4. Lateral Earth Pressure and Retaining Walls

1) General

- Influence factors
  (a)
  (b)
  (c)
  (d)

- Lateral Earth Pressures can be divided into
  1)
  2)
  3)
  depending on wall movements (or deformation modes of soil elements).

2) Lateral Earth Pressure

i) <u>Lateral earth pressure at rest</u>

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-

$$\sigma_h^{'} = K_O \sigma_V^{'}$$

• Jaky,

$K_O = 1 - \sin\phi'$ for loose sand or NC clays.

• Brooker and Ireland,

$$K_O = 0.40 + 0.007(PI) \quad (0 \le PI \le 40)$$
$$K_O = 0.64 + 0.001(PI) \quad (40 \le PI \le 80)$$

- For OC soils,

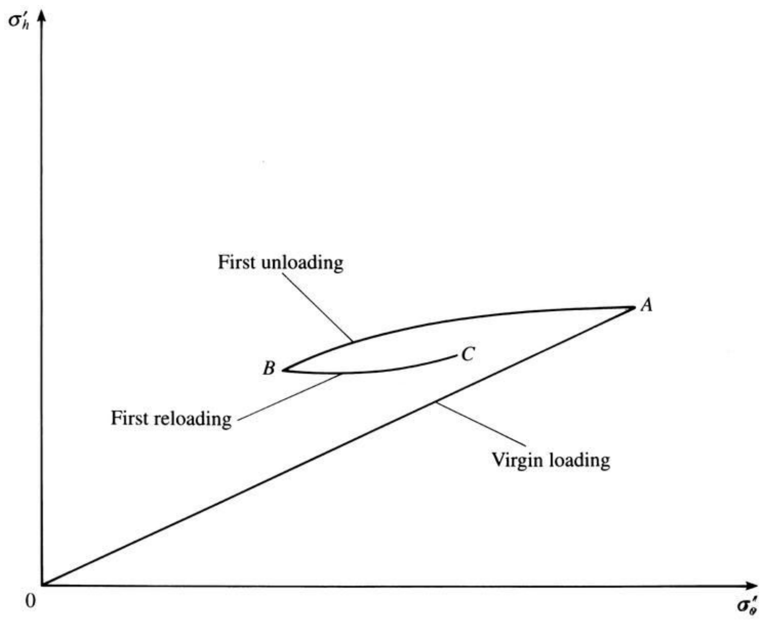


Fig. Stress history for soil under K_0 condition

$$K_0 = K_{O-nc}(\mathrm{OCR})^{\mathrm{h}}$$
$$= (1 - \sin\phi')(\mathrm{OCR})^{\mathrm{h}}$$

h = 0.4 - 0.5 (Alpan, 1967; Schmertmann, 1975)

or

$K_O = (1 - \sin\phi')(OCR)^{\sin\phi'}$ by Mayne & Kulhawy (1982)

- For dense sands,

$$K_O = (1 - \sin\phi') + (\gamma_d / \gamma_{d(\min)} - 1) \times 5.5$$

by Sherif and et al (1984)

ii) Active and passive pressures

* Rankine Approach
* Coulomb Approach

a) Rankine

- **Assumptions**

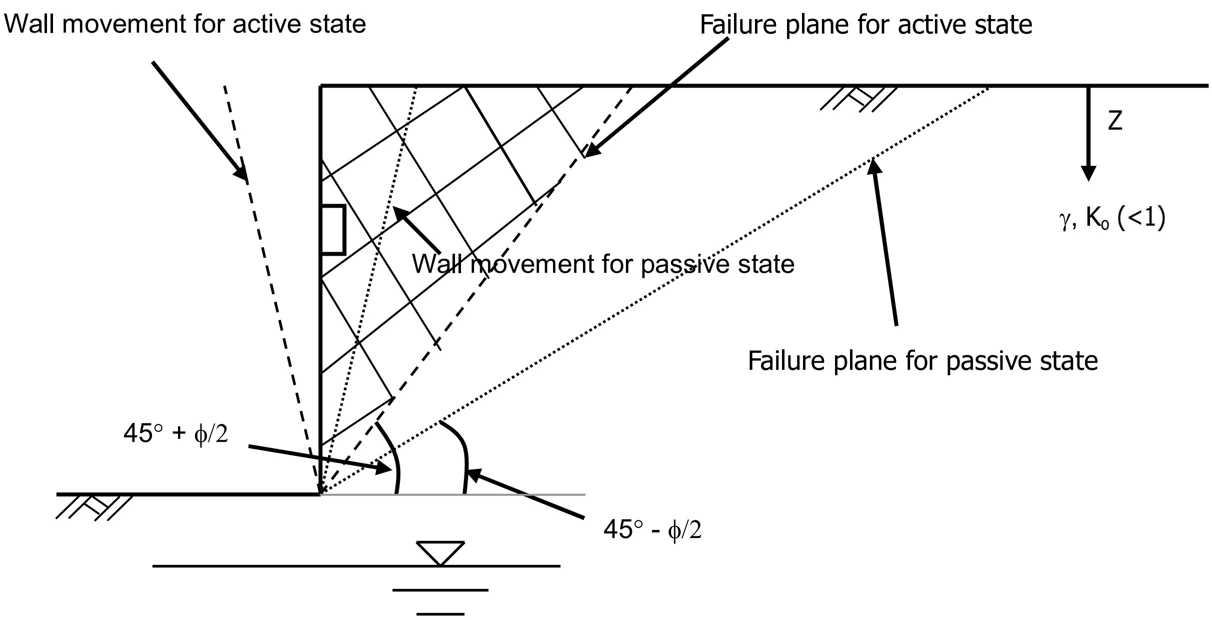
(i)

(ii)

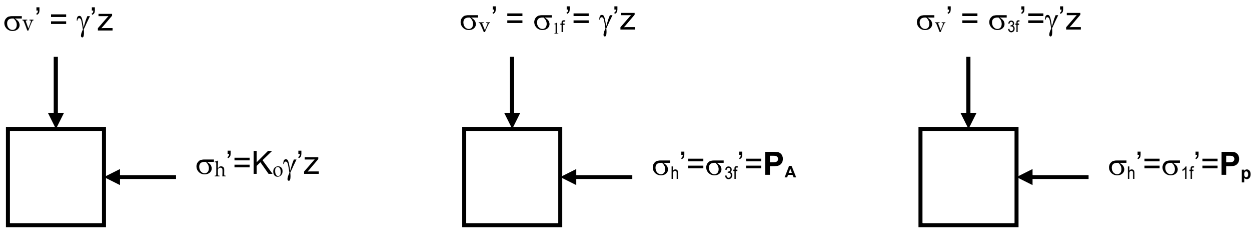
(iii)

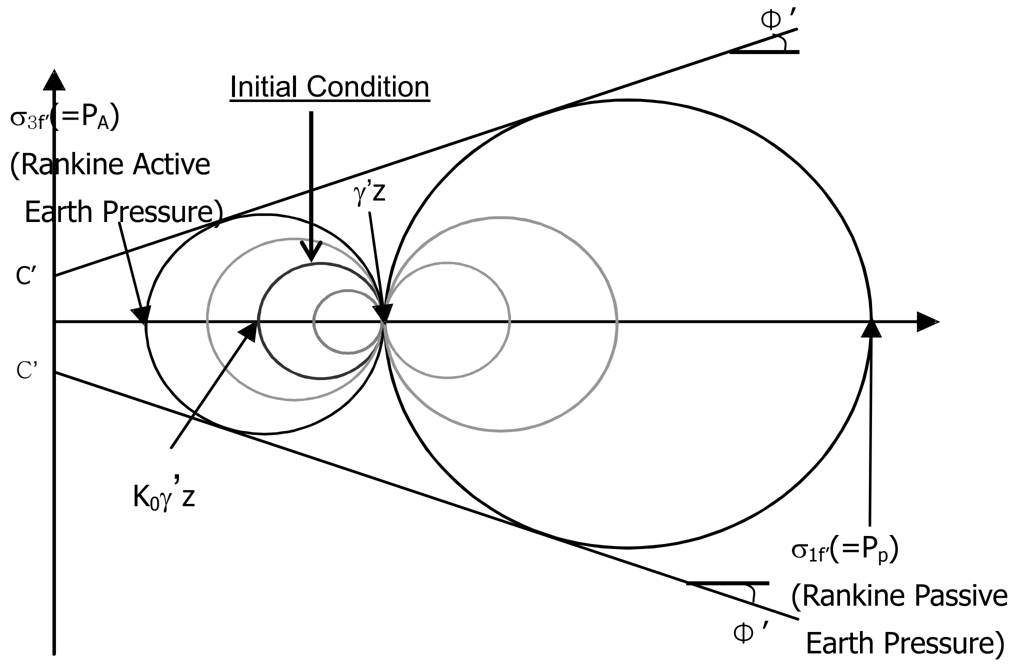
(iv)

(v)



Initial condition | Final condition (Active state) | Final condition (Passive state)





- Rankine's Active Earth Pressure

  $P_A = \gamma' z \tan^2(45-\phi'/2) - 2c'\tan(45-\phi'/2)$

  $= \gamma' z K_a - 2c\sqrt{K_a}$

- Rankine's Passive Earth Pressure

  $P_P = \gamma' z \tan^2(45+\phi'/2) + 2c'\tan(45+\phi'/2)$

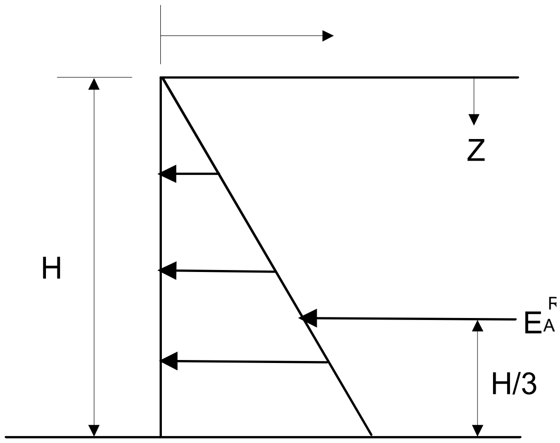
  $= \gamma' z K_p + 2c\sqrt{K_p}$

- **Some Theoretical Earth Pressure Distributions**

(1) ϕ', c=0

Sands

$P_A = \gamma' z \tan^2(45-\phi/2)$



Ex) $\phi = 30^o$

$K_A^R = \tan^2 30 = 0.33$

$P_A = 0.33\gamma z$

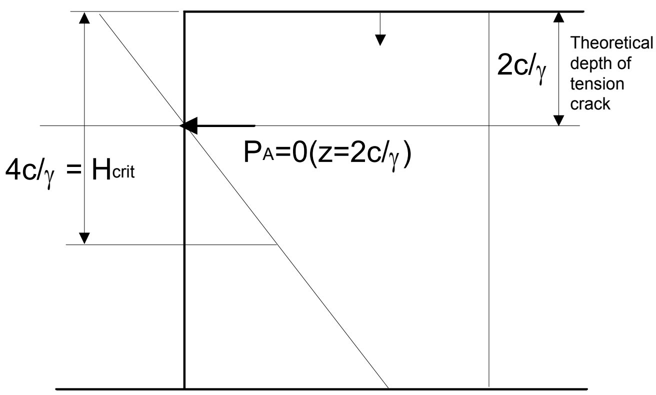
If $\gamma = 1.8 t/m^3$, $P_A = 0.594z$ → Earth Pressure

$P_w = \gamma_w z = z$ → Water pressure,

$P_A << P_w$ → Water loads are very important.

(2) c, ϕ=0

Undrained loading
(short term)
for saturated clay



$P_A = \gamma z - 2c$

$E_A^R = 1/2\gamma H^2 - 2cH$

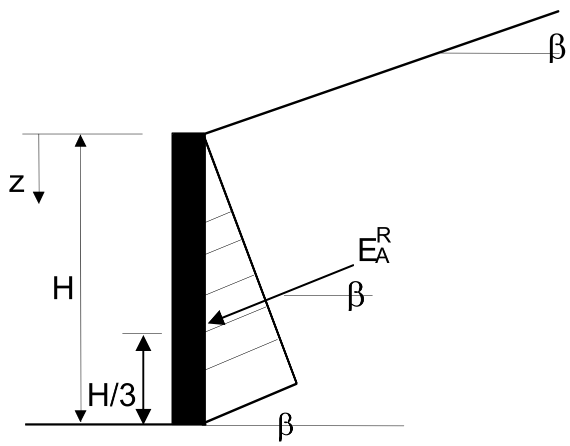
H_{crit} = Theoretical max. height of unsupported cut in clay

- **Rankine Active and Passive Earth Pressure For Inclined Granular backfill**

  - Based on assumption that the resultant force, E_A^R, is parallel to slope of backfill, Rankine's active pressure and resultant force can be obtained as below

    $P_A = \gamma H K_A^R$, $E_A^R = 1/2\gamma H^2 K_A^R$

    where $K_A^R = \cos\beta \dfrac{\cos\beta - \sqrt{\cos^2\beta - \cos^2\phi}}{\cos\beta + \sqrt{\cos^2\beta - \cos^2\phi}}$



Similarly, Rankine's passive pressure,

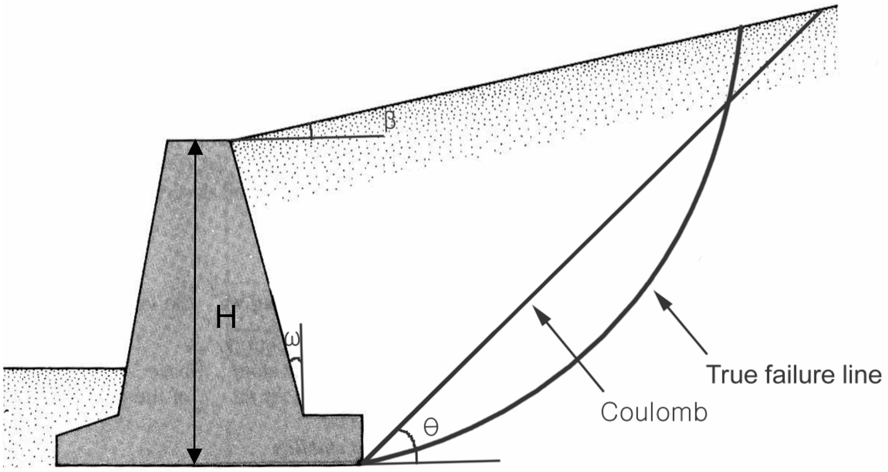
$P_P = \gamma H K_P^R$, $E_P^R = 1/2\gamma H^2 K_P^R$

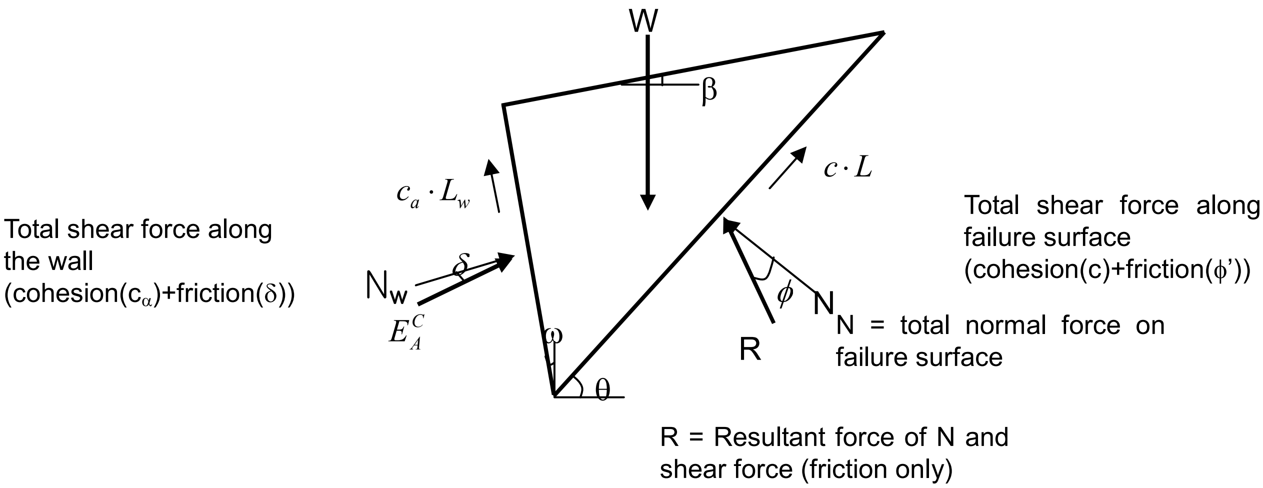
where

$$K_P^R = \cos\beta \frac{\cos\beta + \sqrt{\cos^2\beta - \cos^2\phi}}{\cos\beta - \sqrt{\cos^2\beta - \cos^2\phi}}$$

b) <u>Coulomb</u>

- Uses a straight line to approximate failure surface





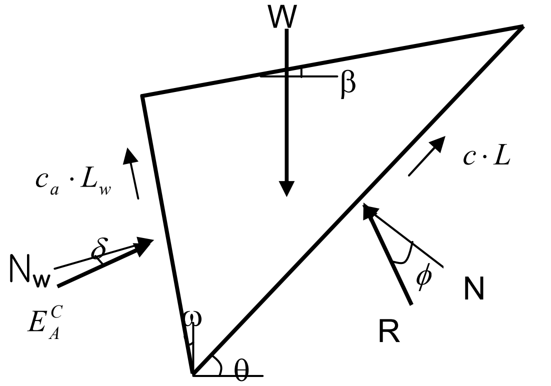
- E_A^C is a function of (a) geometry of wedge (H, β, ω, θ) and (b) soil properties (c, φ', δ, c_α, γ)

  • Known : a)
  b)

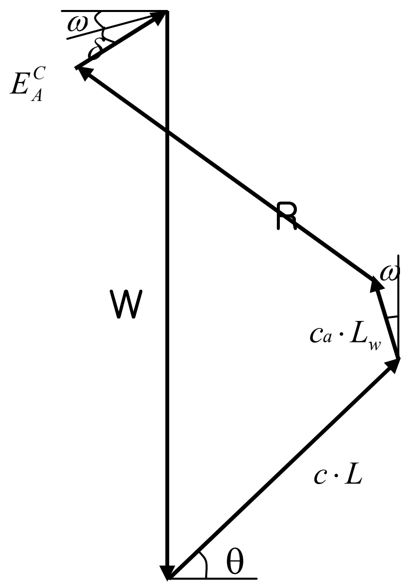
  c)

  • Unknown :

- **Trial Wedge Procedure (c, ϕ' soil)**

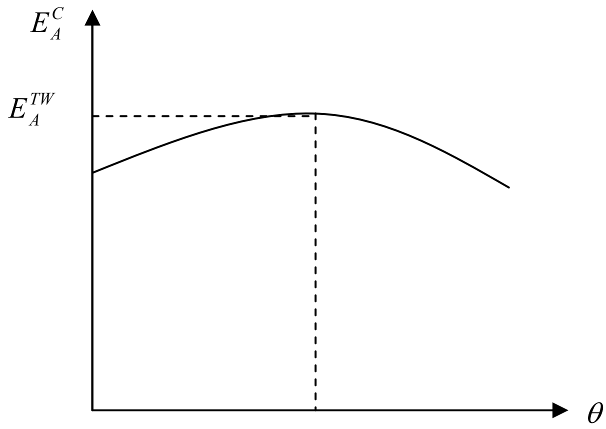


(i) Assume θ
(ii) Calculate E_A^C from vector addition



- Note : Wall friction reduces load against wall.

(iii) Assume additional values of θ, calculate E_A^C(θ) and pick max. value. This max. value is active earth pressure resultant.



*** Analytical Solution for Coulomb's Method (c=0, φ soils)**

- Active earth pressure resultant

$$E_A^C = 1/2\gamma H^2 K_A^C$$

where

$$K_A^C = \frac{\cos^2(\phi-\omega)}{\cos^2\omega\cos(\delta+\omega)\left\{1+\sqrt{\dfrac{\sin(\phi+\delta)\sin(\phi-\beta)}{\cos(\delta+\omega)\cos(\omega-\beta)}}\right\}^2}$$

- Passive earth pressure resultant

$$E_P^C = 1/2\gamma H^2 K_P^C$$

where

$$K_P^C = \frac{\cos^2(\phi+\omega)}{\cos^2\omega\cos(\delta-\omega)\left\{1-\sqrt{\dfrac{\sin(\phi+\delta)\sin(\phi+\beta)}{\cos(\delta+\omega)\cos(\omega-\beta)}}\right\}^2}$$

and for δ=0

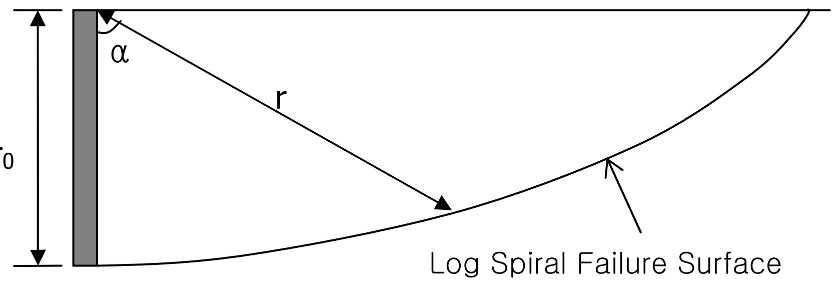
$$K_P^C = \frac{\cos^2(\phi+\omega)}{\cos^2\omega\cos\omega\left\{1-\sqrt{\dfrac{\sin\phi\sin(\phi+\beta)}{\cos\omega\cos(\omega-\beta)}}\right\}^2}$$

- **Notes for Planar Failure Plane of Coulomb's Method**

(1)

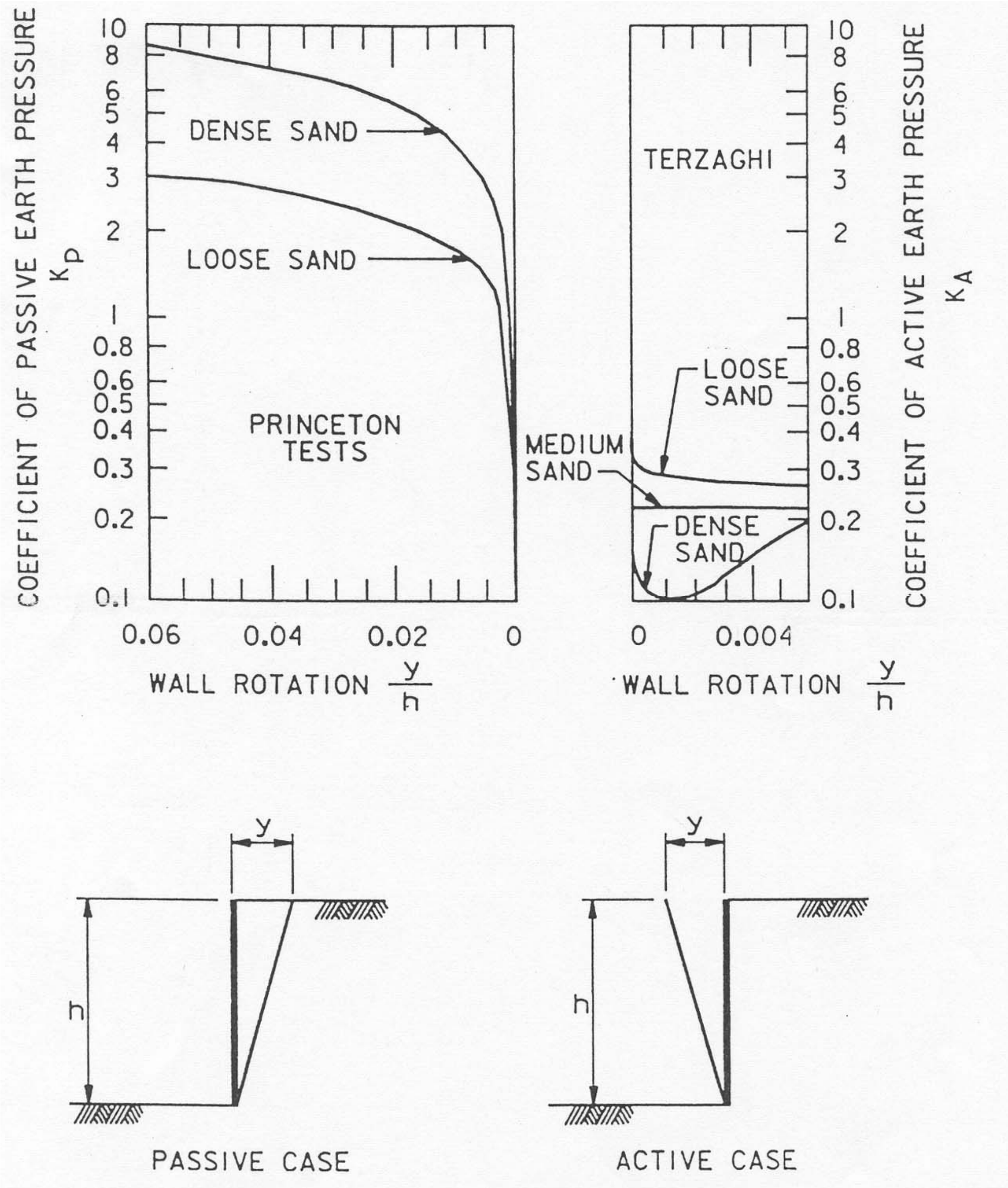
(2)

(3)



$$r = r_0 e^{\alpha \tan\phi}$$

3) Movements to mobilize limit state (i.e. active or passive failure state)



US army corps No.4, Fig 3-2.

Relationship of Earth Pressures to Wall Movements

(after Department of the Navy 1982)

Wall Movements (Rotations) to reach the limit state(y/H)

	DM7		USAC		Das		Coduto	
	A	P	A	P	A	P	A	P
Dense Cohesionless	.0005	.002	.0001	.02	.0005		.001	.02
Loose Cohesionless	.002	.006	.0003	.02	.001	.01	.004	.06
Stiff Cohesive	.01	.002			.01		.01	.02
Soft Cohesive	.02	.04			.04	.05	.02	.04

Movements

passive state > active state

clay > sand

loose or soft > dense or stiff