Principles of Foundation Engineering

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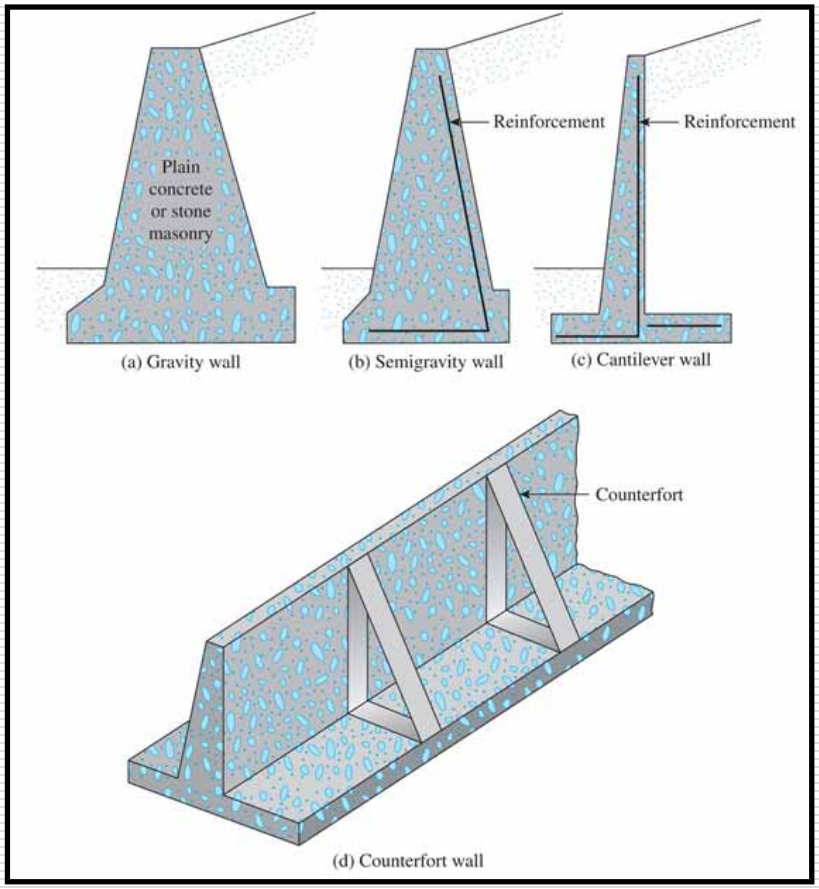
Chapter 8
Retaining Walls

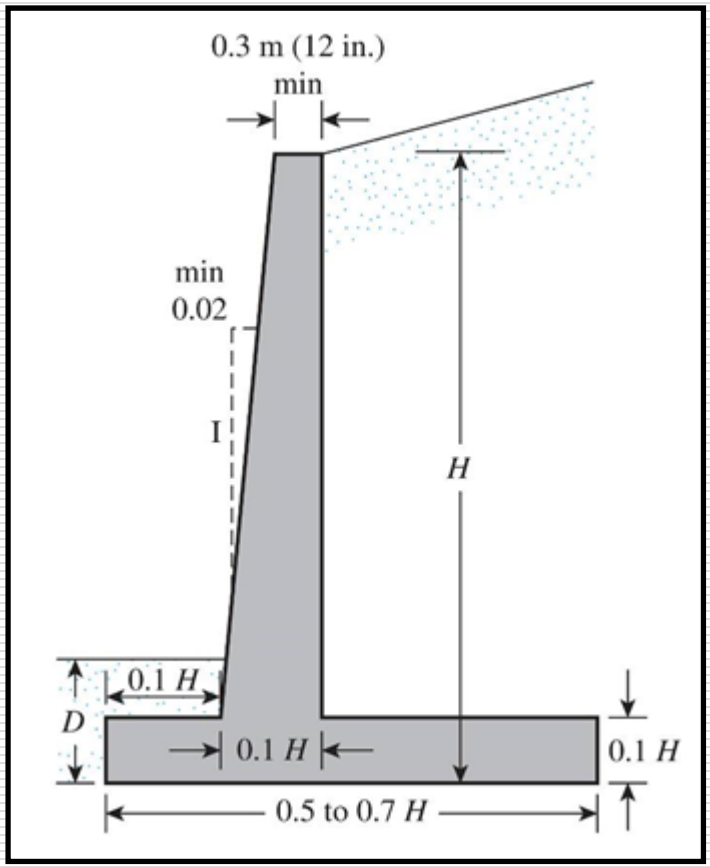
Moments

- Review Moments

Types of retaining walls

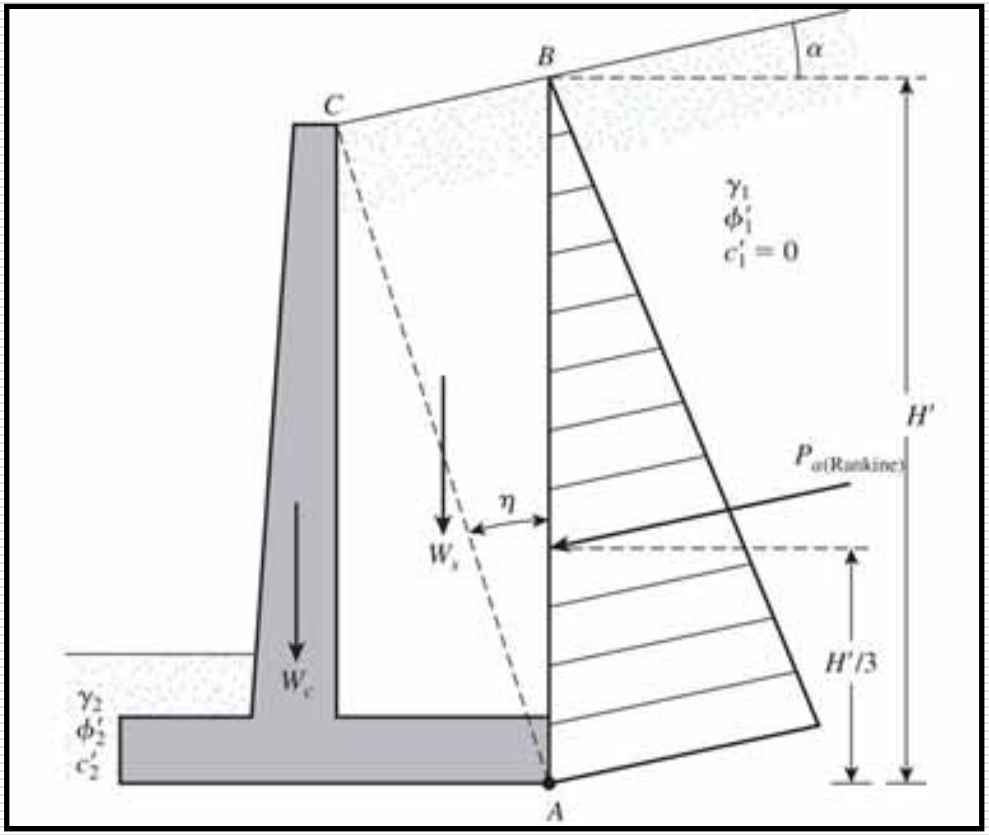


Dimensions

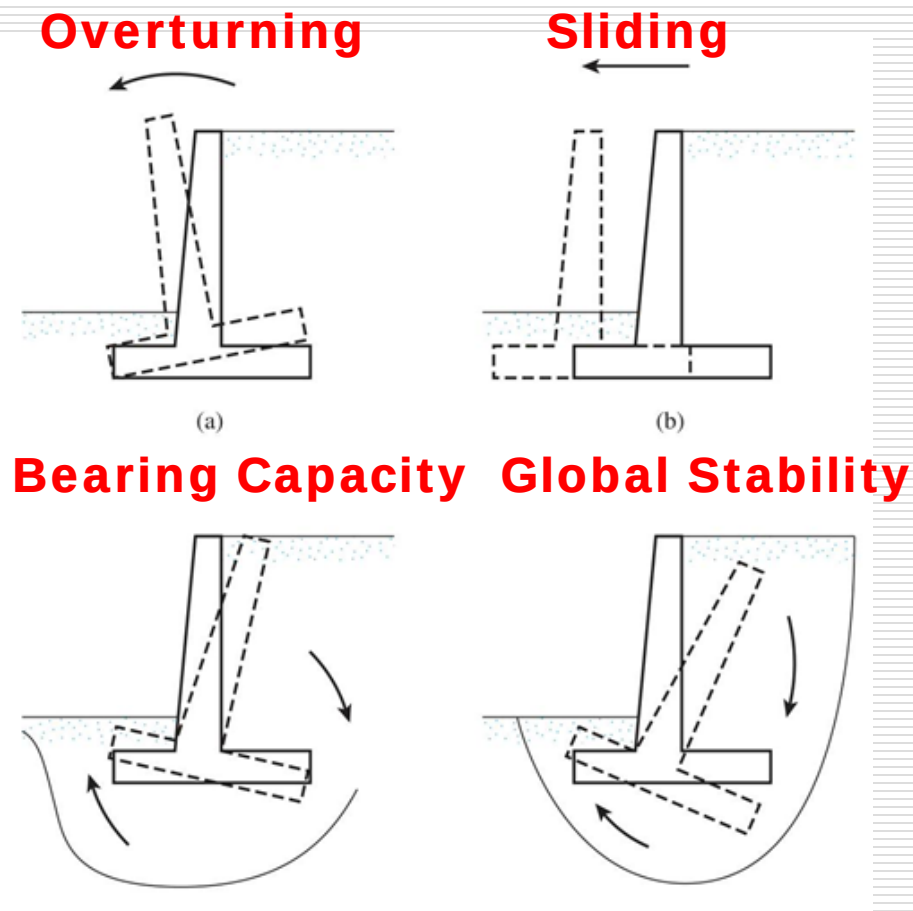


Approximate dimensions for various components of retaining wall for initial stability checks: cantilever wall

Active Earth Pressure



Stability Issues

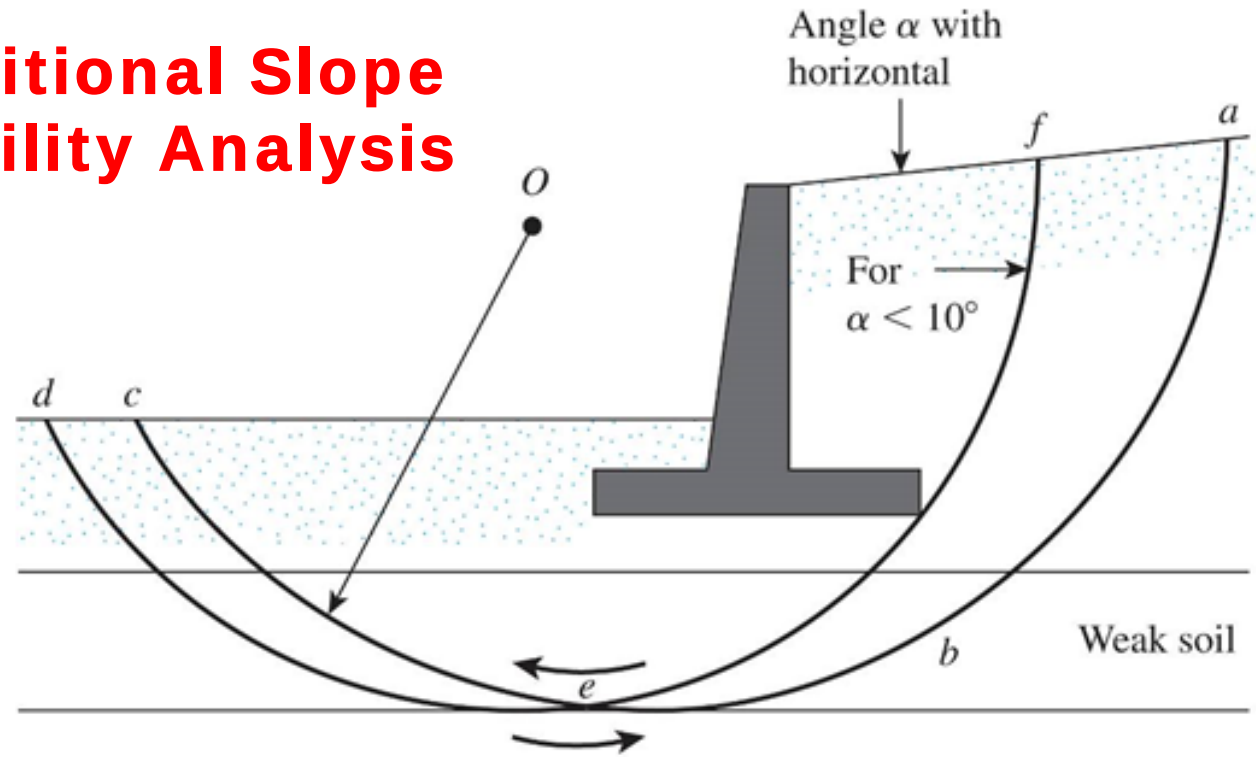


Failure of retaining wall:

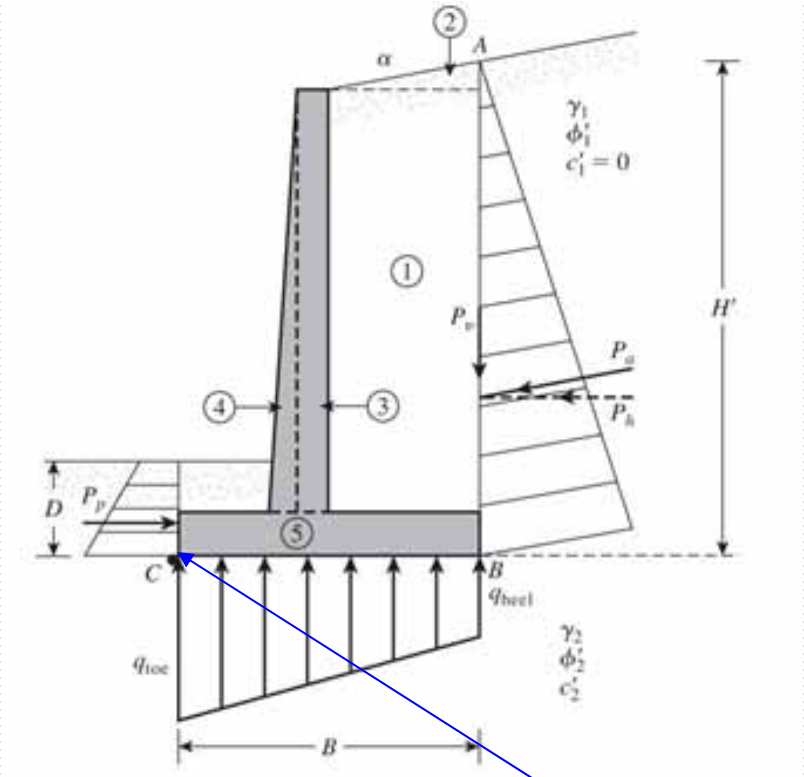
(a) by overturning
(b) by sliding
(c) by bearing capacity failure
(d) by deep-seated shear failure

Deep-seated shear failure

Traditional Slope Stability Analysis



Check for overturning, assuming that the Rankine pressure is valid



Forces at Work

Overturning

- Active Earth Pressure Using H'
- Any load along top – q

Resisting

- Weight of Soil (1 & 2)
- Weight of Structure (3, 4 & 5)
- Bearing Capacity of Base
- Passive Pressure Against Base

Point of Rotation

Moment Table

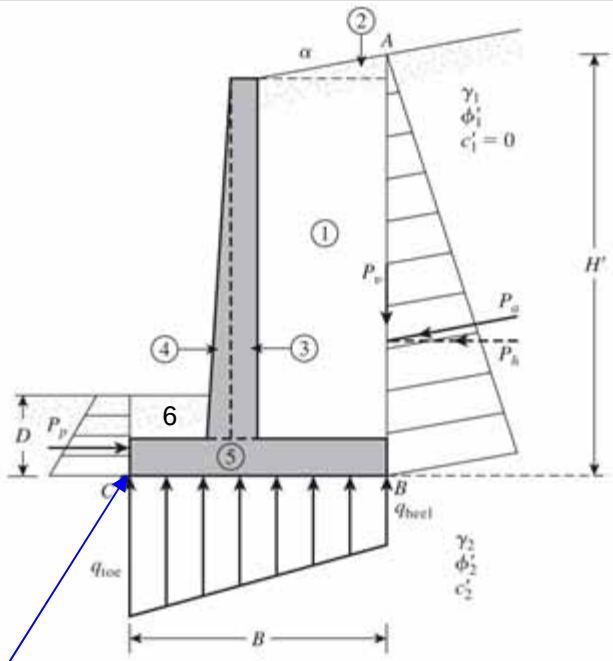
Procedure for Calculating ΣM_R

Section	Area	Weight per unit length of wall	Moment arm measured from C	Moment about C
1	2	3	4	5
1	A1	$W_1 = \gamma_1 \cdot A_1$	X_1	M_1
2	A2	$W_2 = \gamma_2 \cdot A_2$	X_2	M_2
3	A3	$W_3 = \gamma_3 \cdot A_3$	X_3	M_3
4	A4	$W_4 = \gamma_4 \cdot A_4$	X_4	M_4
5	A5	$W_5 = \gamma_5 \cdot A_5$	X_5	M_5
6	A6	$W_6 = \gamma_6 \cdot A_6$	X_6	M_6
		P_v	B	M_v
		ΣV		ΣM_R

P_v = Vertical Component of P_a if sloped ground

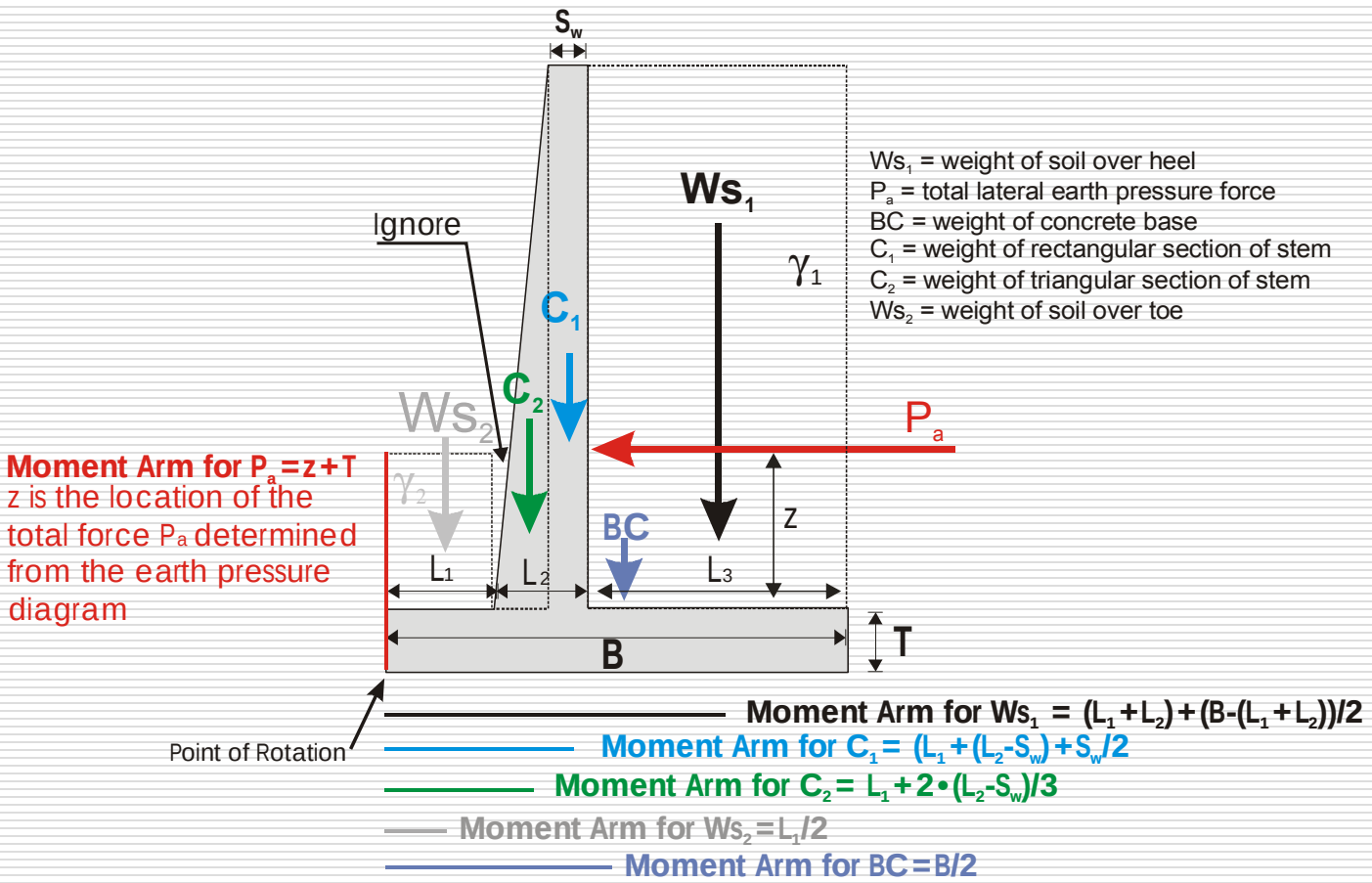
Pp neglected in overturning

Always build the moment table



C = Point of Rotation

Check Overturning



Overturning (Continued)

Overturning Moment

$M_o = P_a \cdot (z+T)$

Resisting Moments

$Ms_1 = \gamma_1 \cdot H \cdot [(L_1+L_2)+(B-(L_1+L_2))/2]$

$Mc_1 = \gamma_c \cdot H \cdot S_w \cdot [(L_1+(L_2-S_w)+S_w/2]$

$Mc_2 = \gamma_c \cdot 0.5H \cdot [L_1+(L_2-S_w)/2]$

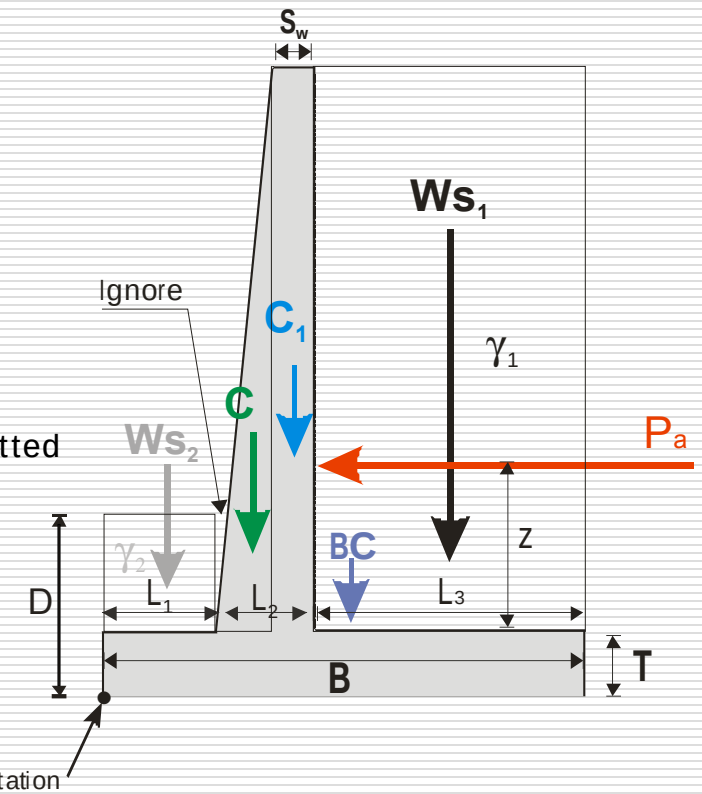
$MBC = \gamma_c \cdot B \cdot T \cdot B/2$

$Ms_2 = \gamma_2 \cdot (D-T) \cdot L_1 \cdot [L_1/2]$

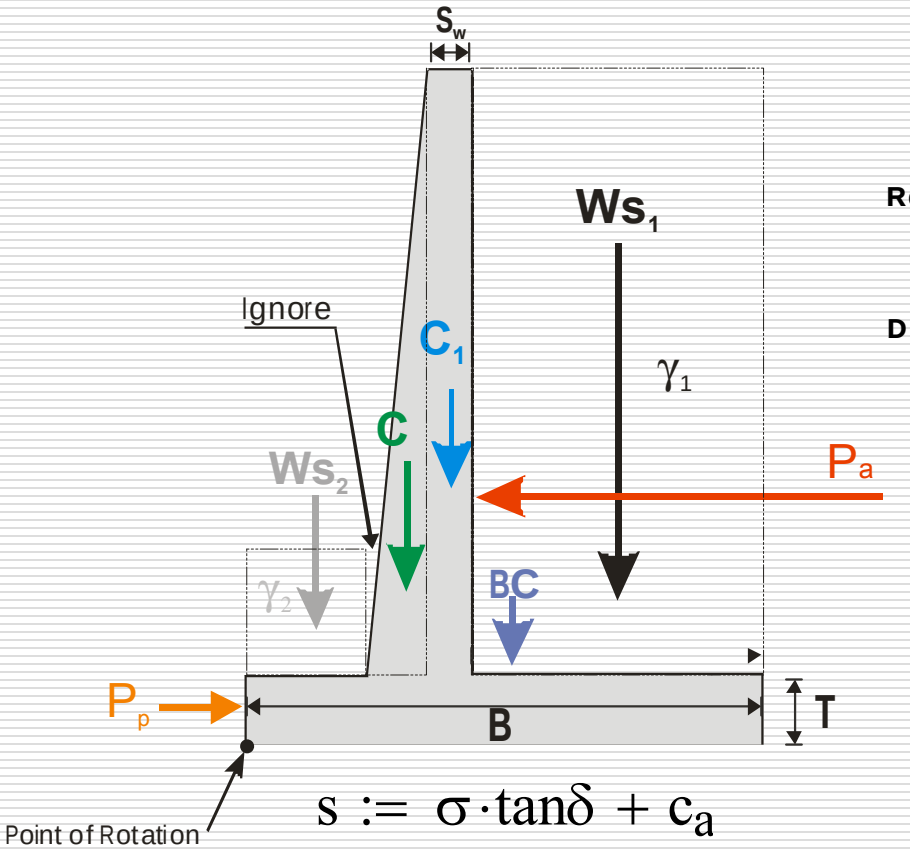
$$FS := \frac{\Sigma M_r}{\Sigma M_o} \qquad FS = 2 \text{ to } 3$$

$$\Sigma M_r := Ms_1 + Ms_2 + MC_1 + MC_2 + MB_c$$

Unit Width Omitted



Check for sliding along the base



Resisting Forces

$$\Sigma R_f := \Sigma V \cdot \tan\delta + B \cdot c_a + P_p$$

Driving Forces

$$\Sigma D_f := P_a$$

$$FS_{sliding} := \frac{\left(\Sigma V \cdot \tan\delta + B \cdot c_a + P_p\right)}{P_a}$$

$$Pp := \frac{1}{2} \cdot \gamma_2 \cdot D_1^2 \cdot K_p + 2 \cdot c_2 \cdot D_1 \cdot \sqrt{K_p}$$

FS >1.5

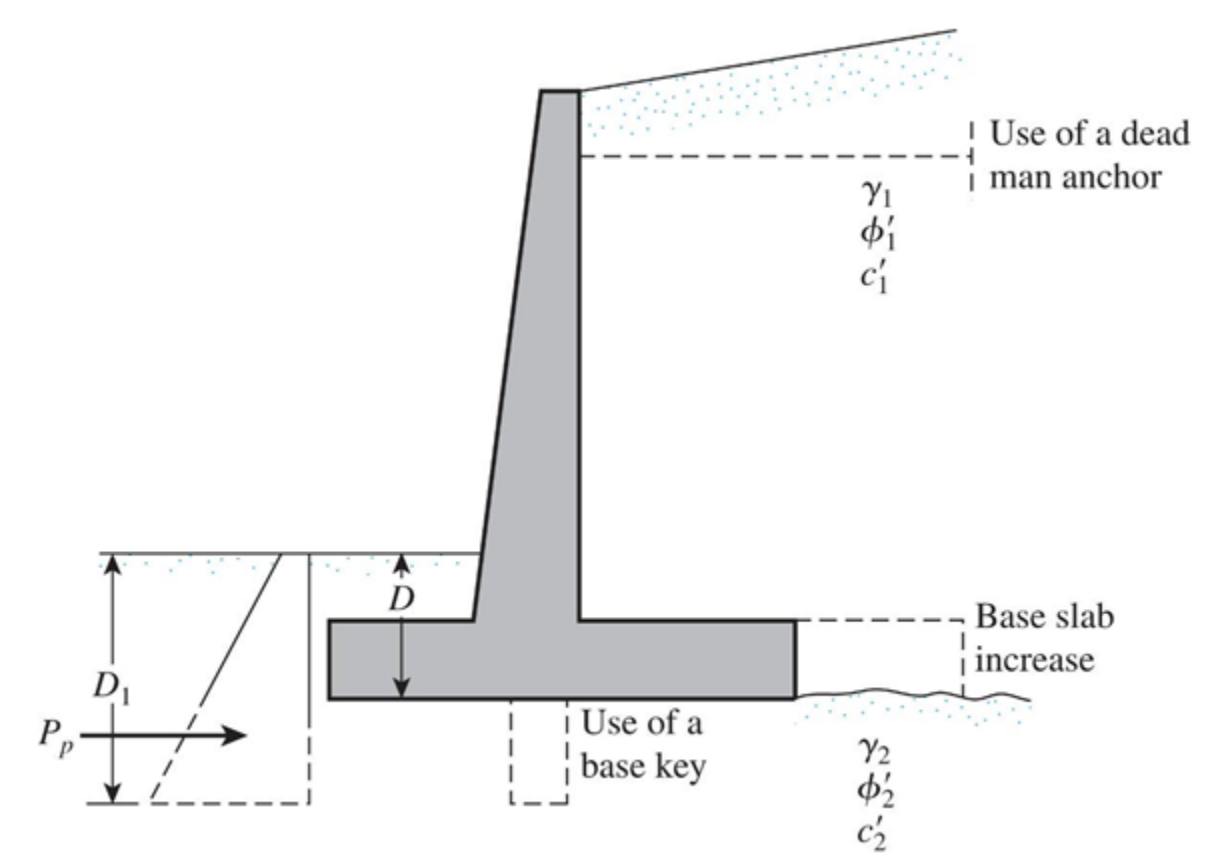
δ = angle of friction between soil & slab

Coefficient of Friction

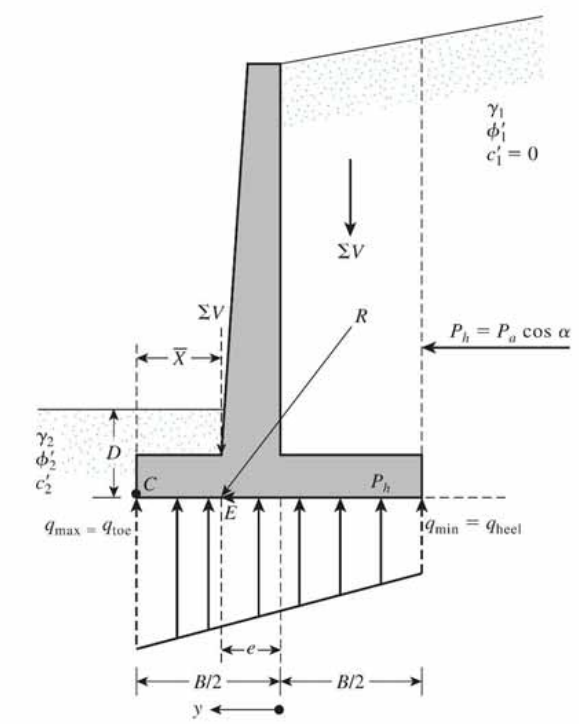
Coefficient of Friction for Cohesionless Soil

Material	tan δ	δ
Wood	0.40	22°
Rough concrete, cast against soil	tan ϕ	ϕ
Smooth, formed concrete	0.3-0.4	17°
Clean steel	0.20	11°
Rusty steel	0.40	22°
Corrugated metal	tan ϕ	ϕ

Alternatives for increasing the factor of safety with respect to sliding



Check for bearing capacity failure



Resultant Force R acting on base

$$R := \Sigma V + P_a$$

Net Moment

$$M_{net} := \Sigma M_r - \Sigma M_o$$

Location of Resultant Force "R"

$$CE = \overline{X} := \frac{M_{net}}{\Sigma V}$$

So Eccentricity "e"

$$e := \frac{B}{2} - \overline{X} \quad \text{<B/6}$$

Pressure on Base

$$q := \frac{\Sigma V}{A} := M_{net} \cdot \frac{y}{I} := \frac{(\Sigma V \cdot e)}{\frac{1}{12} \cdot 1 \cdot B^2}$$

I=Moment of Inertia
Per Unit Length

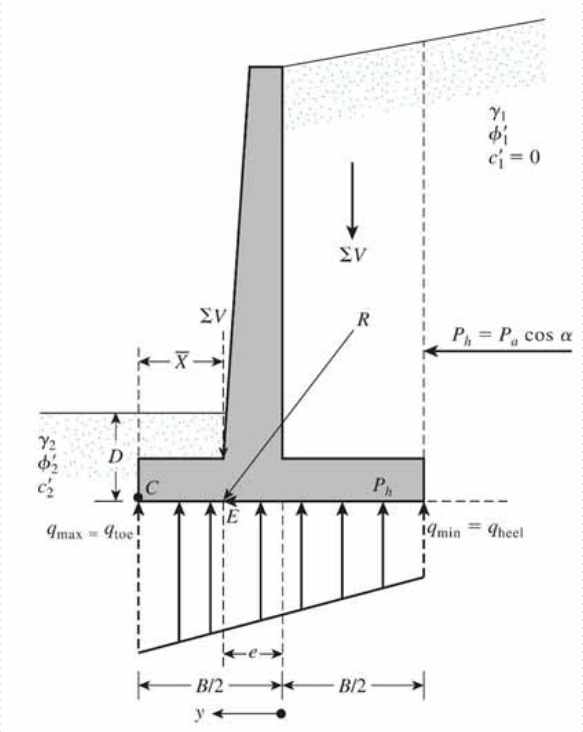
Max Pressure @ Toe

$$q_{max} := \frac{\Sigma V}{B} \cdot \left(1 + \frac{6e}{B}\right)$$

Min Pressure @ Heel

$$q_{min} := \frac{\Sigma V}{B} \cdot \left(1 - \frac{6e}{B}\right)$$

Bearing Capacity



Note you use only the lowest fill height over the footing.

$$q_u := \frac{\left(\gamma_2 \; B' \cdot N_\gamma\right)}{2} + c_2 \cdot N_c \; F_{cd} + \gamma_2 \cdot D \cdot N_q \cdot F_{qd}$$

$$B' := B - 2\,e$$

$$F_{cd} := 1 + 0.4 \cdot \frac{D}{B'}$$

$$F_{qd} := 1 + 2 \cdot \tan\phi_2 \cdot \left(1 - \sin\phi_2\right)^2 \cdot \frac{D}{B'}$$

$$F_{\gamma d} := 1$$

$$FS := \frac{q_u}{q_{max}}$$

FS > 3

For inclined surface, add inclination factors F_{ci}, F_{qi}, $F_{\gamma i}$

$$F_{\gamma i} := \left(1 - \frac{\psi^\circ}{\phi^\circ}\right)^2 \qquad F_{ci} := F_{qi} := \left(1 - \frac{\psi^\circ}{90^\circ}\right)^2$$

$$\psi := \tan^{-1}\left[\frac{Pa \cdot \cos(\alpha)}{\Sigma V}\right]$$

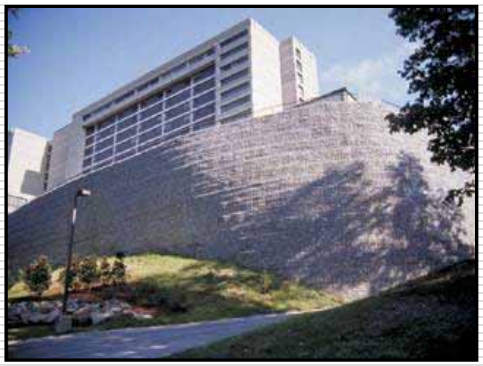
Example

Review Example 8.1 on Page 390-393

MSE Walls

Mechanically Stabilized Earth (MSE) Walls



Geogrid Reinforcement for MSE

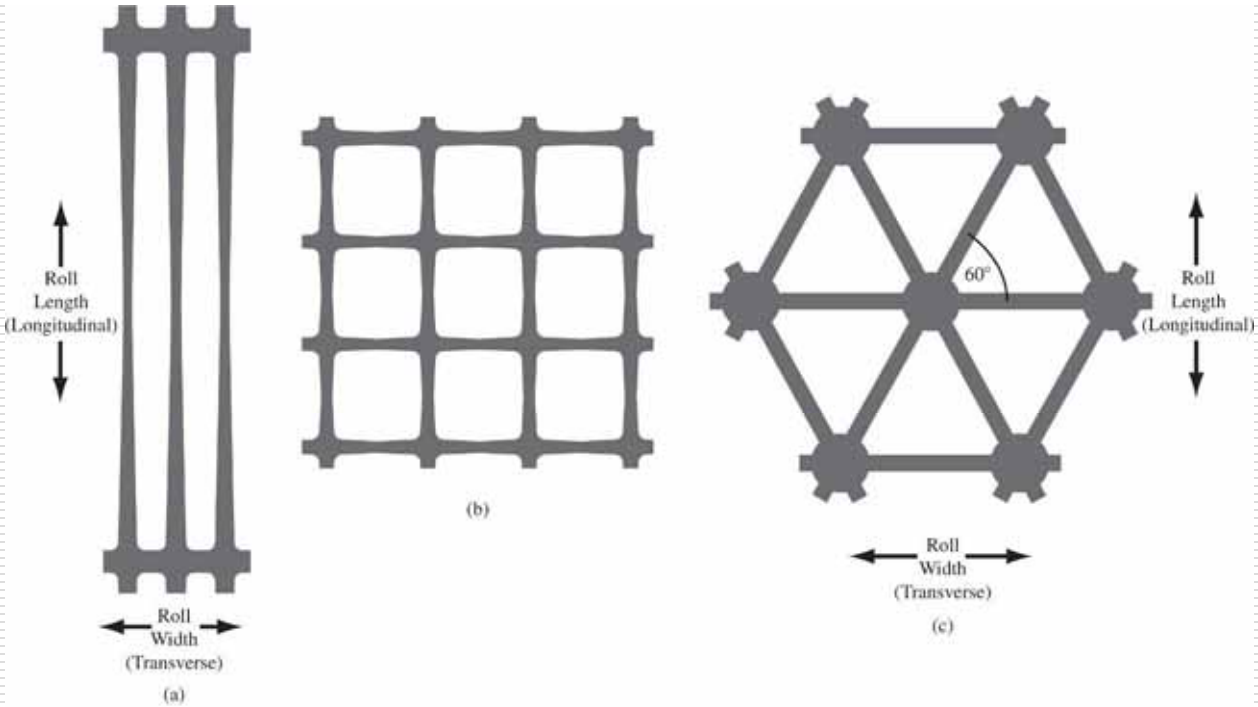


Figure 8.22 Geogrid: (a) uniaxial; (b) biaxial; (c) with triangular apertures (*Courtesy of Tensar International Corporation*)

How Geogrids Work

$$B_{GG} > 3.5D_{50}$$

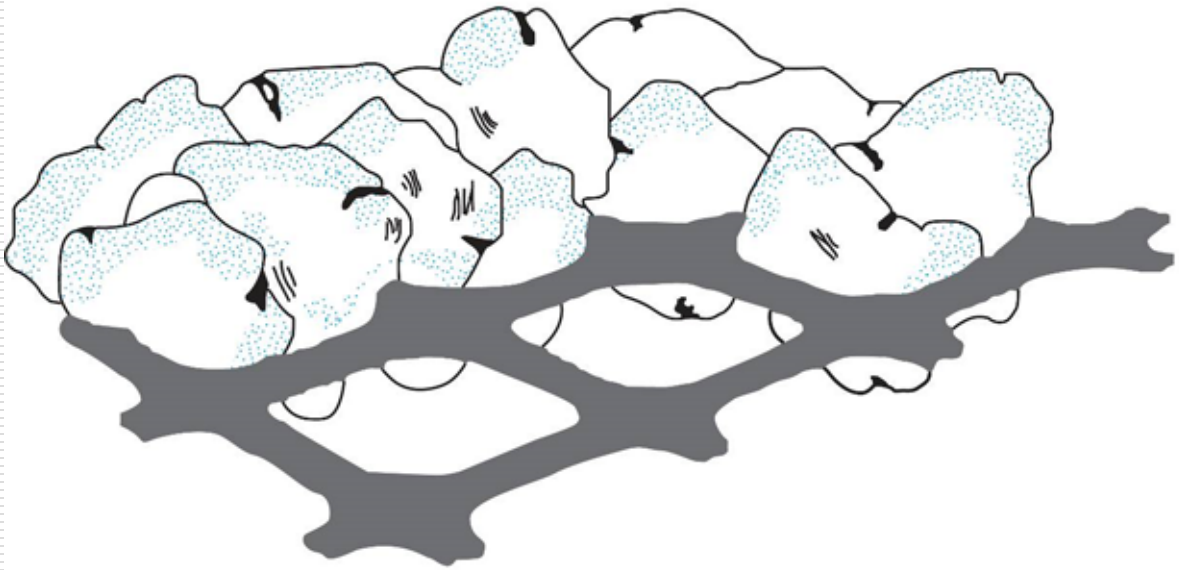


Figure 8.23 Geogrid apertures allowing interlocking with surrounding soil

Similar Checks to Retaining Wall

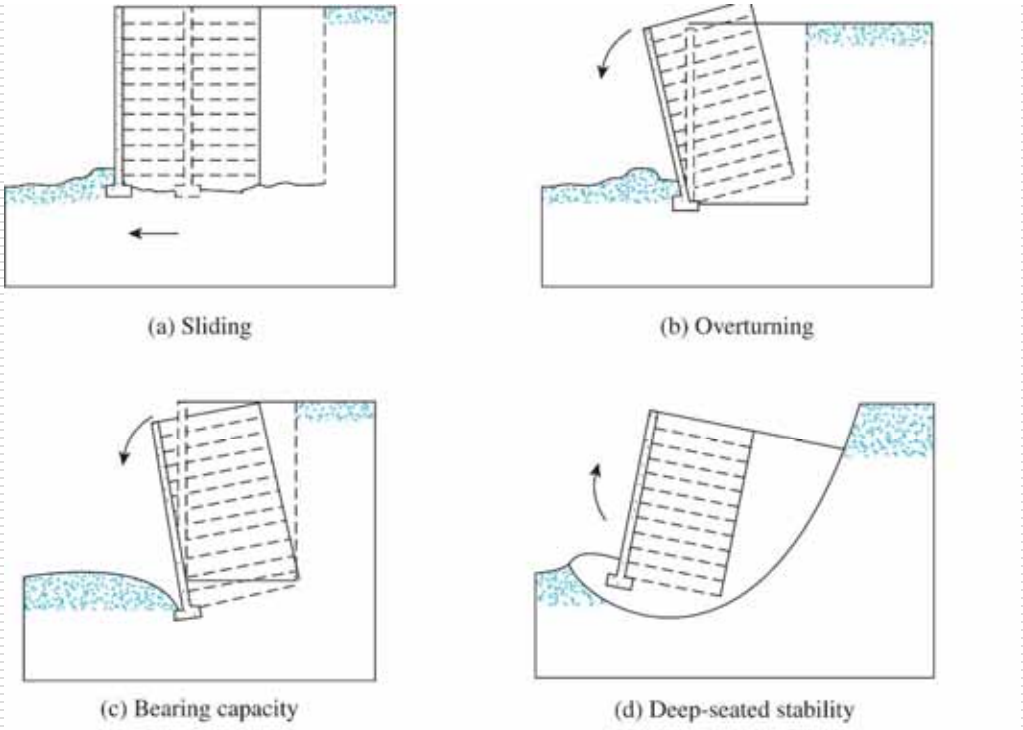


Figure 8.24 External stability checks (After Transportation Research Board, 1995) (From Transportation Research Circular 444: Mechanically Stabilized Earth Walls. Transportation Research Board, National Research Council, Washington, D.C., 1995, Figure 3, p. 7. Reproduced with permission of the Transportation Research Board.)

Types of MSE Walls

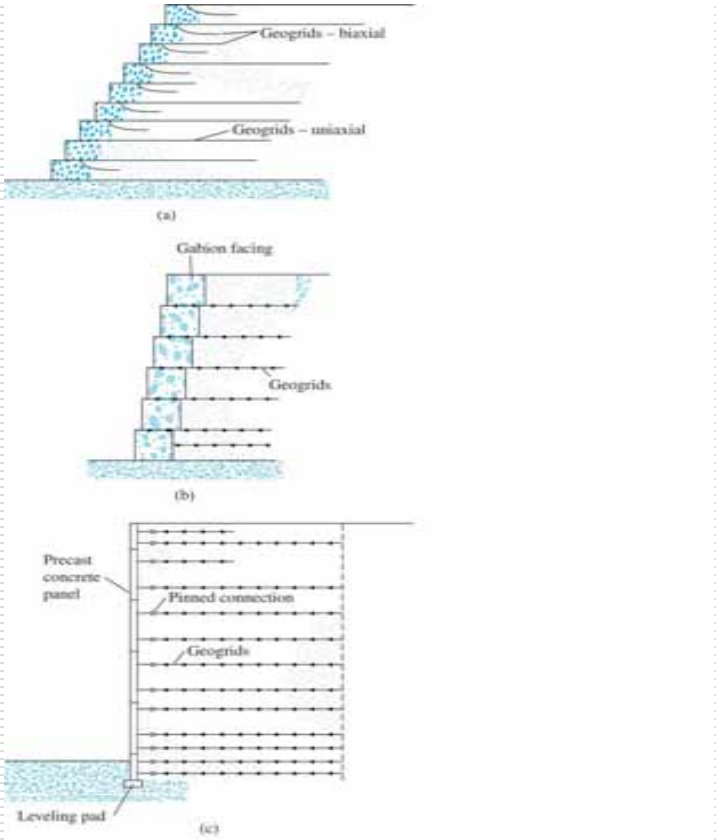
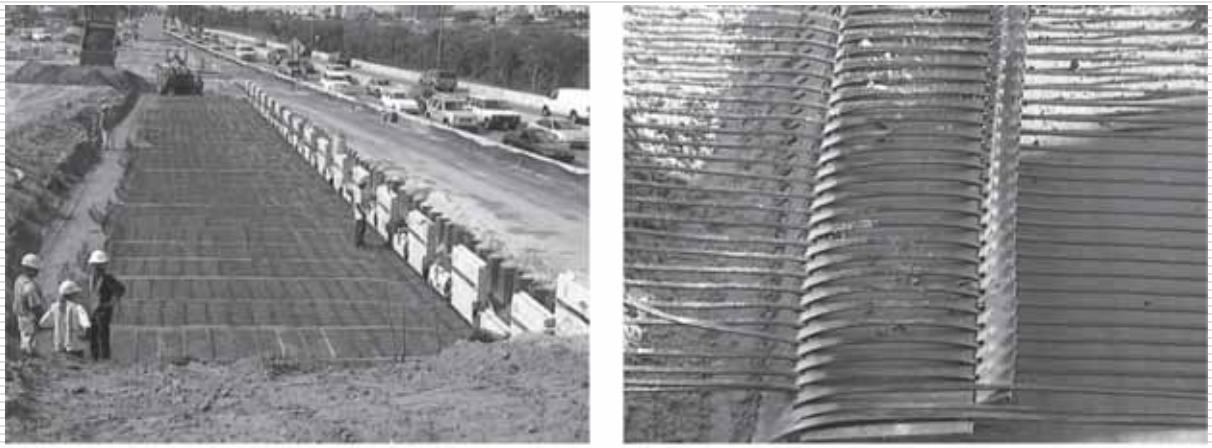


Figure 8.38 Typical schematic diagrams of retaining walls with geogrid reinforcement: (a) geogrid wraparound wall; (b) wall with gabion facing; (c) concrete panel-faced wall (After The Tensar Corporation, 1986)

Geogrid Reinforced Walls



(a) (b)

(c)

Figure 8.39 (a) HDPE geogrid-reinforced wall with precast concrete panel facing under construction; (b) Mechanical splice between two pieces of geogrid in the working direction; (c) Segmented concrete-block faced wall reinforced with uniaxial geogrid (*Courtesy of Tensar International Corporation, Atlanta, Georgia*)

Comments

- Active Versus At-Rest Pressures
  - You must have sufficient movement to get active pressure
- Creep
- Prolonged Rainfall & Groundwater Fluctuations
- Vibrations Due to Traffic and Other Sources
- Temperature
- Tides and Wave Action
- Seismic Events

Homework

CE 430

- 8.1

CE 530

- All of CE 430 plus 8.2