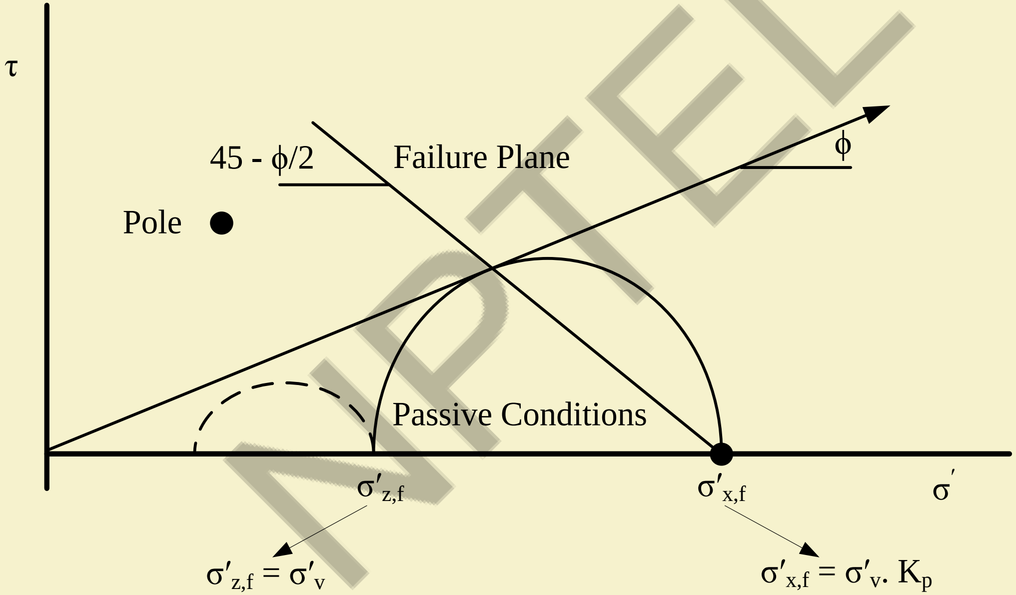
Mohr's circle for passive earth pressure condition



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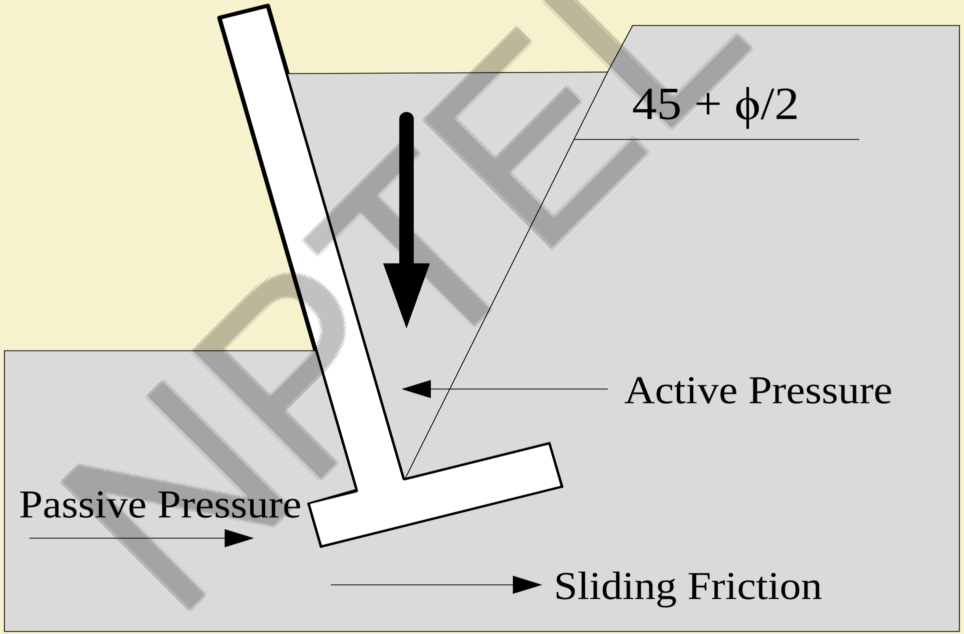
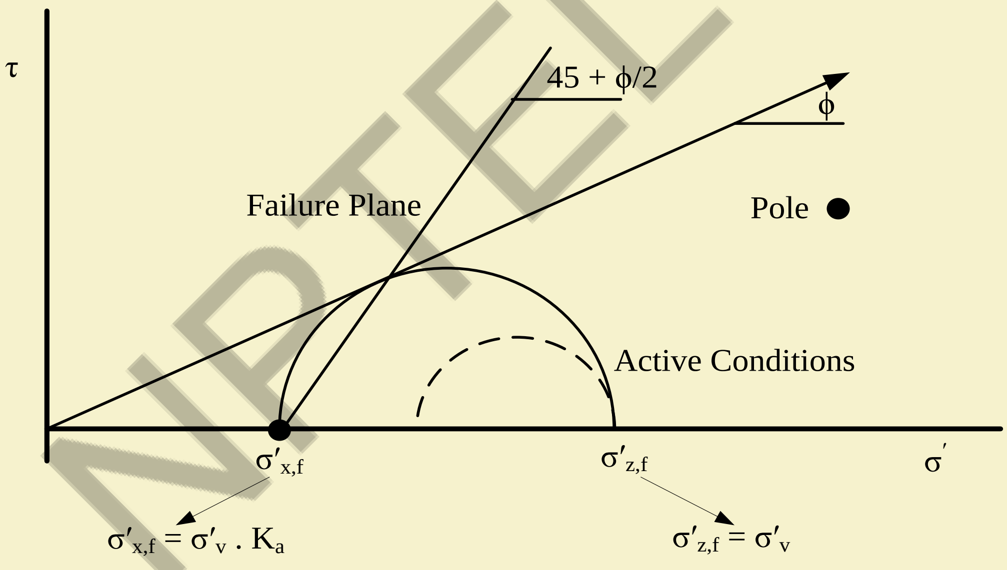
Active earth pressure

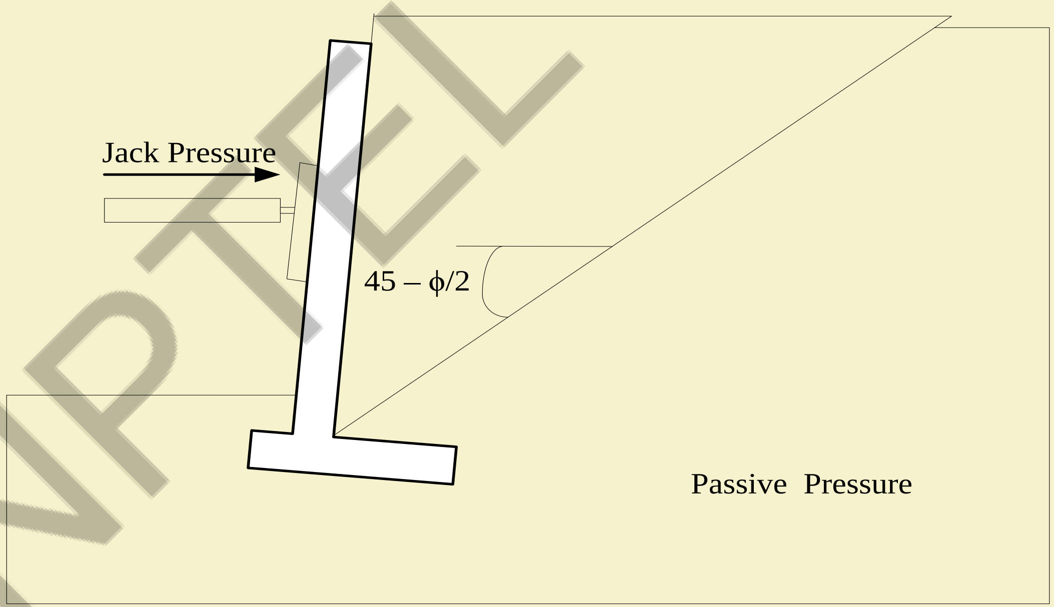


Mohr circle for active earth pressure condition



EARTH PRESSURE

Passive earth pressure



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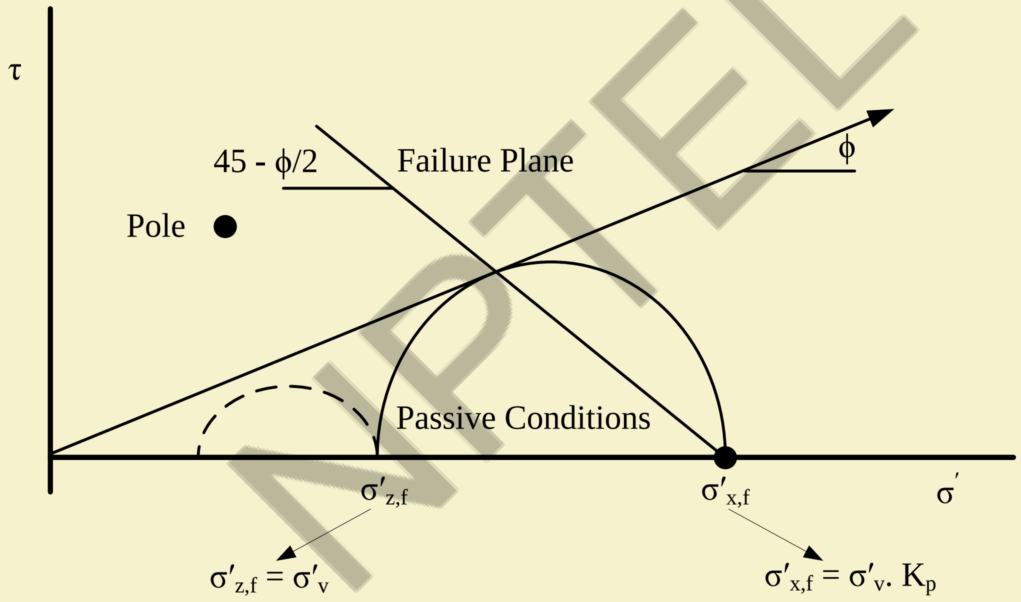
Mohr's circle for passive earth pressure condition



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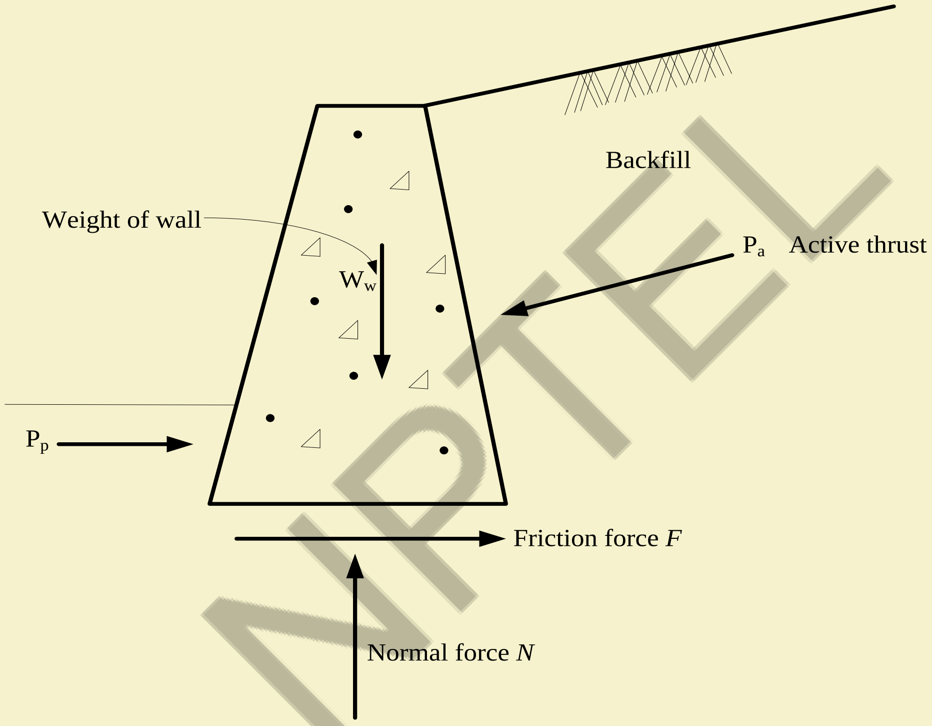

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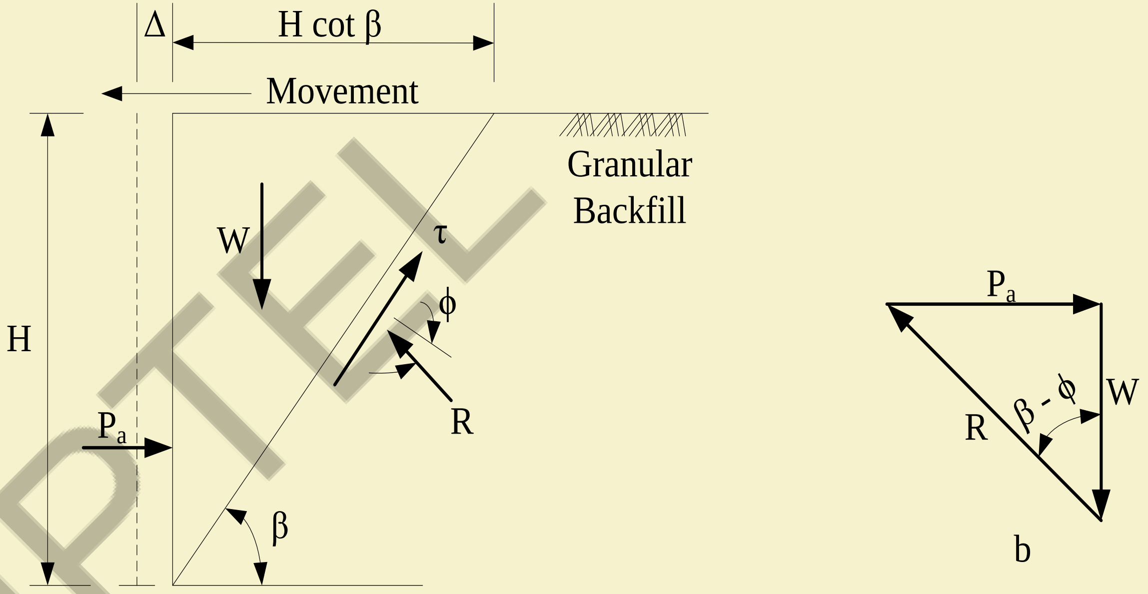
EARTH PRESSURE

Assumptions:

- Frictional force between backfill and retaining wall are assumed to be negligible
- The wall is straight and the surface of the backfill ids horizontal
- The backfill is a homogeneous granular material
- The failure surface is assumed to be plane



Movement of wall is away from backfill

a

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EARTH PRESSURE

$$P_a = W \tan(\beta - \emptyset)$$

$$W = \frac{1}{2}\gamma H(H\cot\beta) = \frac{1}{2}\gamma H^2 \cot\beta$$

$$P_a = \frac{1}{2}\gamma H^2 \cot\beta \tan(\beta - \emptyset)$$

$$\frac{\partial P_a}{\partial \beta} = 0 \qquad 2\beta - \emptyset = 90$$

$$\beta_{cr} = 45 + \frac{\emptyset}{2}$$

$$P_a = \frac{1}{2}\gamma H^2 \tan^2\left(45 - \frac{\emptyset}{2}\right)$$

$$P_a = \frac{1}{2}\gamma H^2 k_a$$

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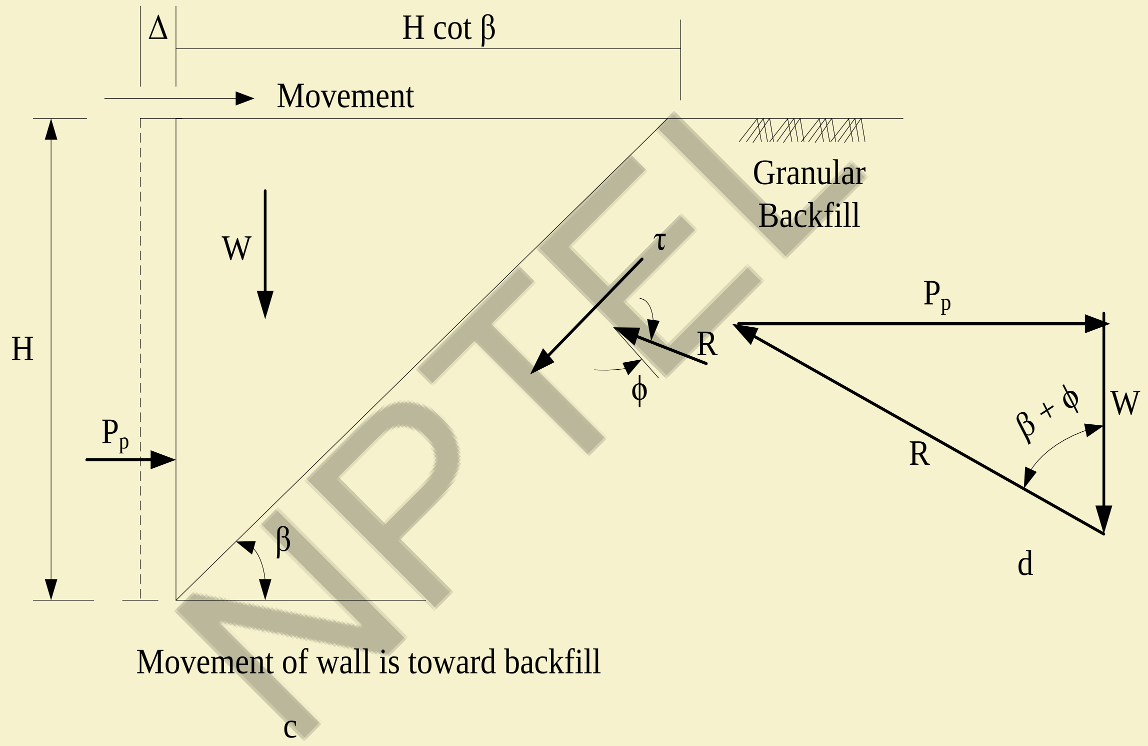
EARTH PRESSURE



Movement of wall is toward backfill

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$$P_p = W\ tan(\beta + \emptyset)$$

$$W = \frac{1}{2}\gamma H(Hcot\beta) = \frac{1}{2}\gamma H^2 cot\beta$$

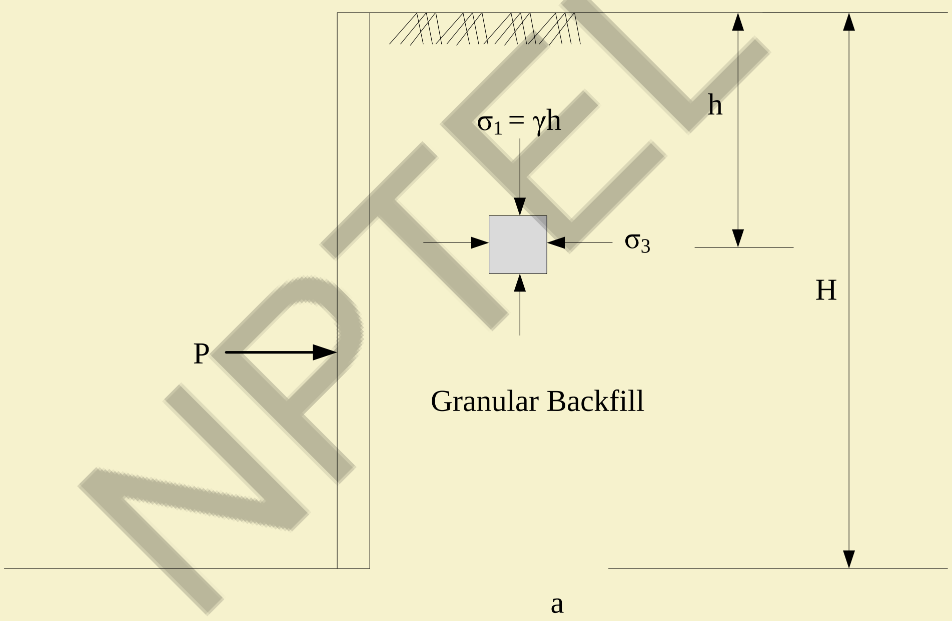
$$P_p = \frac{1}{2}\gamma H^2 cot\beta tan(\beta + \emptyset)$$

$$\frac{\partial P_p}{\partial \beta} = 0 \qquad \emptyset + 2\beta = 90$$

$$\beta_{cr} = 45 - \frac{\emptyset}{2}$$

$$P_p = \frac{1}{2}\gamma H^2 tan^2\left(45 + \frac{\emptyset}{2}\right) = \frac{1}{2}\gamma H^2 k_p$$

Cohesionless granular level backfill: Rankine's theory



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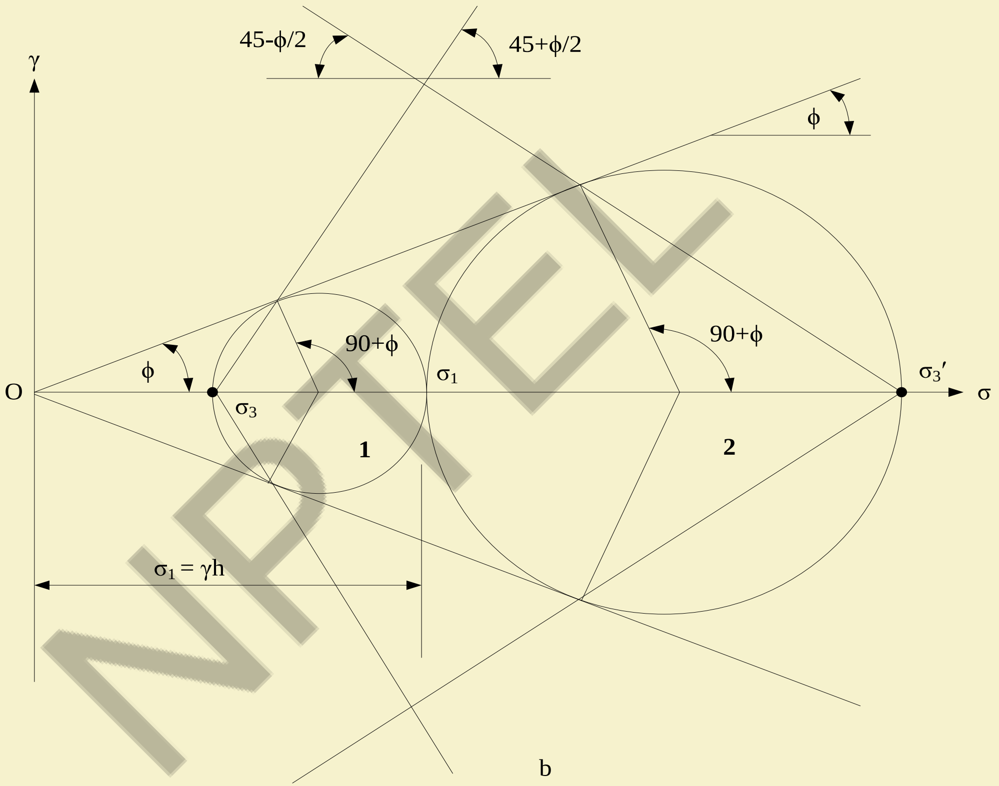

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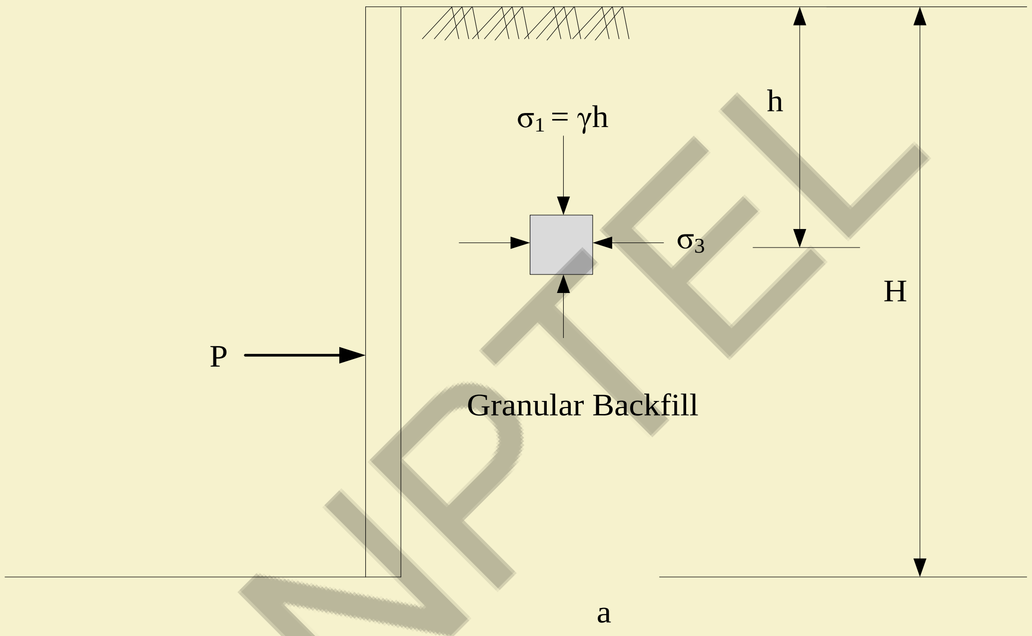

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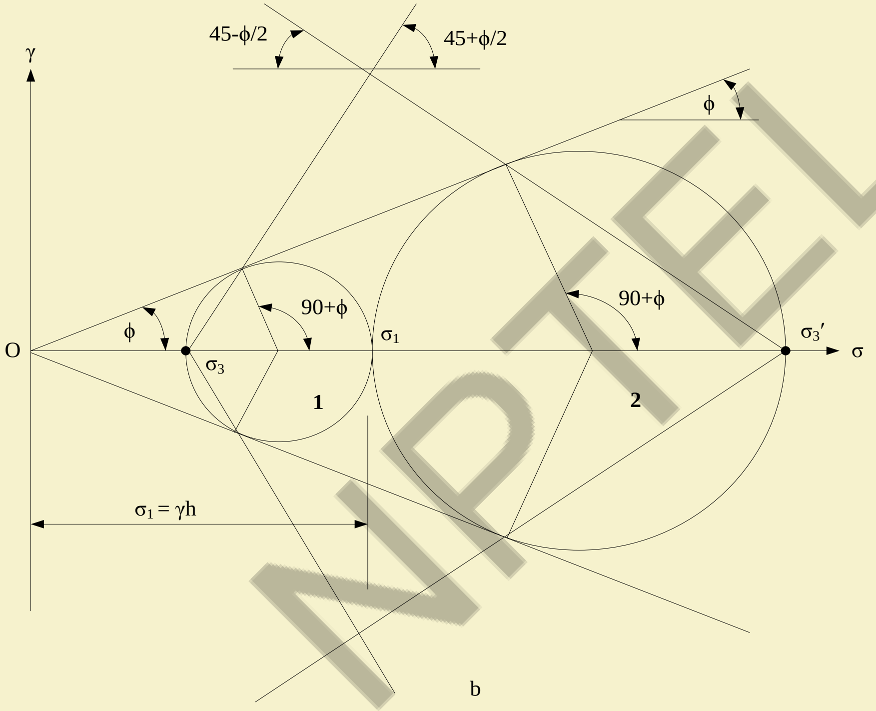

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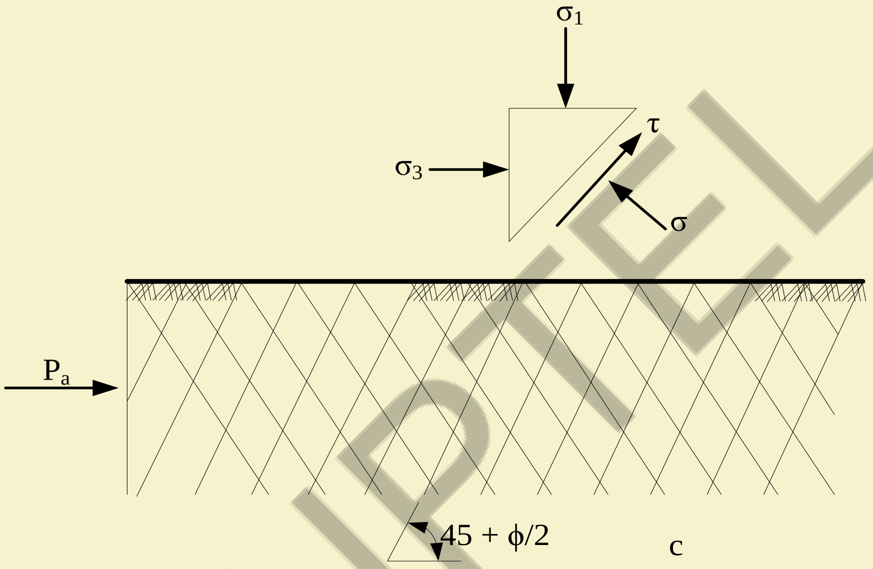

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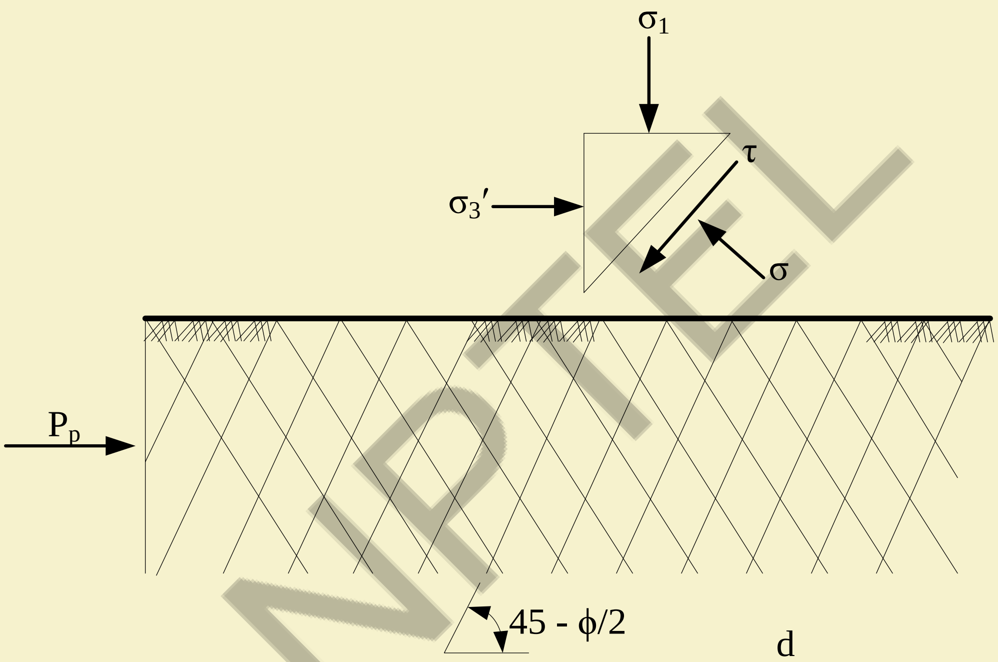

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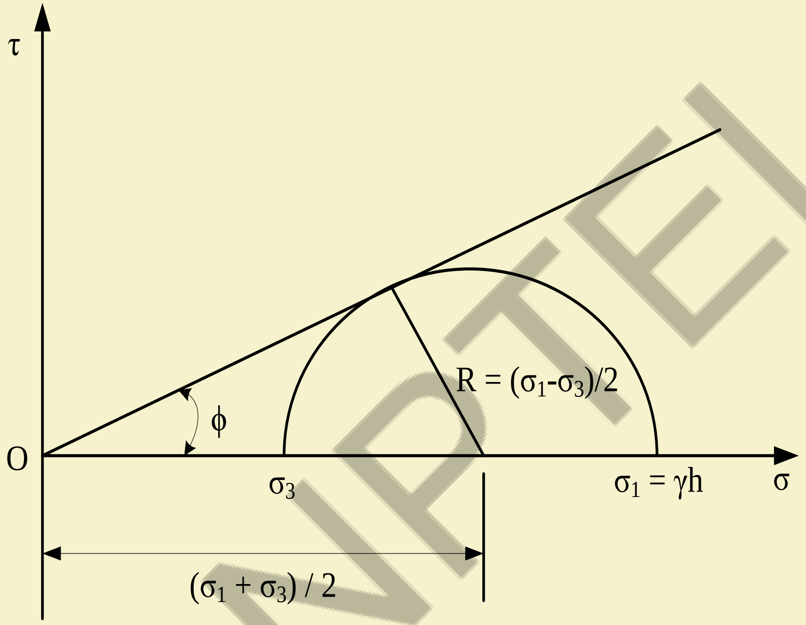

EARTH PRESSURE

$$sin\emptyset = \frac{(\sigma_1 - \sigma_3)/2}{(\sigma_1 + \sigma_3)/2} = \frac{\sigma_1 - \sigma_3}{\sigma_1 + \sigma_3}$$

$$\sigma_3 = \sigma_1 \frac{1 - sin\emptyset}{1 + sin\emptyset} = \gamma h \frac{1 - sin\emptyset}{1 + sin\emptyset}$$

$$\sigma_3 = \gamma h tan^2\left(45 - \frac{\emptyset}{2}\right)$$

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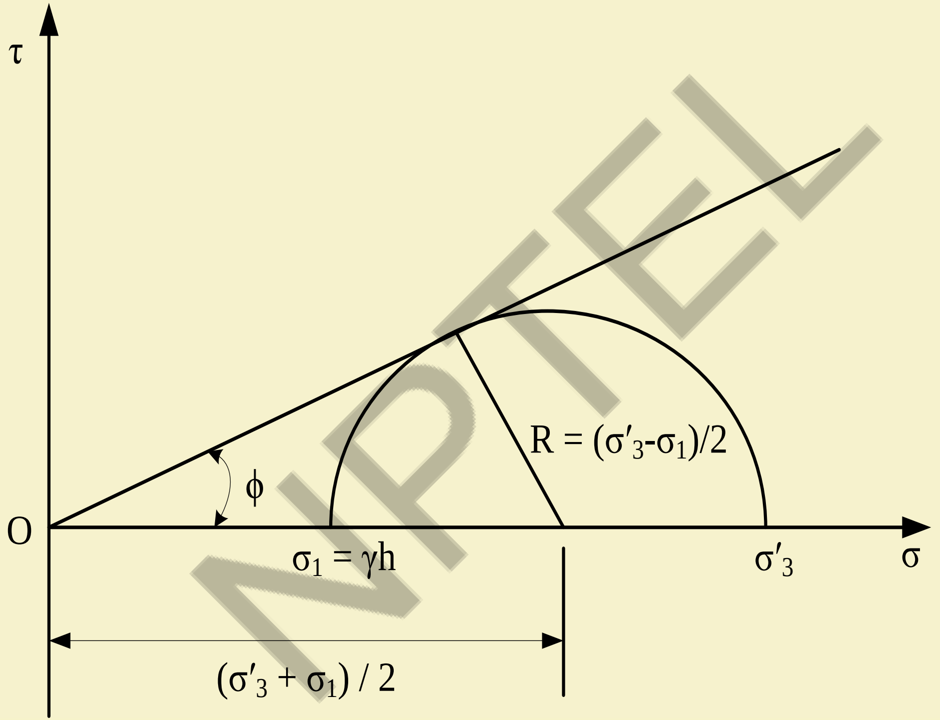
EARTH PRESSURE



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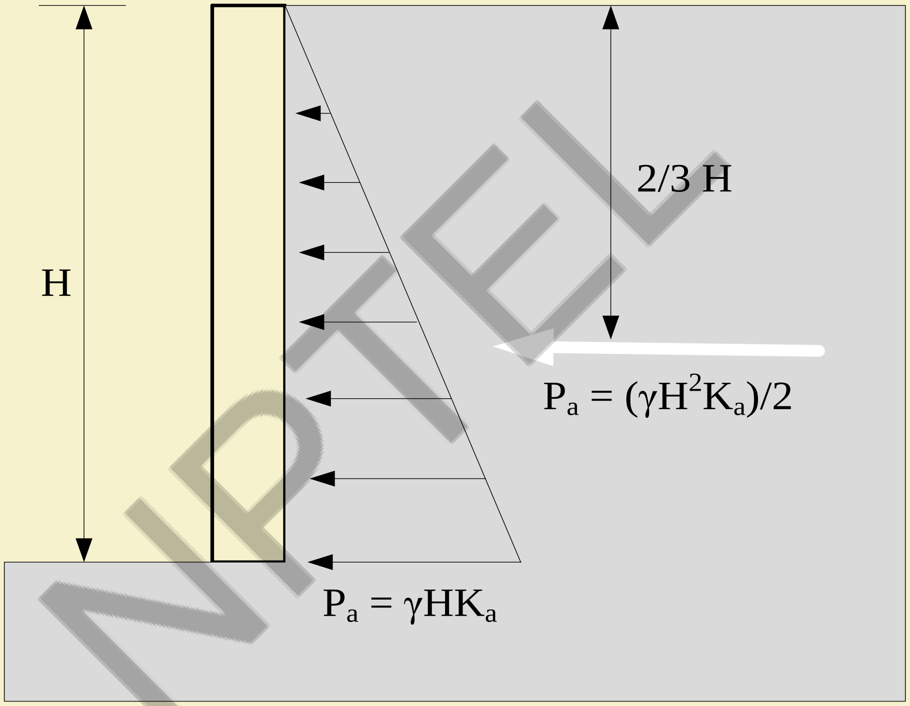
$$\sin\phi = \frac{(\sigma_3' - \sigma_1)/2}{\frac{(\sigma_3' + \sigma_1)}{2}} = \frac{\sigma_3' - \sigma_1}{\sigma_3' + \sigma_1}$$

$$\sigma_3' = \sigma_1 \frac{1 + \sin\phi}{1 - \sin\phi} = \gamma h \frac{1 + \sin\phi}{1 - \sin\phi}$$

$$\sigma_3' = \gamma h \tan^2\left(45 + \frac{\phi}{2}\right)$$

EARTH PRESSURE



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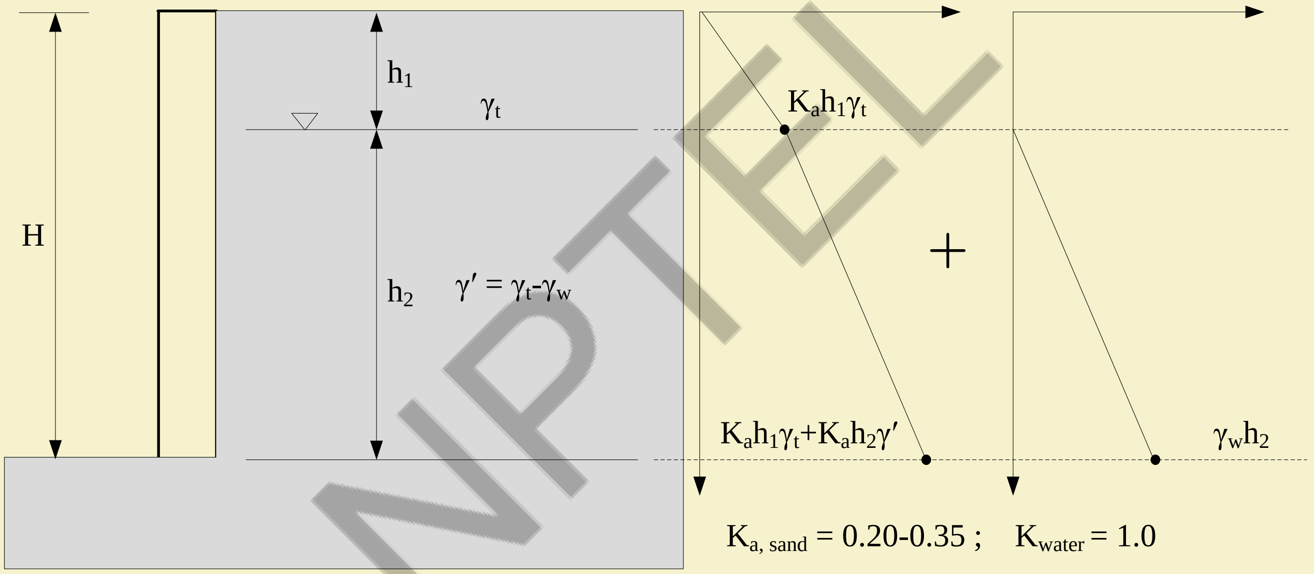

$K_{a,\ sand} = 0.20\text{-}0.35$; $K_{water} = 1.0$

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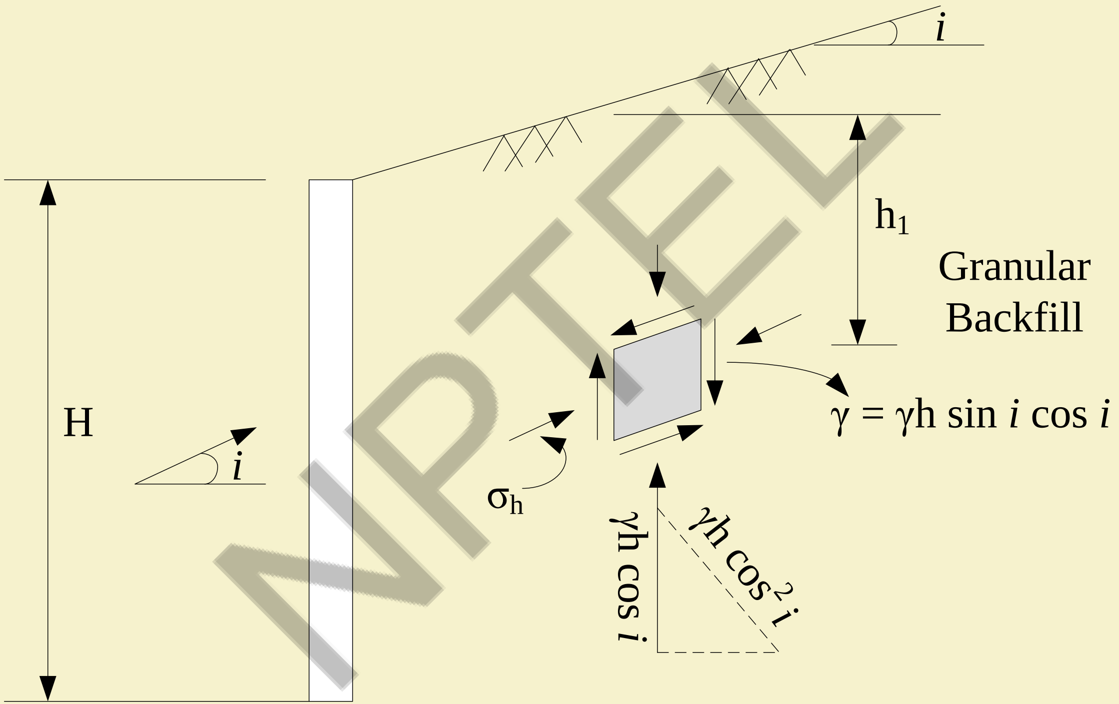
Cohesionless back fill and inclined surface: Let us consider a cohesionless mass with a sloping surface behind the smooth vertical retaining wall. The lateral stress acting on the vertical faces of the element are parallel to the inclined surface. Thus any such planes experience not only normal but also shear stresses. Needless to say, they are no longer principal planes as was the case for horizontal surfaces.

The corresponding resultant pressure on the wall could be determined with the aid of Mohr's circle. The magnitude of the vertical stress is depicted by the distance OC, the lateral stress, acting parallel to the sloped surface is represented by the distance OA. Hence σh = OA

EARTH PRESSURE



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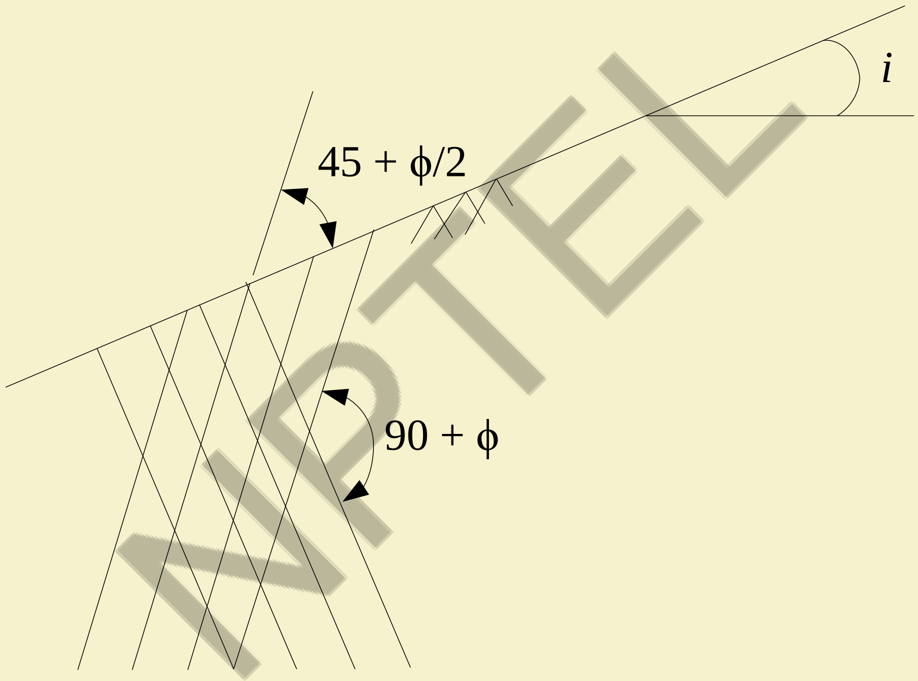

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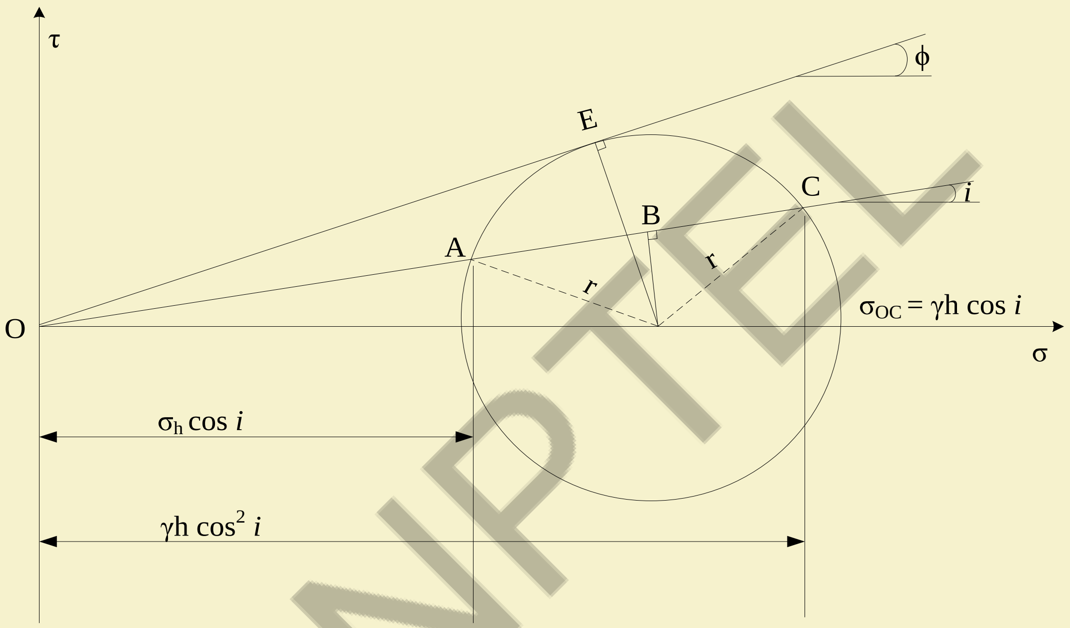

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EARTH PRESSURE

$$OA = \frac{(OB - OA)}{(OB + AB)} OC = \frac{(OB - AB)}{(OB + AB)} \gamma h cos i$$

$$OB = OD cos i$$

$$r = OD \sin\emptyset$$

$$BD = OD \sin i$$

$$AB = \sqrt{(r^2 - BD^2)} = \sqrt{(OD \sin\emptyset)^2 - (OD \sin i)^2}$$

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EARTH PRESSURE

$$OA = \left(\frac{\text{OD}\cos i - OD\sqrt{\sin^2\emptyset - \sin^2 i}}{OD\ \cos + OD\sqrt{\sin^2\emptyset - \sin^2 i}}\right)\gamma h\cos i$$

$$OA = \left(\frac{\cos i - \sqrt{\cos^2 i - \cos^2\emptyset}}{\cos i + \sqrt{\cos^2 i - \cos^2\emptyset}}\right)\gamma h\cos i$$

$$\sigma_h = OA = \gamma h k_a$$

$$P_a = \frac{1}{2}\gamma h^2 k_a = \frac{1}{2}\gamma h^2\left(\frac{\cos i - \sqrt{\cos^2 i - \cos^2\emptyset}}{\cos i + \sqrt{\cos^2 i - \cos^2\emptyset}}\right)\cos i \quad k_a = \left(\frac{\cos i - \sqrt{\cos^2 i - \cos^2\emptyset}}{\cos i + \sqrt{\cos^2 i - \cos^2\emptyset}}\right)\cos i$$

EARTH PRESSURE

$$P_p = \frac{1}{2}\gamma h^2 k_p = \frac{1}{2}\gamma h^2 \left(\frac{cosi + \sqrt{cos^2 i - cos^2 \emptyset}}{Cosi - \sqrt{cos^2 i - cos^2 \emptyset}}\right) cosi$$

$$k_p = \left(\frac{cosi + \sqrt{cos^2 i - cos^2 \emptyset}}{cosi - \sqrt{cos^2 i - cos^2 \emptyset}}\right)$$

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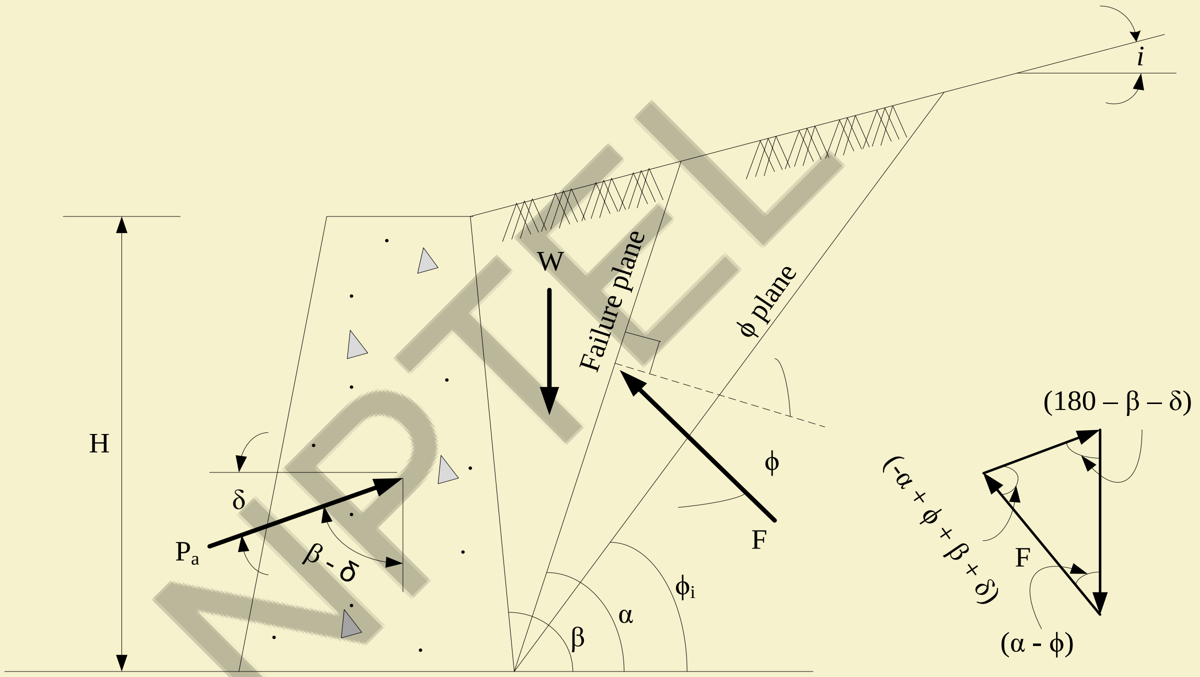

EARTH PRESSURE

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

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

TOPIC NAME

Thank You!!