PBW 620 Advanced Soil Mechanics
PBW 584 Applied Soil Mechanics

Public Works Department

MSc. Degree

Spring Semester

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Faculty of Engineering- Cairo University

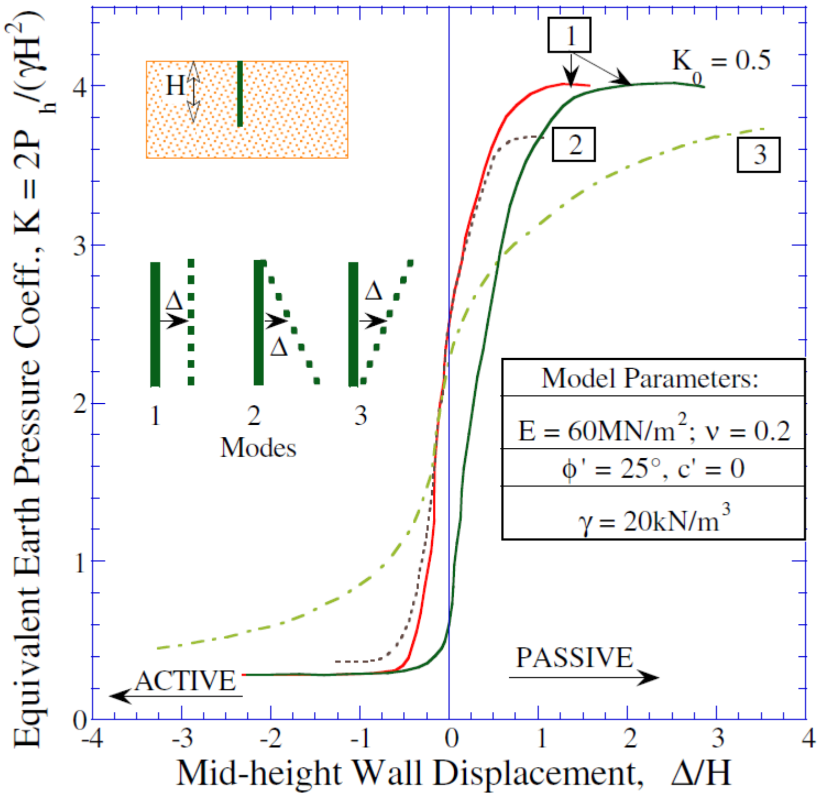
Lecture Four

SPECIAL CONDITIONS IN EARTH PRESSURE CALCULATIONS-PART I

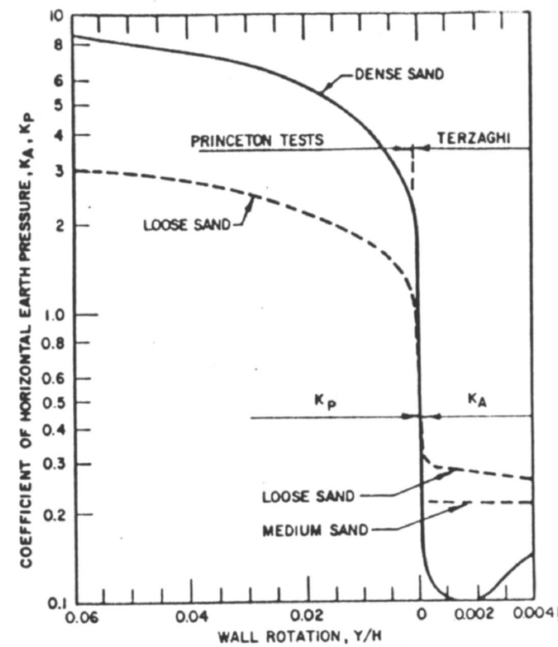
Lecture Outline

- Rigid Body Motion of Walls
- Effect of Arching
- Dealing With Surface Loads
- Narrow Backfill

Early Experiments on Earth Pressure



Potts (1992):



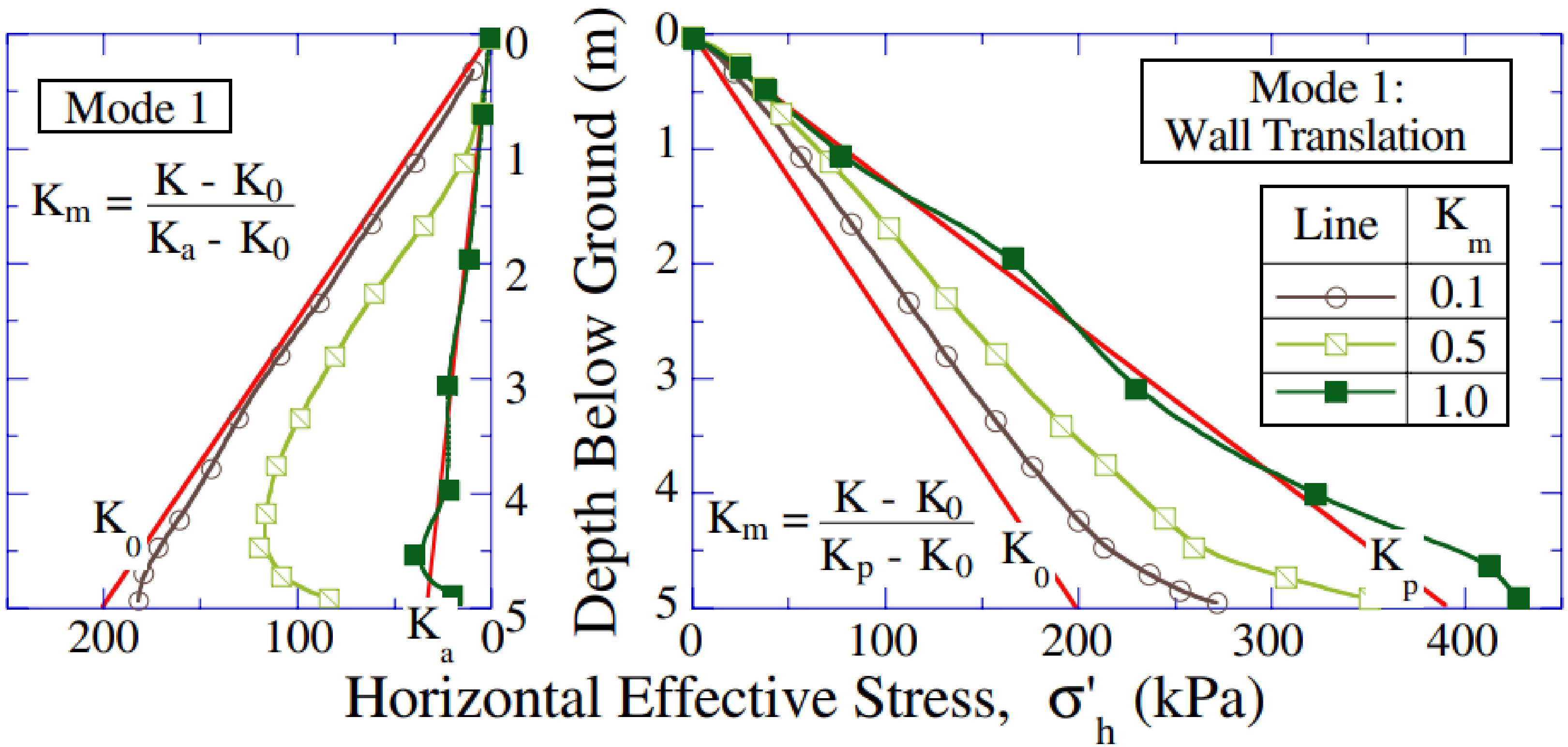
(Terzaghi & Tshebatarioff, 1940's)

$ECP202$

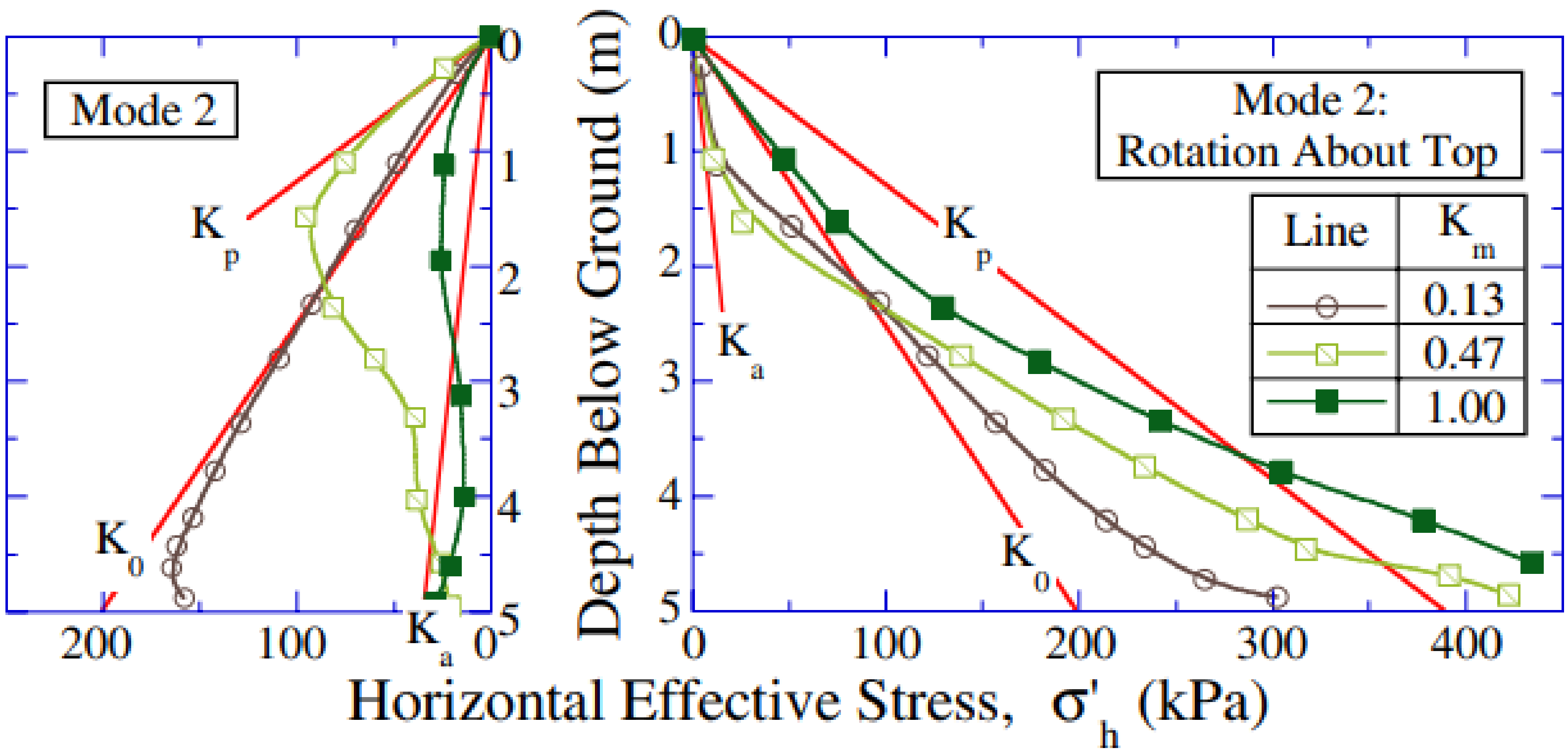
$$\mathbf{k_o = 1 - \sin \phi}$$

$$\mathbf{k_o = 0.19 + 0.233 \log PI}$$

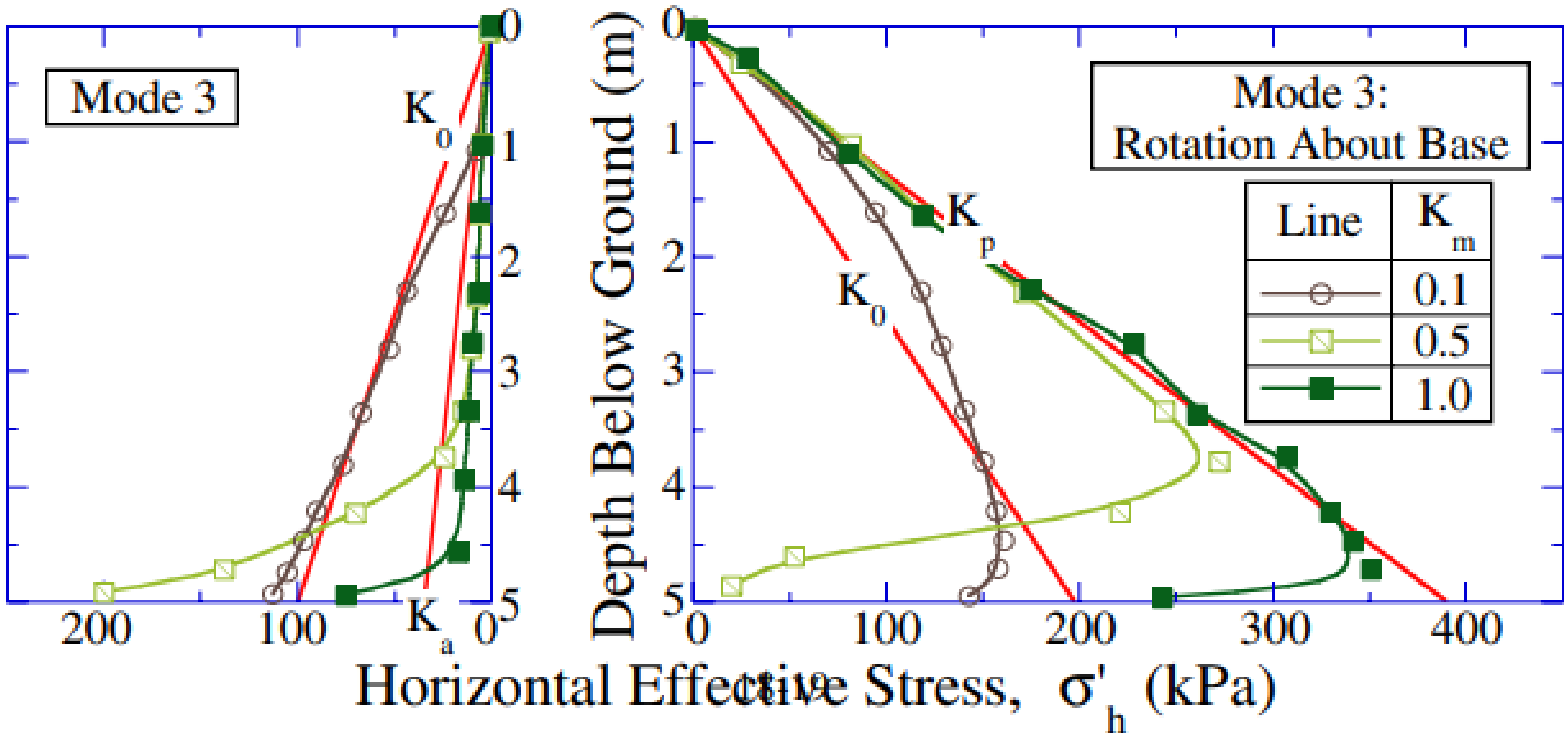
Intermediate Cases



Intermediate Cases



Intermediate Cases



Allowable Movements (AASHTO)

Δ = movement of top of wall required to reach minimum active or maximum passive pressure by tilting or lateral translation (ft)

H = height of wall (ft)

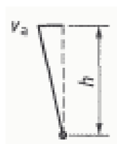
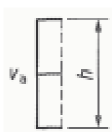
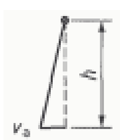
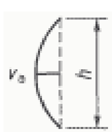
Table C3.11.1-1—Approximate Values of Relative Movements Required to Reach Active or Passive Earth Pressure Conditions (Clough and Duncan, 1991)

Type of Backfill	Values of Δ/H	
	Active	Passive
Dense sand	0.001	0.01
Medium dense sand	0.002	0.02
Loose sand	0.004	0.04
Compacted silt	0.002	0.02
Compacted lean clay	0.010	0.05
Compacted fat clay	0.010	0.05

$Translated\ into\ ECP202$

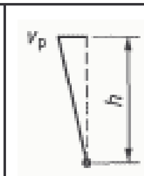
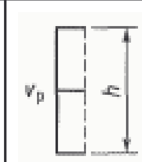
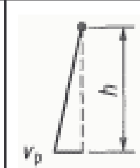
Allowable Movements (BS EN 1997)

Table C.1 — Ratios v_a/h

Kind of wall movement		v_a/h loose soil %	v_a/h dense soil %
a)		0,4 to 0,5	0,1 to 0,2
b)		0,2	0,05 to 0,1
c)		0,8 to 1,0	0,2 to 0,5
d)		0,4 to 0,5	0,1 to 0,2

where:
v_a is the wall motion to mobilise active earth pressure
h is the height of the wall

Table C.2 — Ratios v_p/h

Kind of wall movement		v_p/h loose soil %	v_p/h dense soil %
a)		7 (1,5) to 25 (4,0)	5 (1,1) to 10 (2,0)
b)		5 (0,9) to 10 (1,5)	3 (0,5) to 6 (1,0)
c)		6 (1,0) to 15 (1,5)	5 (0,5) to 6 (1,3)

where:
v_p is the wall motion to mobilise passive earth pressure
h is the height of the wall

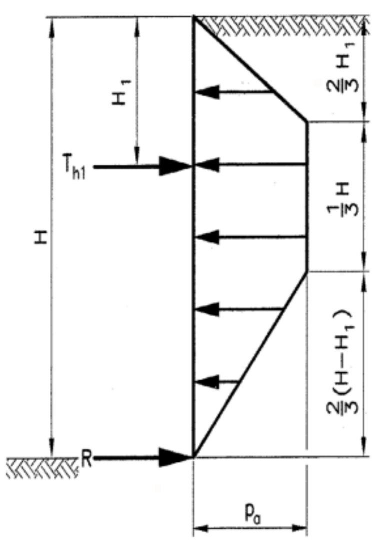
Braced Excavation (Flexible Walls)

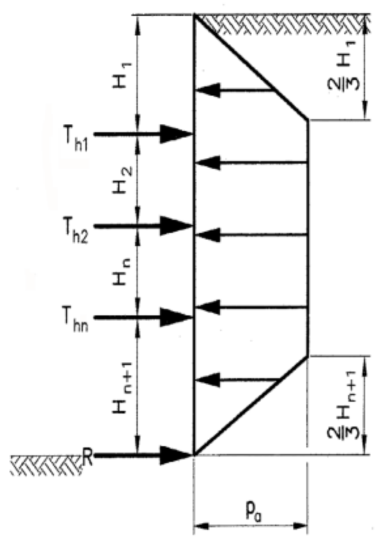
For walls with one anchor level:

$$p_a = k_a \gamma'_s H \qquad (3.11.5.7.1\text{-}1)$$

For walls with multiple anchor levels:

$$p_a = \frac{k_a \gamma'_s H^2}{1.5H - 0.5H_1 - 0.5H_{n+1}} \qquad (3.11.5.7.1\text{-}2)$$





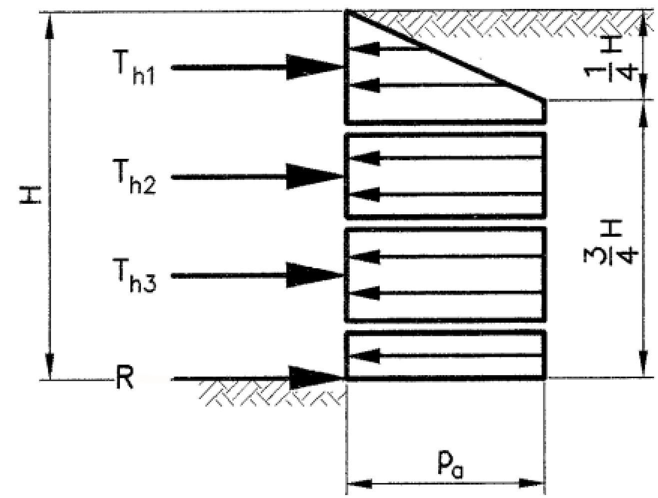


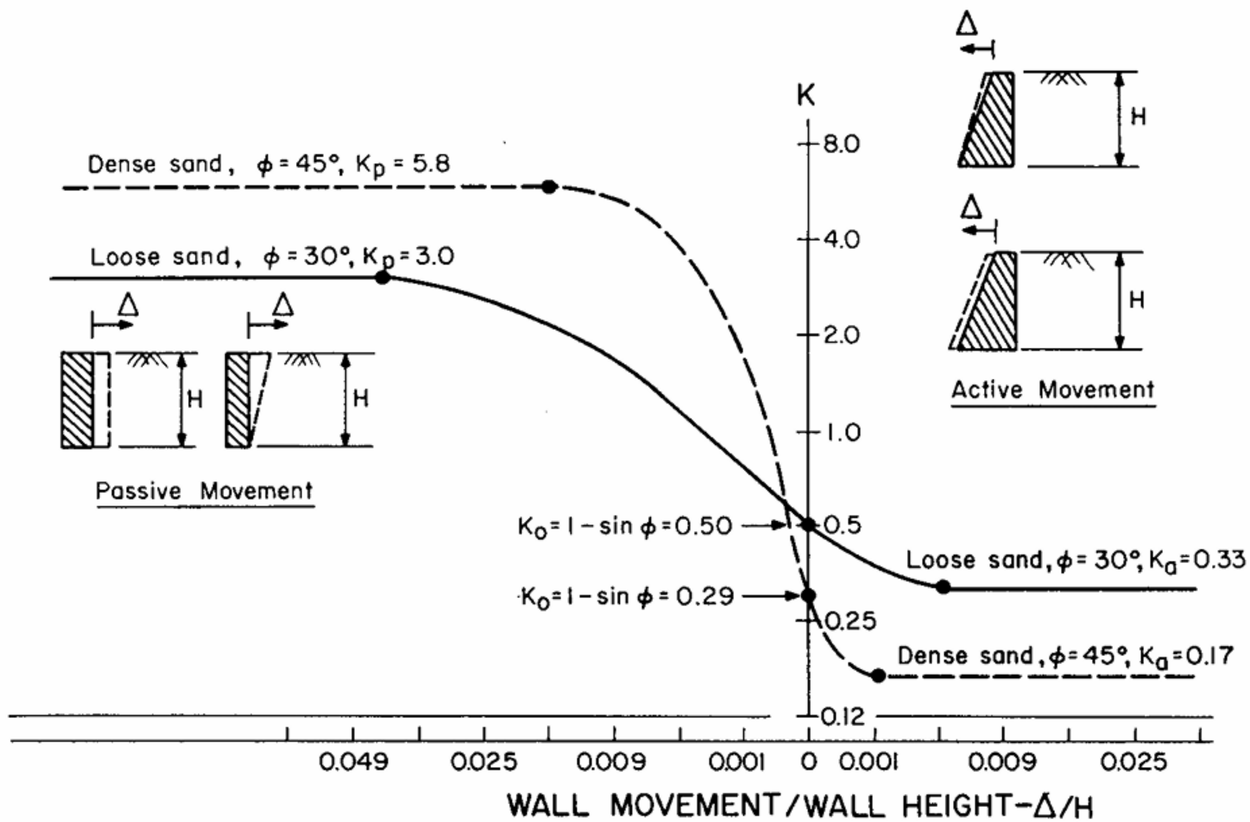
Figure 3.11.5.7.2b-1—Apparent Earth Pressure Distribution for Anchored Walls Constructed from the Top Down in Soft to Medium Stiff Cohesive Soils

$$k_a = 1 - \frac{4S_u}{\gamma_s H} + 2\sqrt{2}\,\frac{d}{H}\left(1 - \frac{5.14 S_{ub}}{\gamma_s H}\right) \geq 0.22 \qquad (3.11.5.7.2b\text{-}2)$$

where:

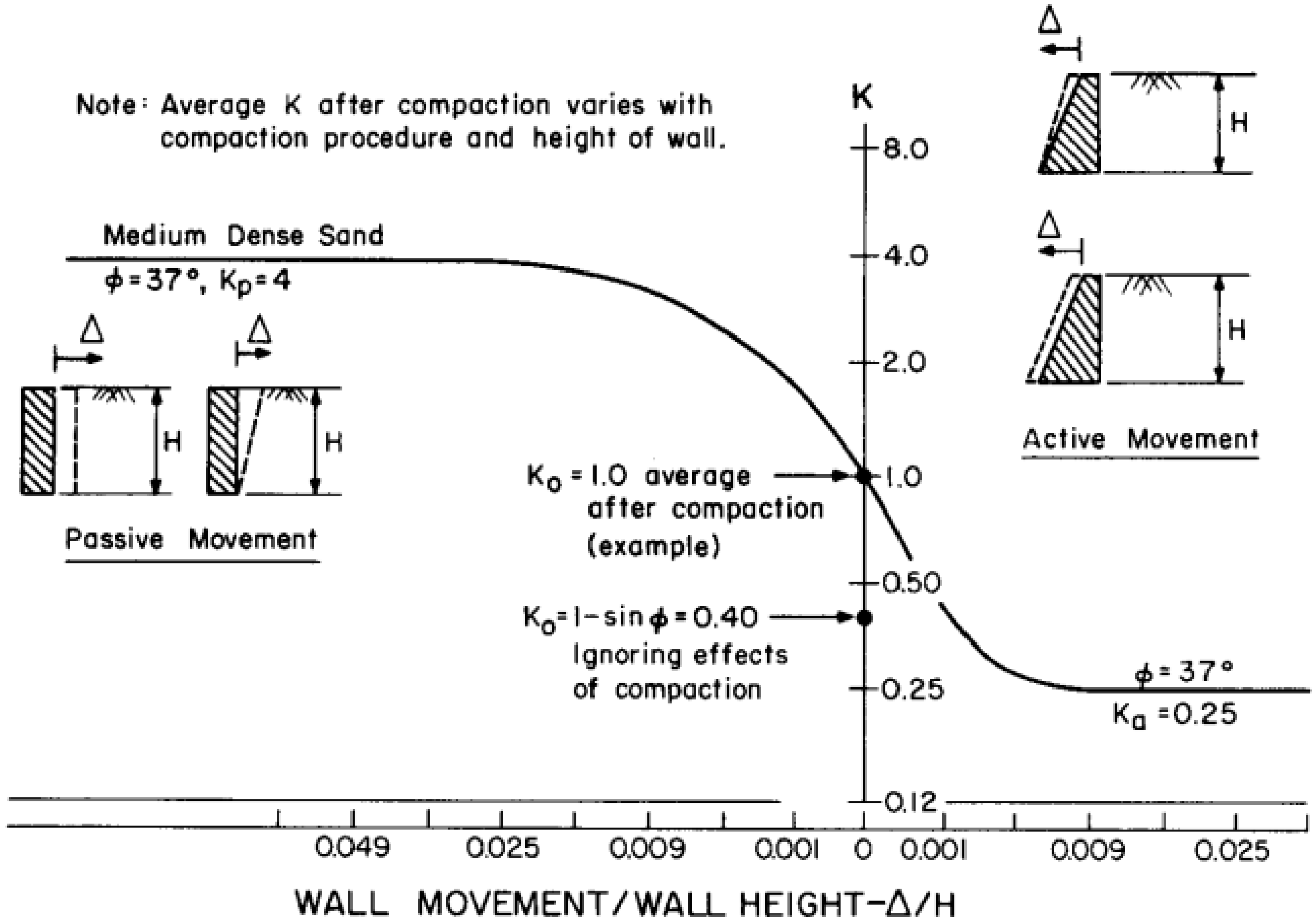
S_u	=	undrained strength of retained soil (ksf)
S_{ub}	=	undrained strength of soil below excavation base (ksf)
γ_s	=	total unit weight of retained soil (kcf)
H	=	total excavation depth (ft)
d	=	depth of potential base failure surface below base of excavation (ft)

Effect of soil density



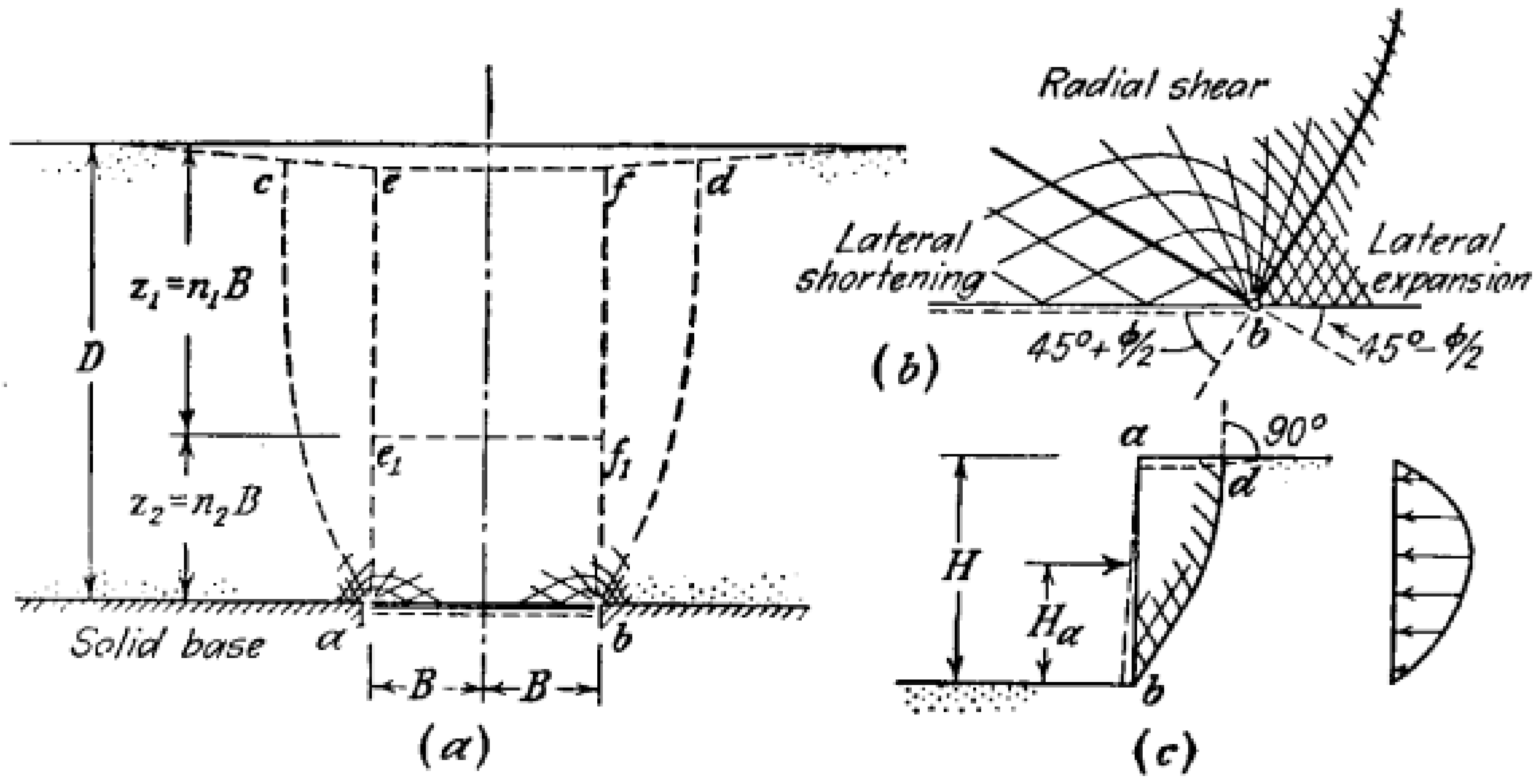
Clough, G. W., & Duncan, J. M. (1991). Earth pressures. *Foundation engineering handbook*, 223-235.

Effect of Compaction



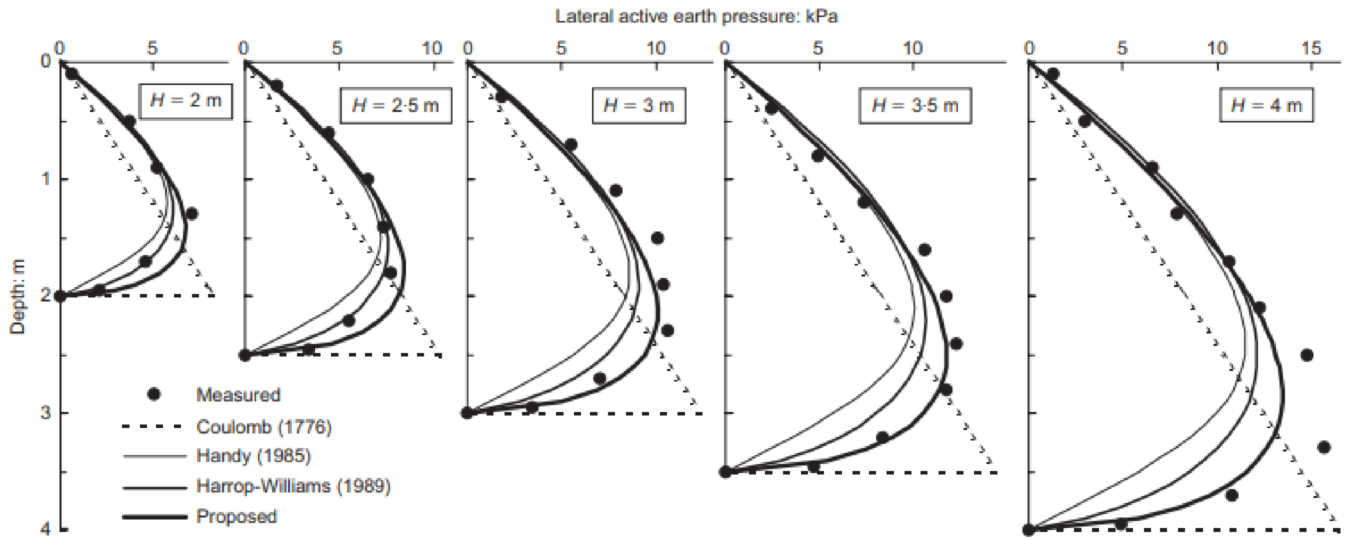
Clough, G. W., & Duncan, J. M. (1991). Earth pressures. *Foundation engineering handbook*, 223-235.

Arching Effects



Karl, Terzaghi. "Theoretical soil mechanics." (1943).

Modified Earth Pressure



$$P_{ah} = \frac{\gamma H^2}{2} \frac{K_{awn}}{1 + K_{awn} \tan\delta \tan\alpha}$$

where N is the ratio of major to minor principal stresses $= \tan^2(45° + \phi/2)$.

$$K_{awn} = \frac{\sigma_{ahw}}{\overline{\sigma}_v} = \frac{3(N\cos^2\theta + \sin^2\theta)}{3N - (N-1)\cos^2\theta}$$

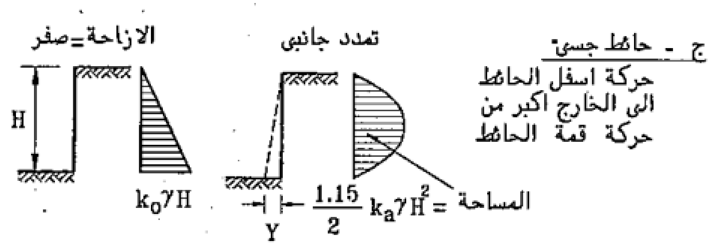
$$\theta = \tan^{-1}\left[\frac{(N-1) \pm \sqrt{(N-1)^2 - 4N\tan^2\delta}}{2\tan\delta}\right]$$

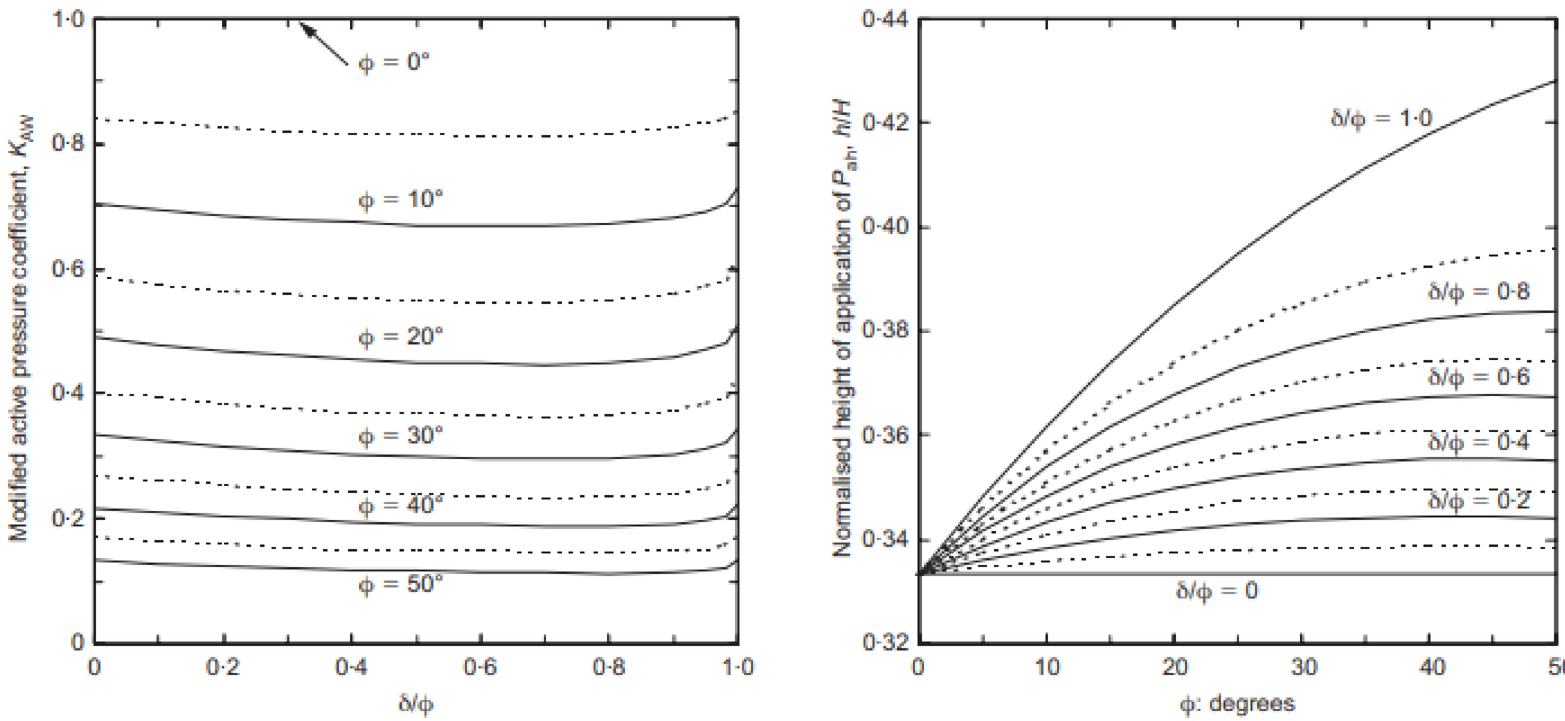
α angle of failure line to horizontal $= 45 + \phi/2$

Paik, K. H., & Salgado, R. (2003). Estimation of active earth pressure against rigid retaining walls considering arching effects. *Geotechnique*, *53*(7), 643-653.

Simplified Method (P&S 2003 vs ECP202)

$$P_{\mathrm{ah}} = \frac{1}{2} K_{\mathrm{AW}} \cdot \gamma \cdot H^2$$

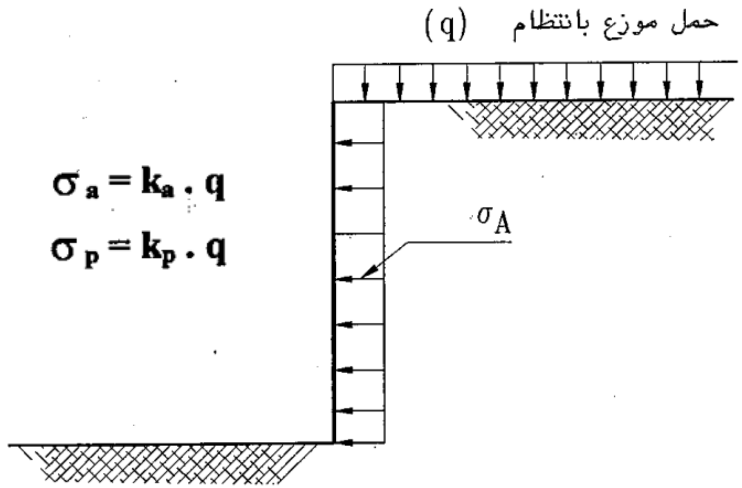




(a)

(b)

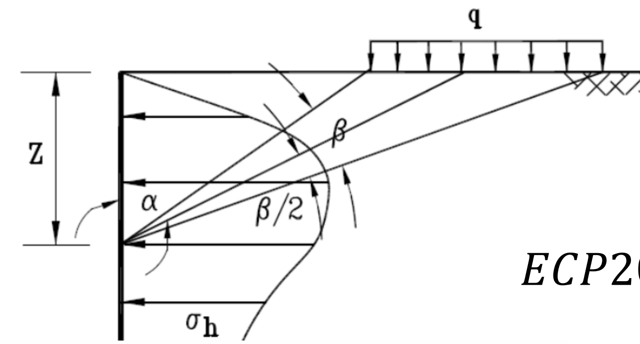
Dealing with Surface Loads



$\sigma_a = k_a \cdot q$

$\sigma_p = k_p \cdot q$

شكل (٧-٩) ضغط جانبى ناتج عن حمل موزع بانتظام



*ECP*202

$$\sigma_h = 2q\,(\beta - \sin\beta \cos 2\alpha\,)\,/\,\pi$$

$$\Delta_{ph} = \frac{2p}{\pi}\,[\delta - \sin\delta\cos(\delta + 2\alpha)] \qquad (3.11.6.2\text{-}1)$$

where:

p = uniform load intensity on strip parallel to wall (ksf)

α = angle specified in Figure 3.11.6.2-1 (rad)

δ = angle specified in Figure 3.11.6.2-1 (rad)

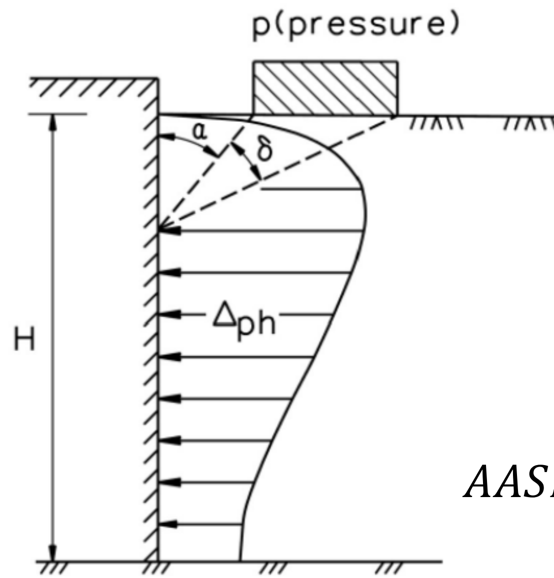
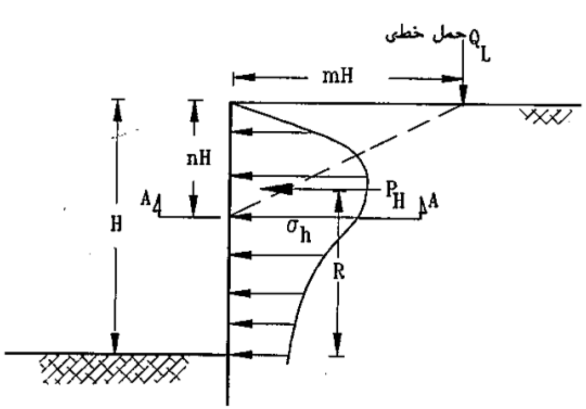


Figure 3.11.6.2-1—Horizontal Pressure on Wall Caused by a Uniformly Loaded Strip

AASHTO 2014

Line Loads

ECP202



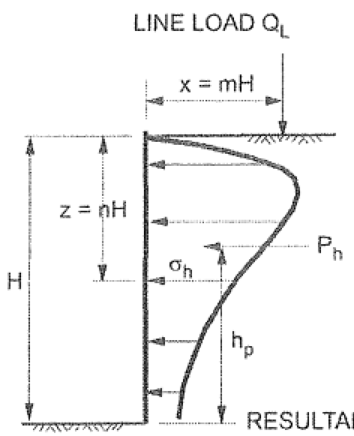
$$\sigma_h = 1.27 \frac{q}{H} \cdot \frac{m^2 . n}{(m^2 + n^2)^2} \qquad m > 0.4$$

$$P_h = 0.64 \ q / (m^2 + 1)$$

$$\sigma_h = 0.203 \frac{q}{H} \cdot \frac{n}{(0.16 + n^2)^2} \qquad m \leq 0.4$$

$$P_h = 0.55 \quad q$$

Canadian Foundation Manual



FOR m ≤ 0.4 :

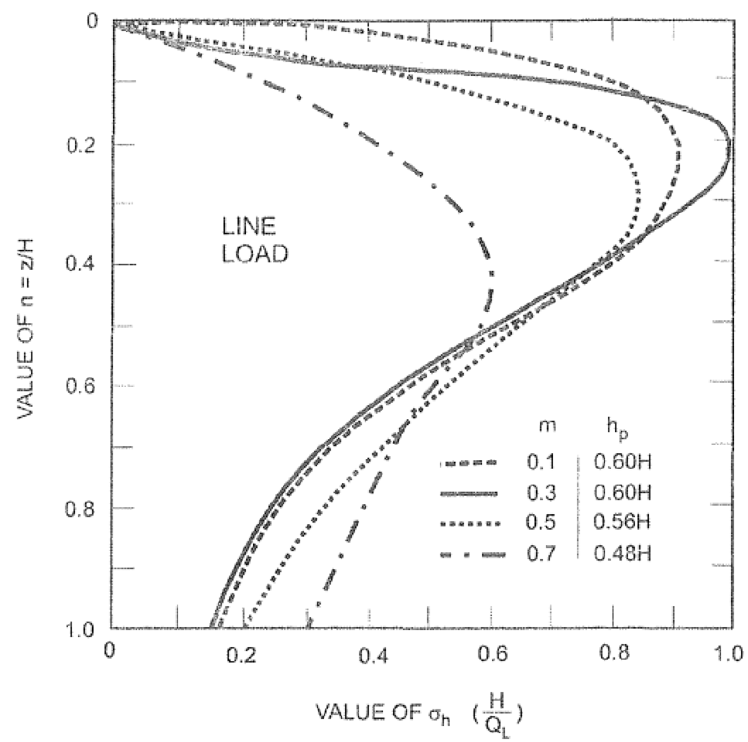
$$\sigma_h \left(\frac{H}{Q_L}\right) = \frac{0.20n}{(0.16 + n^2)^2}$$

$$P_H = 0.55 \ Q_L$$

FOR m > 0.4 :

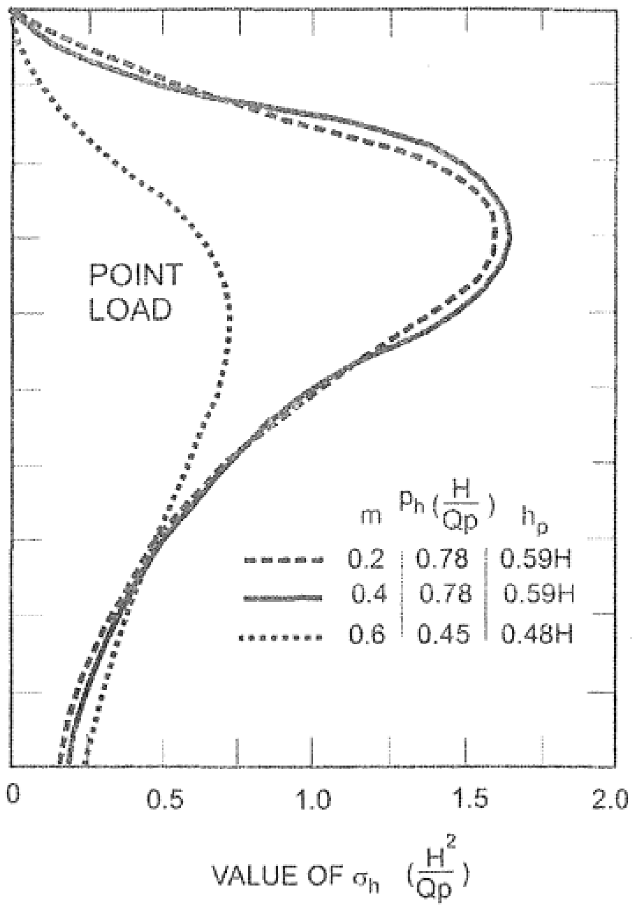
$$\sigma_h \left(\frac{H}{Q_L}\right) = \frac{1.28 \ m^2 n}{(m^2 + n^2)^2}$$

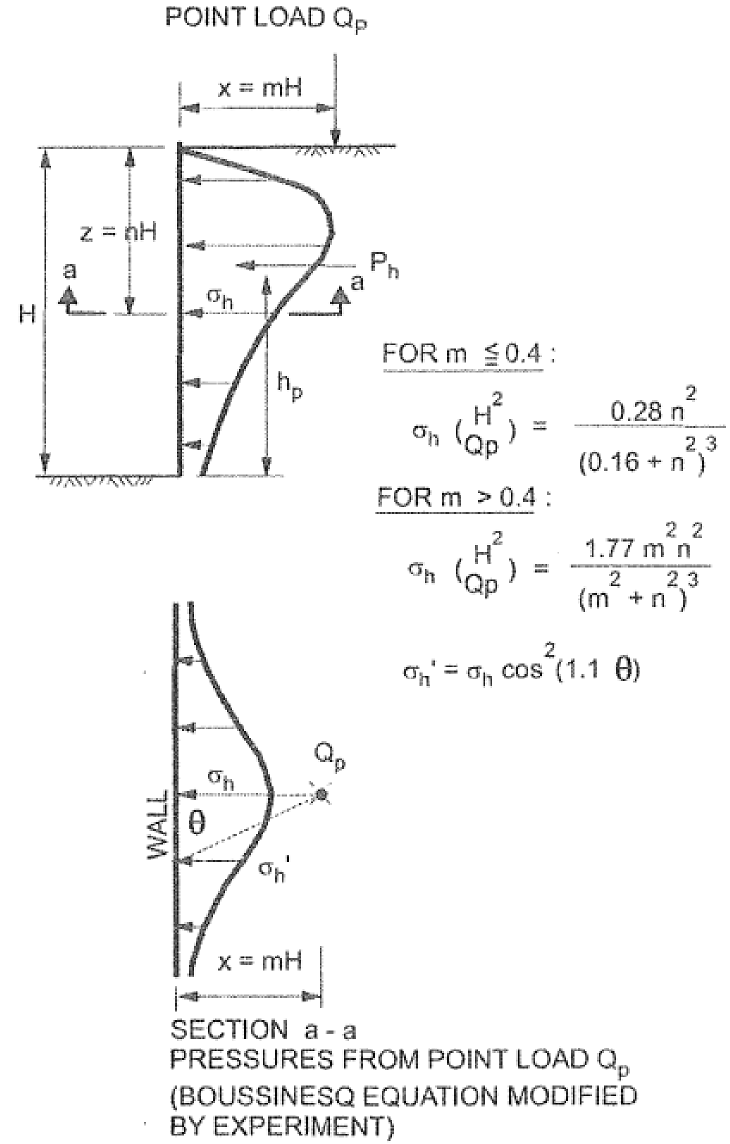
$$\text{RESULTANT } P_h = \frac{0.64 \ Q_L}{(m^2 + 1)}$$



Point Loads

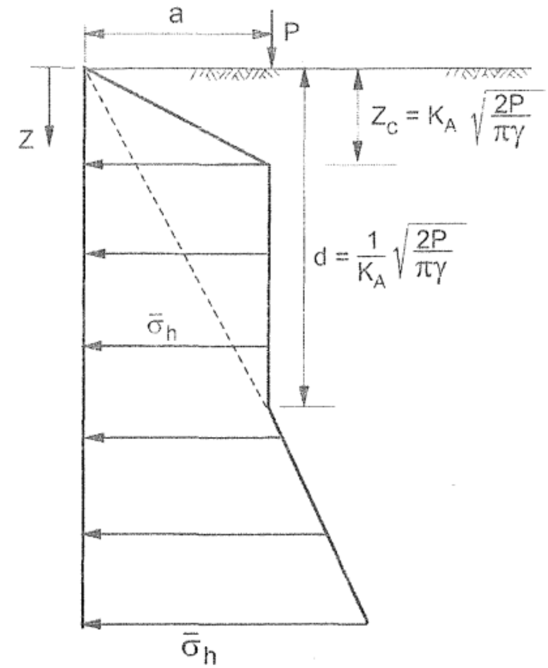
Canadian Foundation Manual





Compaction Induced Earth Pressure

Canadian Foundation Manual



For $Z_c \leq Z \leq d$

$$\bar{\sigma}_h = \sqrt{\frac{2P\gamma}{\pi}}\frac{L}{a+L}$$

For $Z > d$

$$\bar{\sigma} = K_A \gamma z$$

$$P\text{ (roller load)} = \frac{\text{dead weight of roller + centrifugal force}}{\text{weight of roller}}$$

a = distance of roller from wall

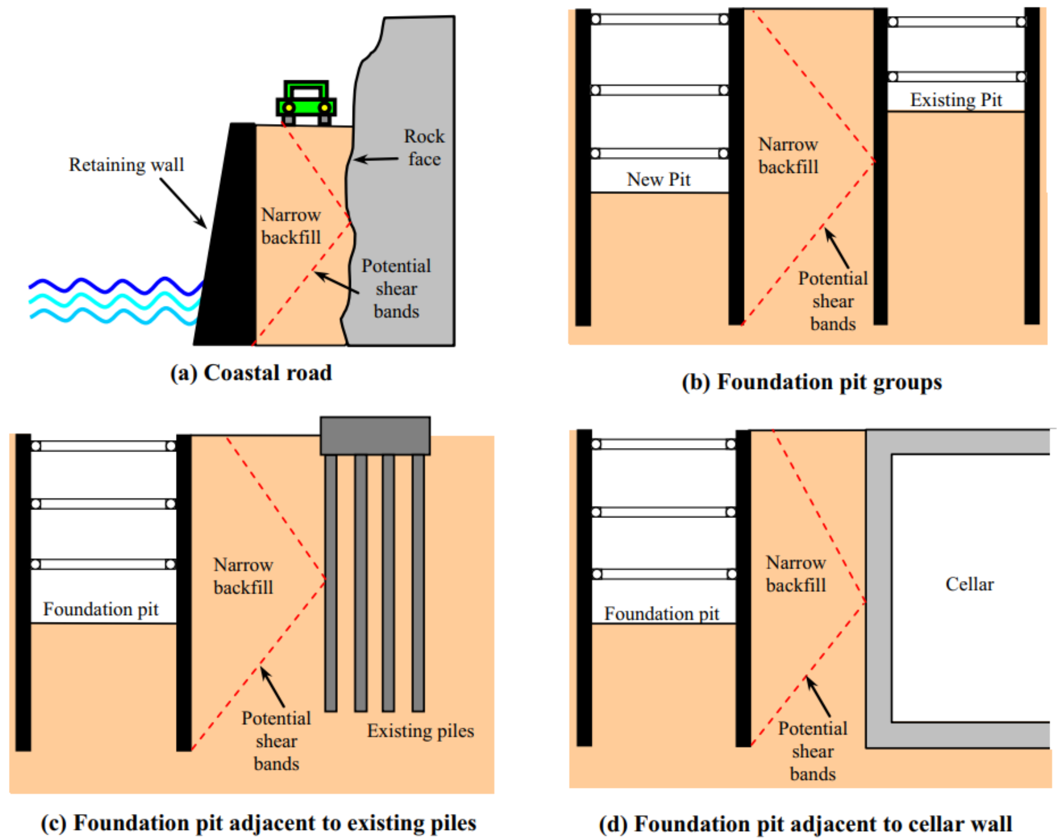
L = length of roller

Typical Compaction Weights

ECP202 translated from Canadian Foundation Manual

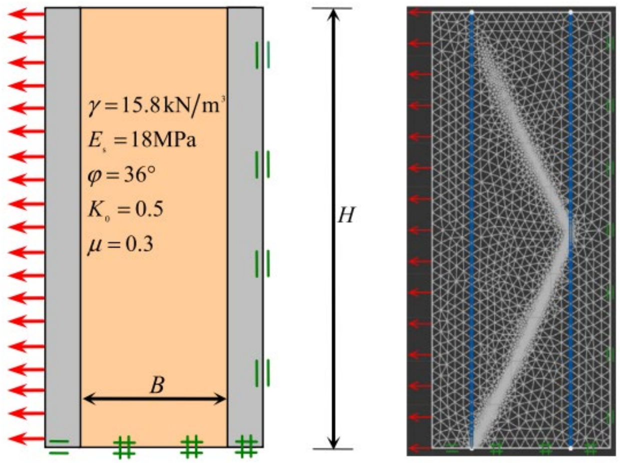
نوع الهراس	الوزن الإستاتيكى للهراس (كيلونيوتن)	قوة الطرد المركزى (كيلونيوتن)	عرض الهراس (مم)	حمل الهراس (P) (كيلونيوتن)
اطار منفرد	٢,٣	٨,٣	٥٦٠	١٨,٩
اطار مزدوج	١,٦	١٠,١	٥٦٠	٢٠,٩
اطار مزدوج	١٢,١	٨,٨	٧٦٠	٢٧,٥
اطار مزدوج	٩,٢	١٩,٨	٧٥٠	٣٨,٧

Narrow Backfill

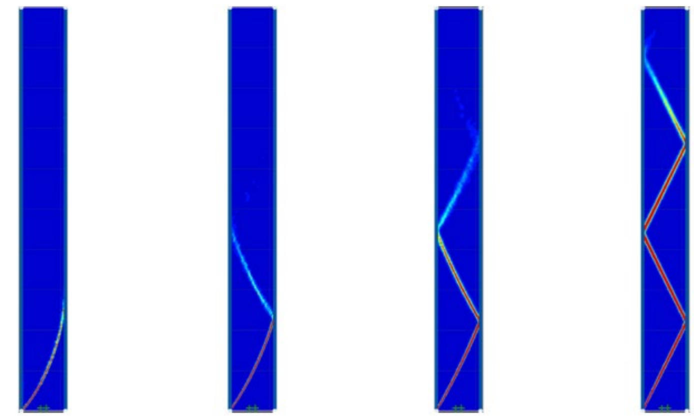


Chen, F., Lin, Y., & Li, D. (2019). Solution to active earth pressure of narrow cohesionless backfill against rigid retaining walls under translation mode. *Soils and Foundations*, *59*(1), 151-161.

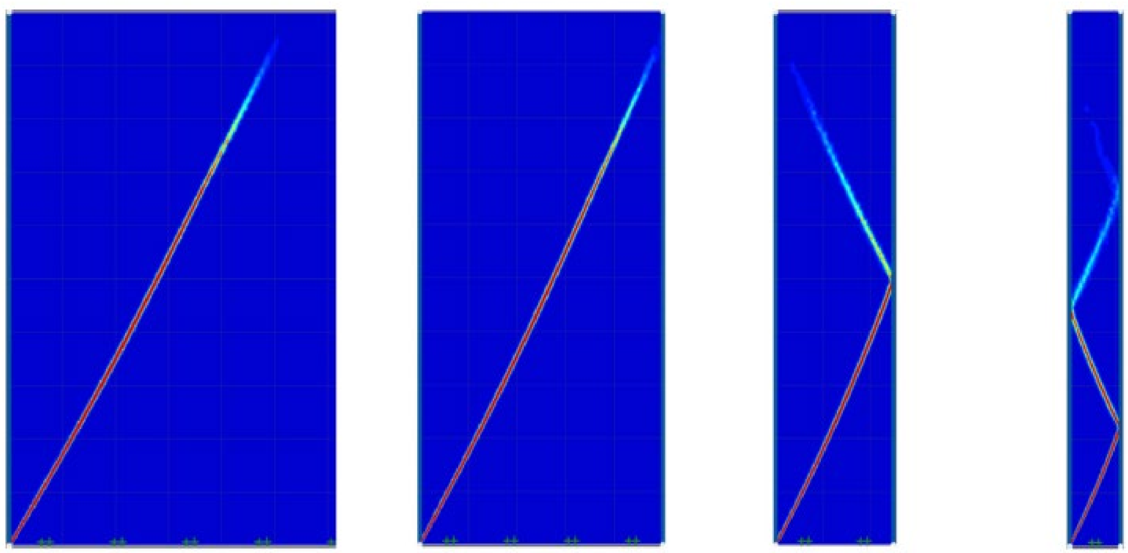
Application of FELA



(a) FELA model (b) FELA mesh



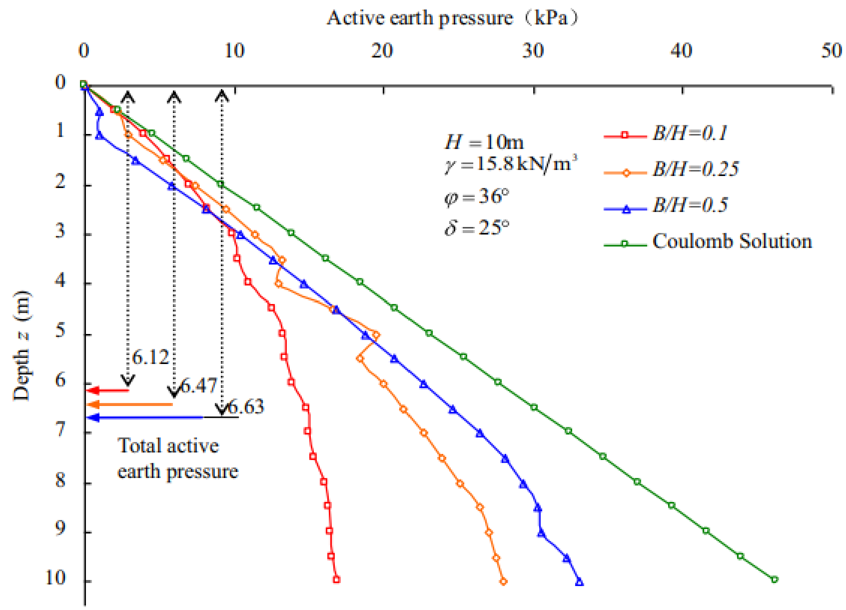
(a) $\delta = 0$ (b) $\delta = 1/3\varphi$ (c) $\delta = 2/3\varphi$ (a) $\delta = \varphi$

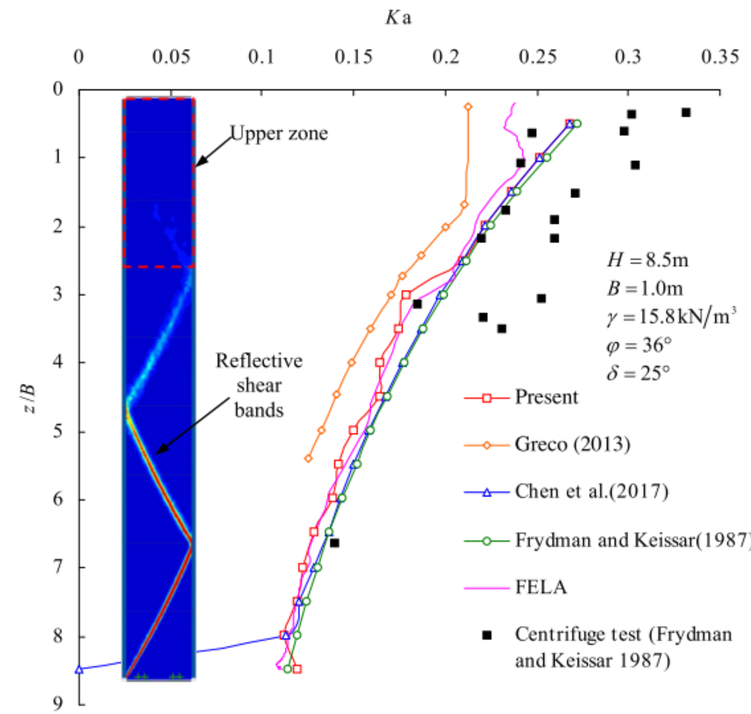


(a) $B/H = 1.500$ (b) $B/H = 0.500$ (c) $B/H = 0.250$ (d) $B/H = 0.125$

Reflective Shear Bands increase with the decrease in width.

Earth Pressure Calculations





Chen, J. J., Li, M. G., & Wang, J. H. (2017). Active earth pressure against rigid retaining walls subjected to confined cohesionless soil. *International Journal of Geomechanics*, *17*(6), 06016041.

$$p_z = \frac{\gamma B}{2\tan\delta}\left[1 - \exp\left(-\frac{2k\tan\delta}{B}z\right)\right] \quad 0 \le z < h \qquad (3)$$

where γ = unit weight of the retained soil; z = depth below the wall top; and k = active lateral stress ratio of $p_z/\bar{q}_z$ and will be discussed in the next section.

$$k = \frac{p_z}{\bar{q}_z} = \frac{3(N\cos^2\theta + \sin^2\theta)}{3N - (N-1)\cos^2\theta} \qquad (8)$$

where $N = \tan^2(45° + \varphi/2)$; θ = rotation angle of the principal stresses; and

$$\theta = \tan^{-1}\left(\frac{N - 1 \pm \sqrt{(N-1)^2 - 4N\tan^2\delta}}{2\tan\delta}\right)$$

Thank you