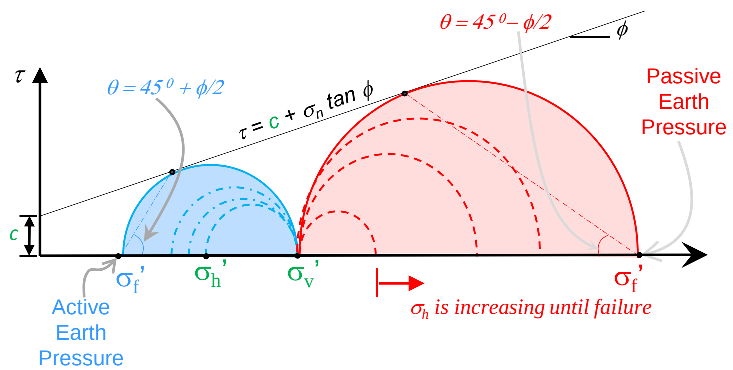
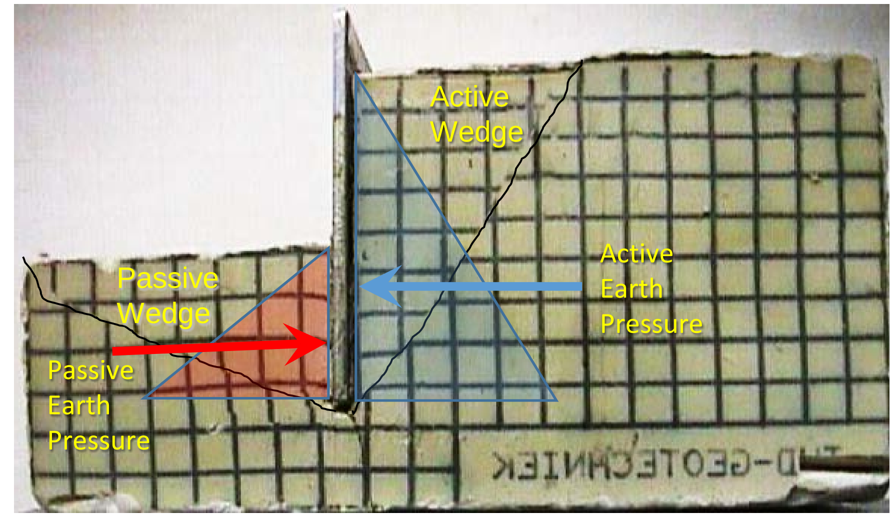
Rankine's Earth Pressure Method for (c- ϕ) Soil

Rankine's Active and Passive Earth Pressure in (c- f) Soil





Rankine's Active Earth Pressure in (f) Soil with inclined backfill

$$K_a = \cos\alpha \cdot \frac{\cos\alpha - \sqrt{(\cos^2\alpha - \cos^2\phi)}}{\cos\alpha + \sqrt{(\cos^2\alpha - \cos^2\phi)}}$$

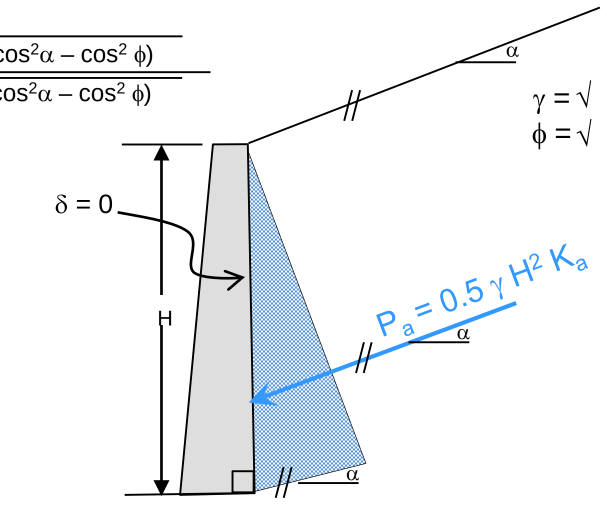


Fig.1

Active Earth Pressure

$$\sigma_f' = \sigma_V' \tan^2\left(45^o - \frac{\emptyset}{2}\right) + 2\,c\,\tan\left(45^o - \frac{\emptyset}{2}\right)$$

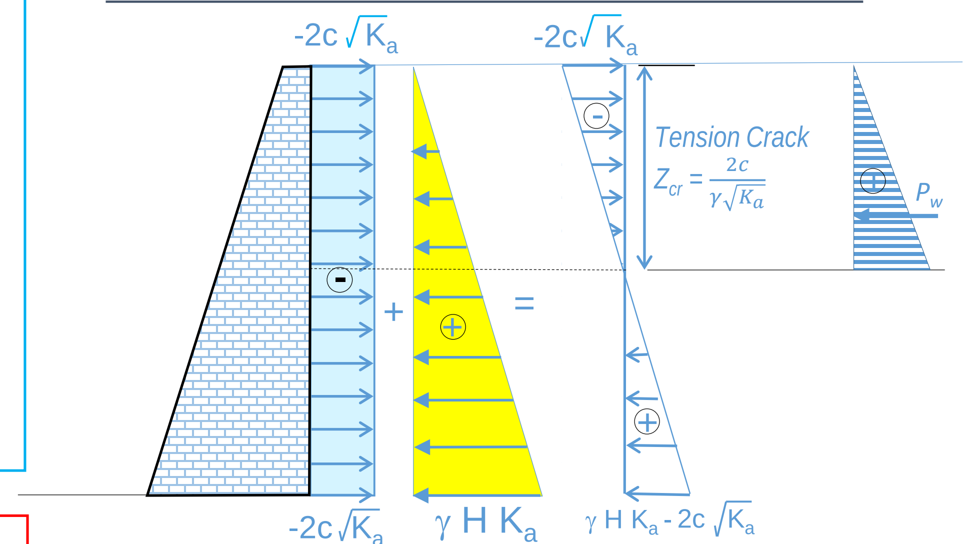
Or

$$\sigma_f' = \sigma_V' K_a - 2\,c\,\sqrt{K_a}$$

$$K_a = \tan^2\left(45^o - \frac{\emptyset}{2}\right) = \frac{1-\sin\emptyset}{1+\sin\emptyset}$$

Coefficient of active earth pressure

Effect of Cohesion of the Rankine's Active and Passive Earth Pressure



Passive Earth Pressure

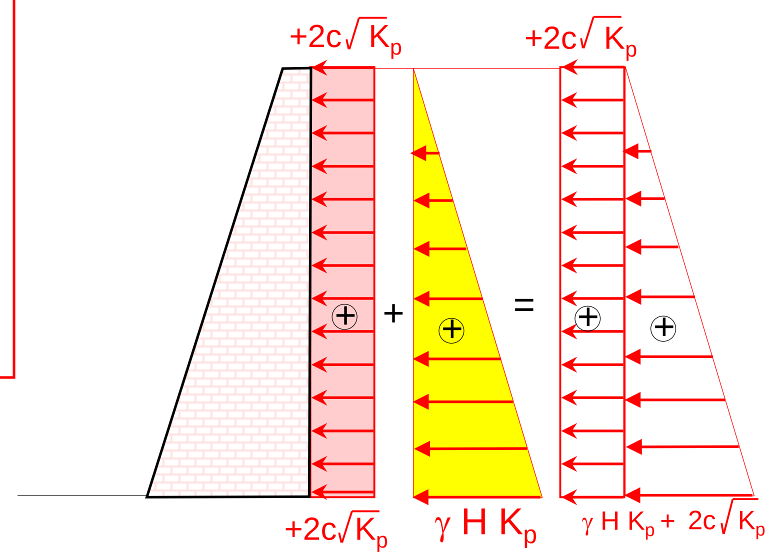
$$\sigma_f' = \sigma_V' \tan^2\left(45^o + \frac{\emptyset}{2}\right) + 2\,c\,\tan\left(45^o + \frac{\emptyset}{2}\right)$$

Or

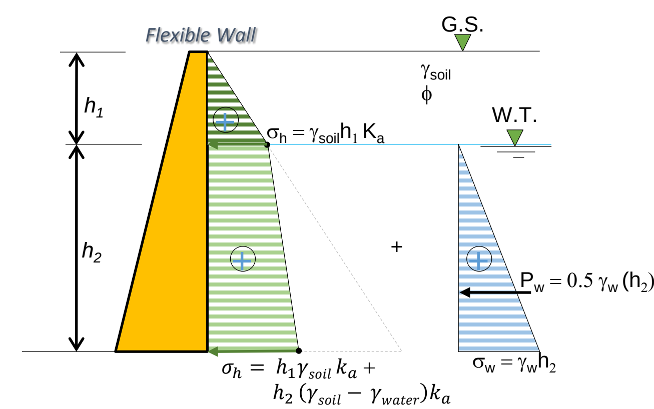
$$\sigma_f' = \sigma_V' K_p + 2\,c\,\sqrt{K_p}$$

$$K_p = \tan^2\left(45^o + \frac{\emptyset}{2}\right) = \frac{1+\sin\emptyset}{1-\sin\emptyset}$$

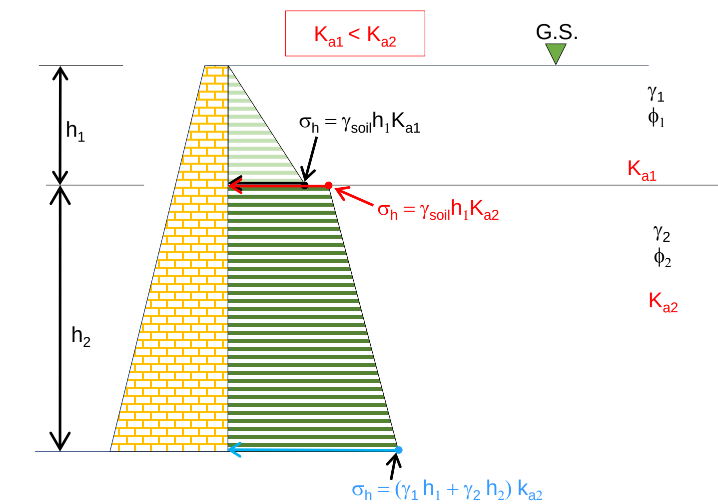
Coefficient of passive earth pressure



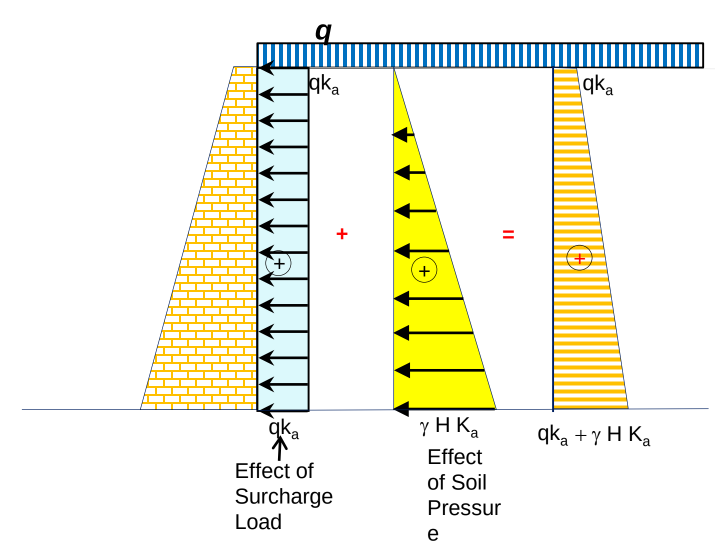
Rankine's Active Earth Pressure in f - Soil & Water Table

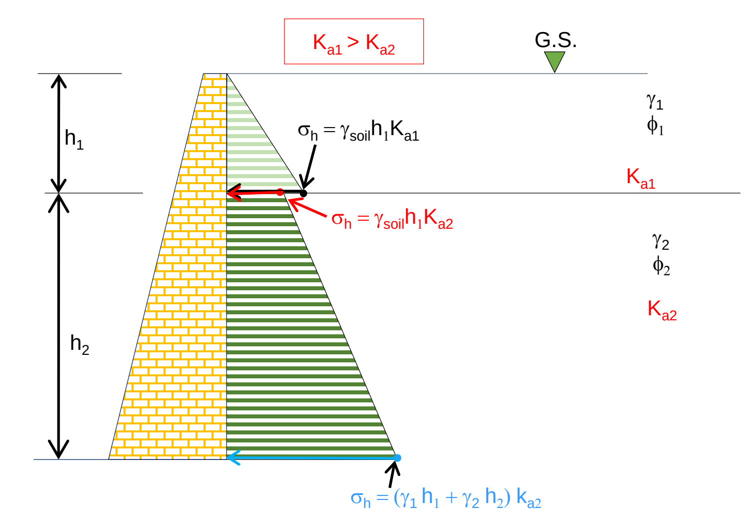


Effect of Two Soil Layers on Active Earth Pressure



Effect of Surcharge (q) Load on Active Earth Pressure





Kamal Tawfiq

Internal Stability

Structural Design
Steel Reinforcement and Thicknesses — Structural Design

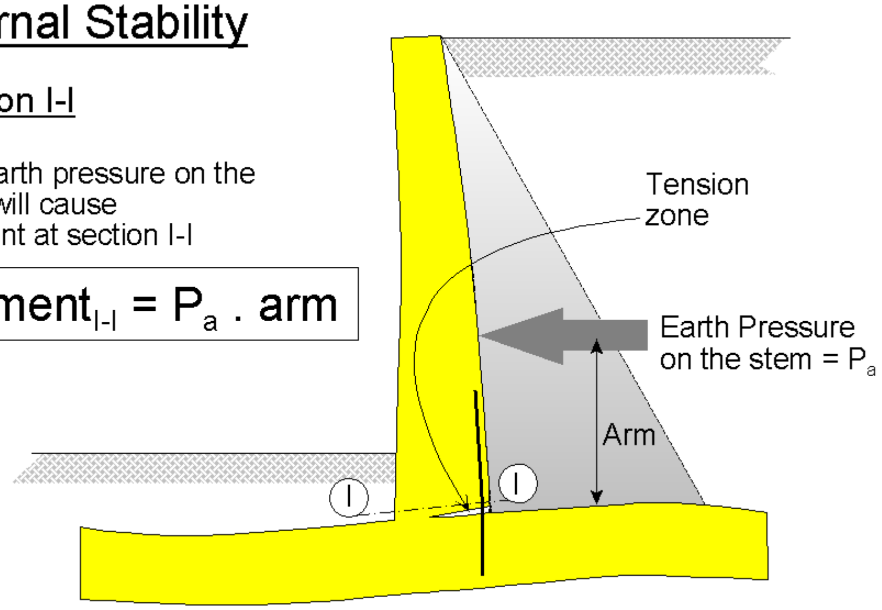
2-

Internal Stability

Section I-I

The earth pressure on the stem will cause moment at section I-I

$$\text{Moment}_{I\text{-}I} = P_a \cdot \text{arm}$$

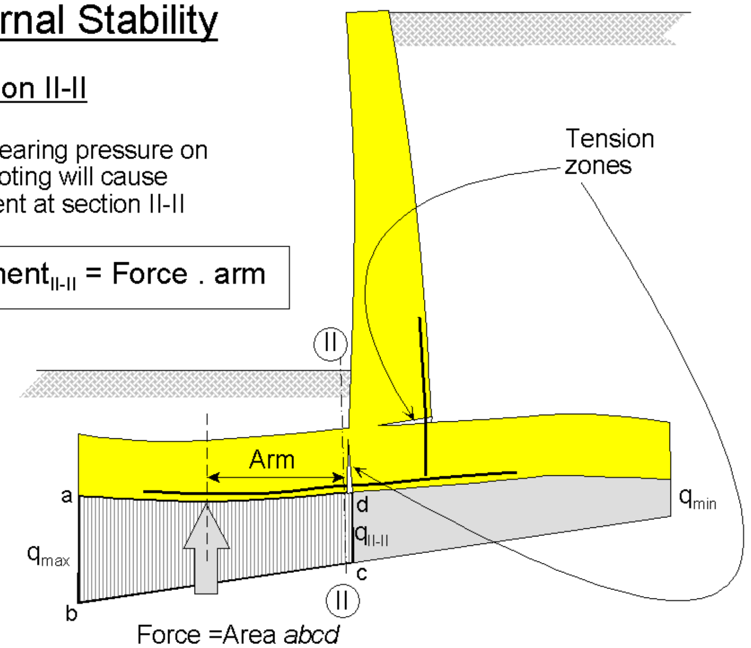


Internal Stability

Section II-II

The bearing pressure on the footing will cause moment at section II-II

$$\text{Moment}_{II\text{-}II} = \text{Force} \cdot \text{arm}$$

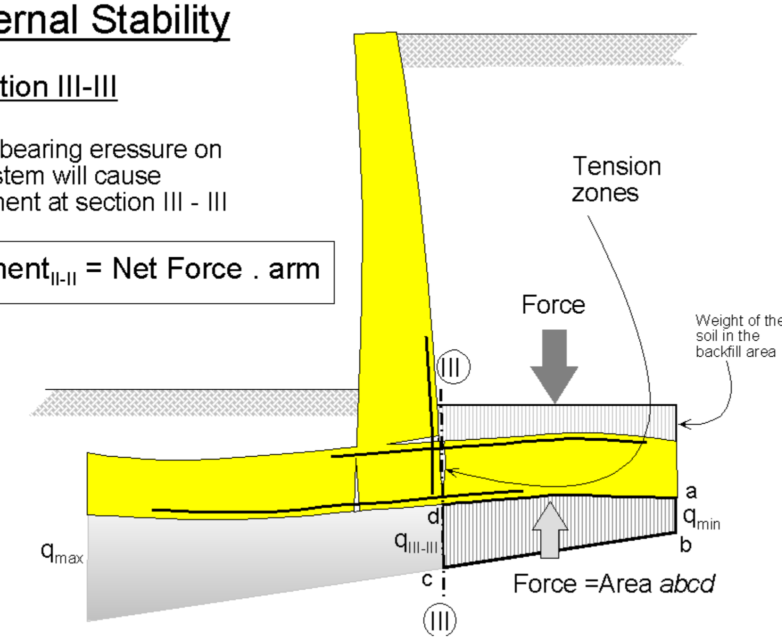


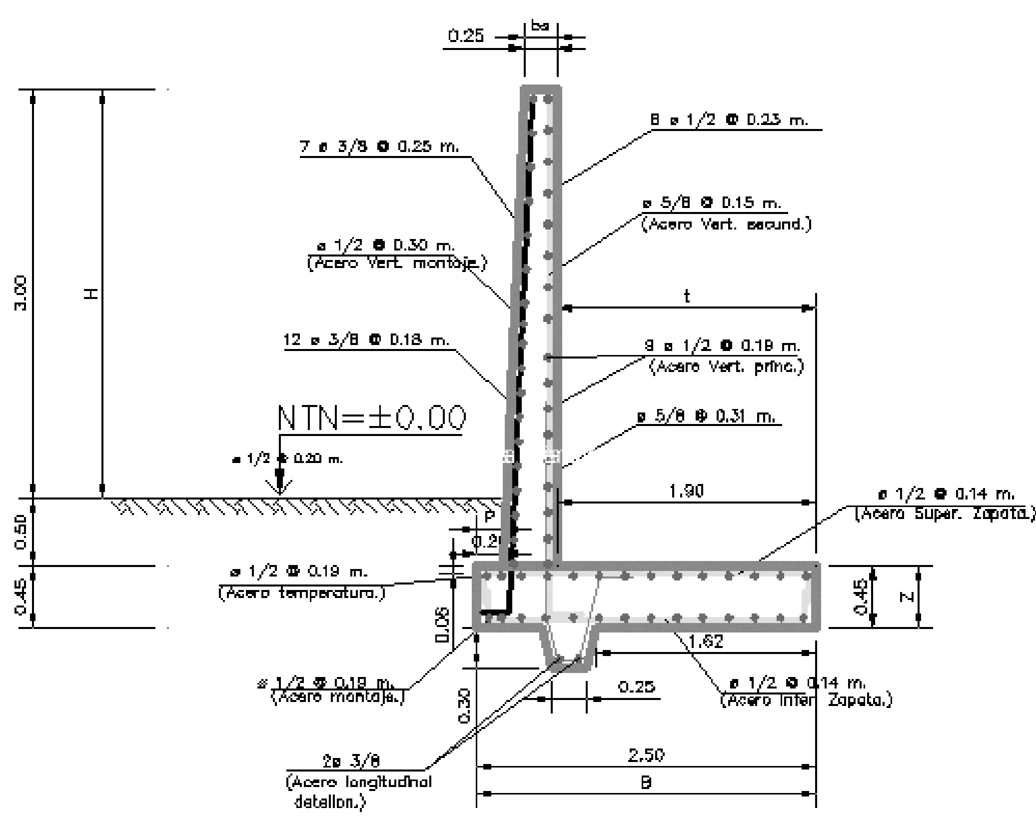
Internal Stability

Section III-III

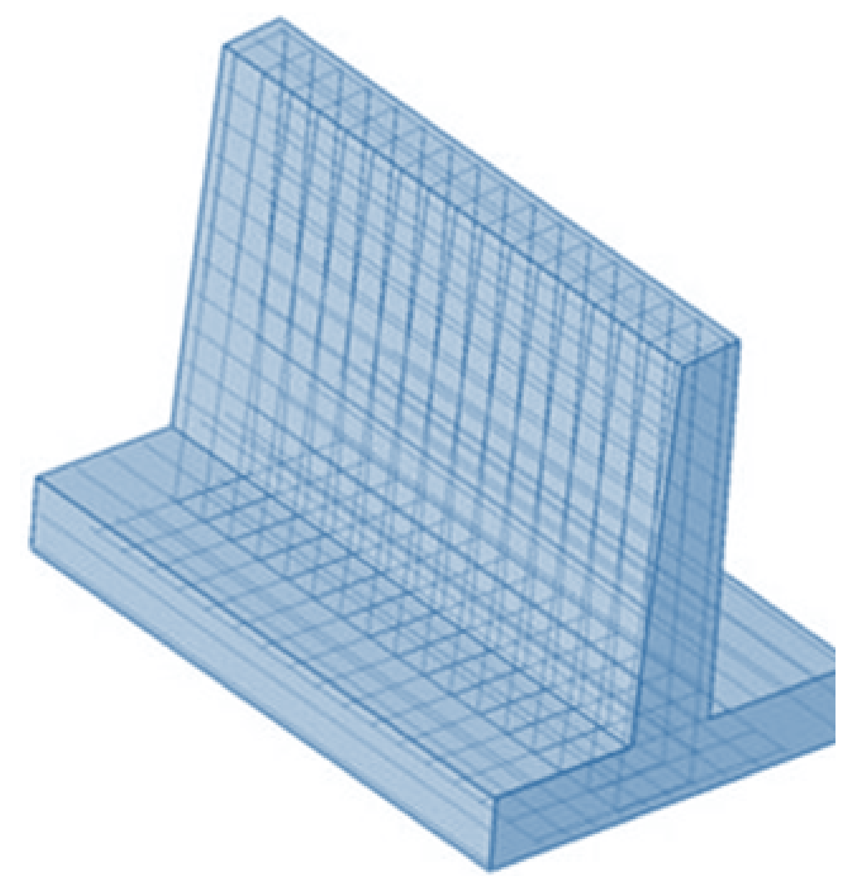
The bearing eressure on the stem will cause moment at section III - III

$$\text{Moment}_{II\text{-}II} = \text{Net Force} \cdot \text{arm}$$





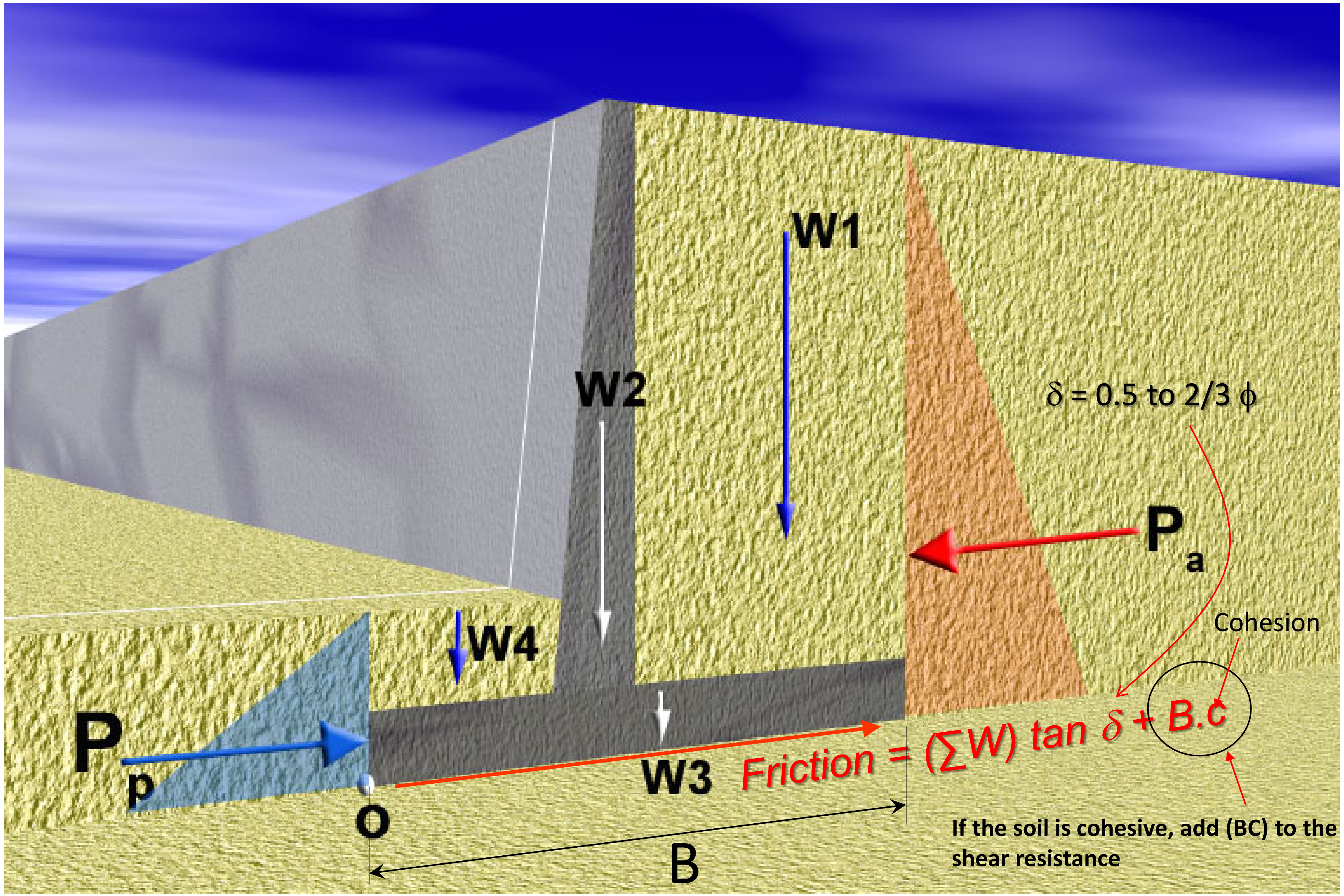
DETALLES DE MURO DE CONTENCION



I. External Stability

1- Sliding

$$\text{Factor of Safety Against Sliding} = \frac{\text{Resisting Force}}{\text{Driving Force}} = \frac{F_R}{F_D}$$

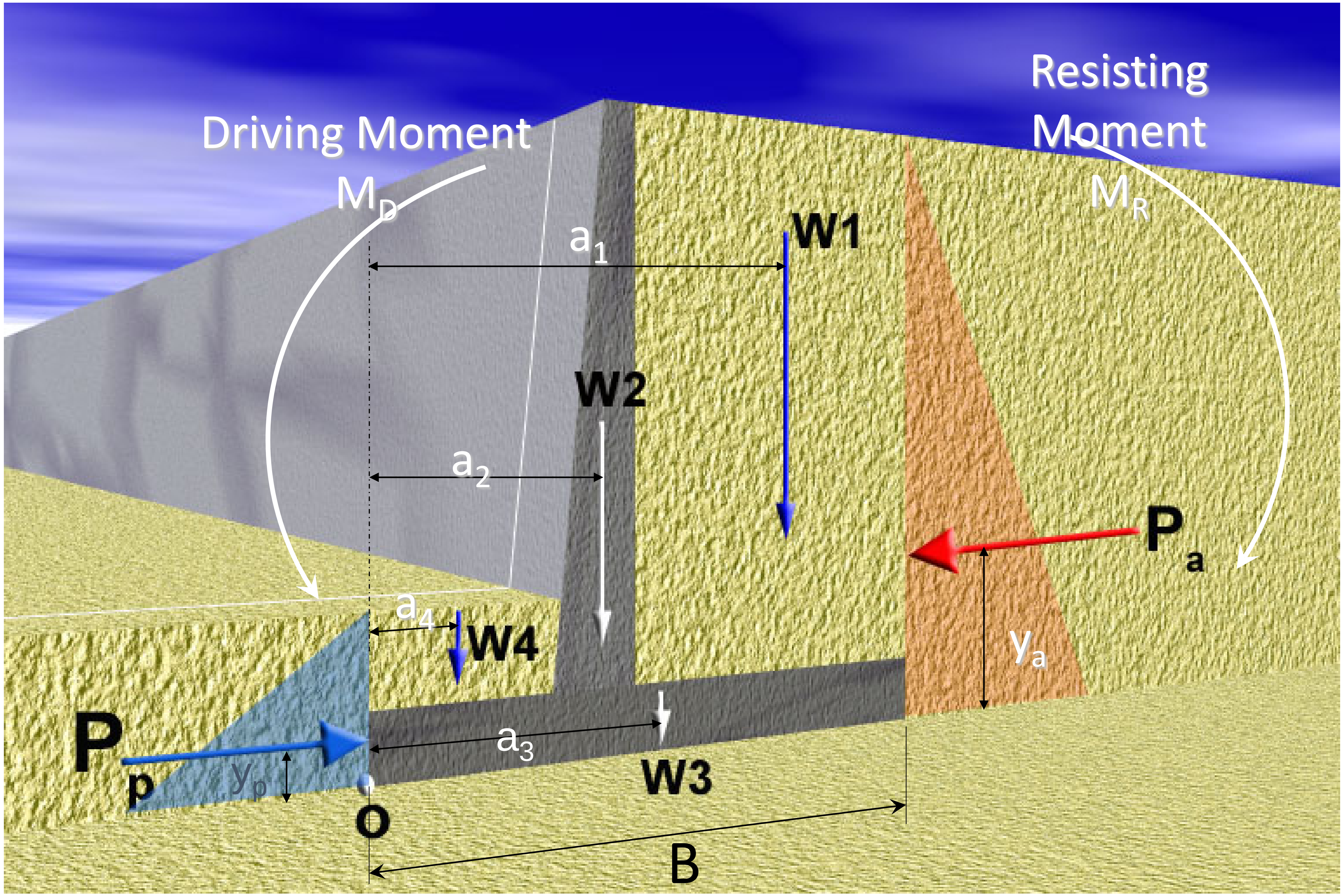


$$F_D = P_a \qquad F_R = P_p + \text{Friction}$$

I. External Stability

2- Overturning

$$\text{Factor of Safety Against Sliding} = \frac{\text{Resisting Moment}}{\text{Driving Moment}} = \frac{M_R}{M_D}$$



Moment About o

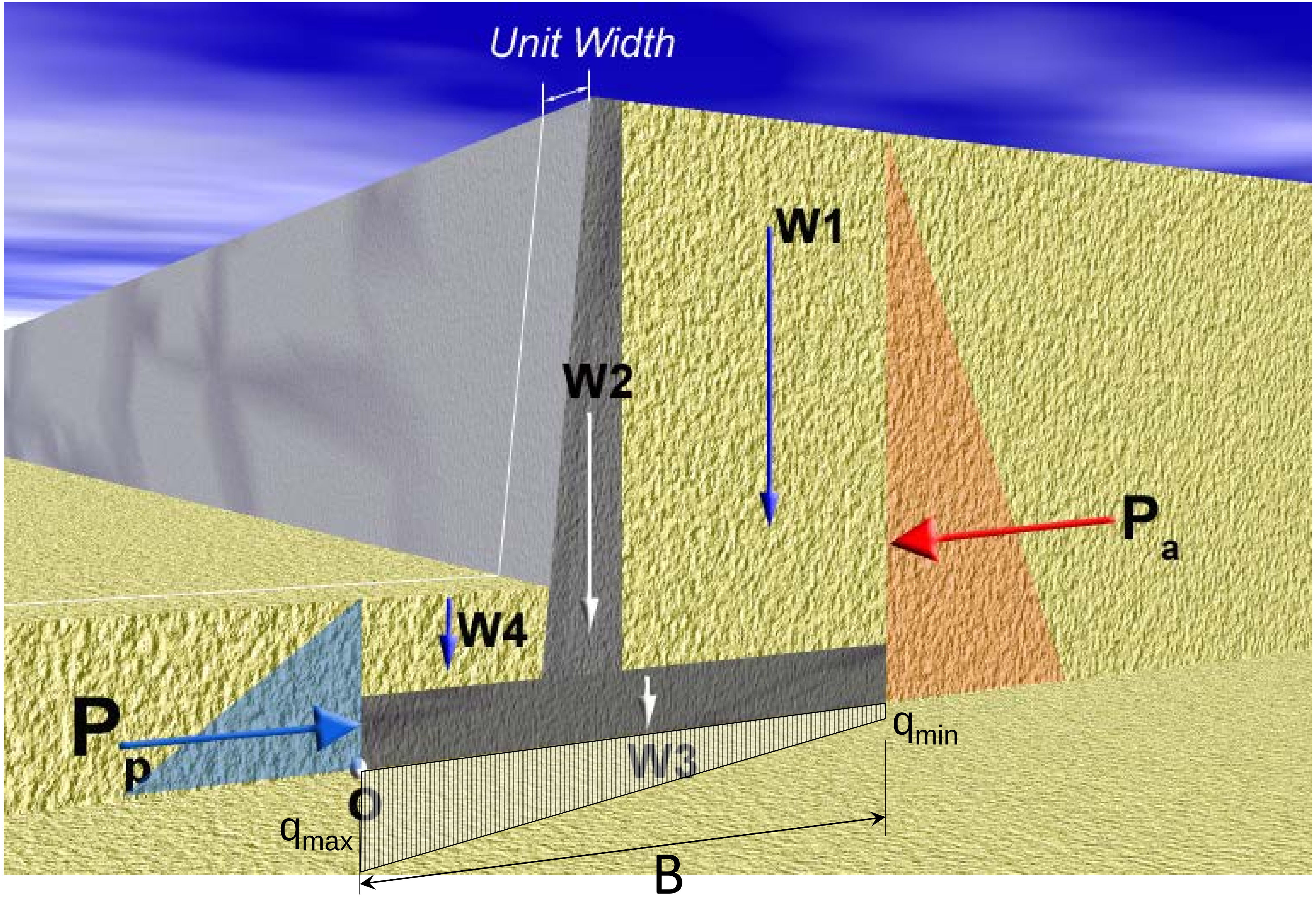
$M_D = P_a \cdot y_a$

$M_R = P_p . y_p + W_1 a_1 + W_2 a_2 + W_3 a_3 + W_4 a_4$

By: Kamal Tawfiq

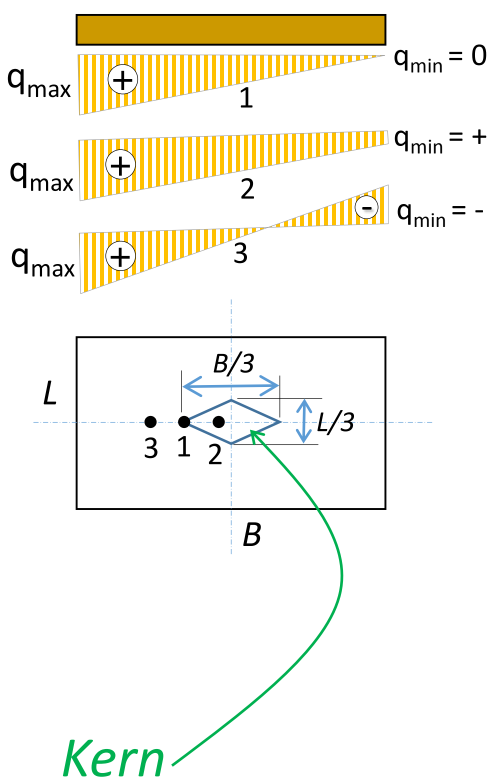
I. External Stability

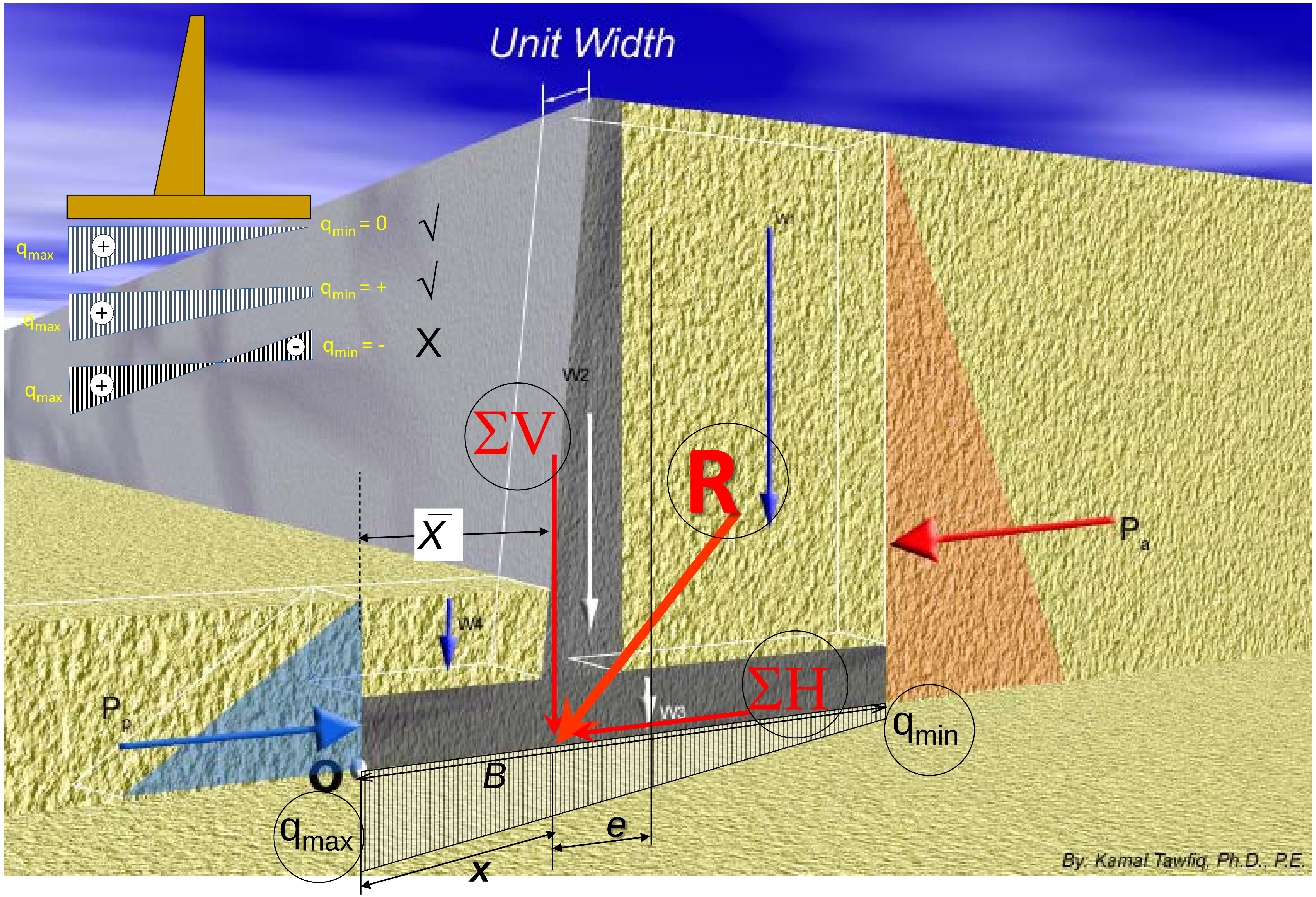
3- Bearing Capacity Failure



3- Check for Bearing Capacity Failure

Factor of Safety Against Bearing Capacity Failure = $\dfrac{q_{all}}{q_{max}}$





ΣV = sum of all vertical loads
ΣH = sum of all horizontal loads

$R = \sqrt{(\Sigma V)^2 + (\Sigma H)^2}$

$M_{net} = \Sigma M_R - \Sigma M_D$

$\Sigma V \, \bar{X} = M_{net}$

$e = \dfrac{B}{2} - \bar{X}$

$q = \dfrac{\Sigma V}{A} \pm \dfrac{M_{net}\, y}{I}$

$q_{\substack{max \\ min}} = \dfrac{\Sigma V}{B}\left(1 \pm \dfrac{6e}{B}\right)$

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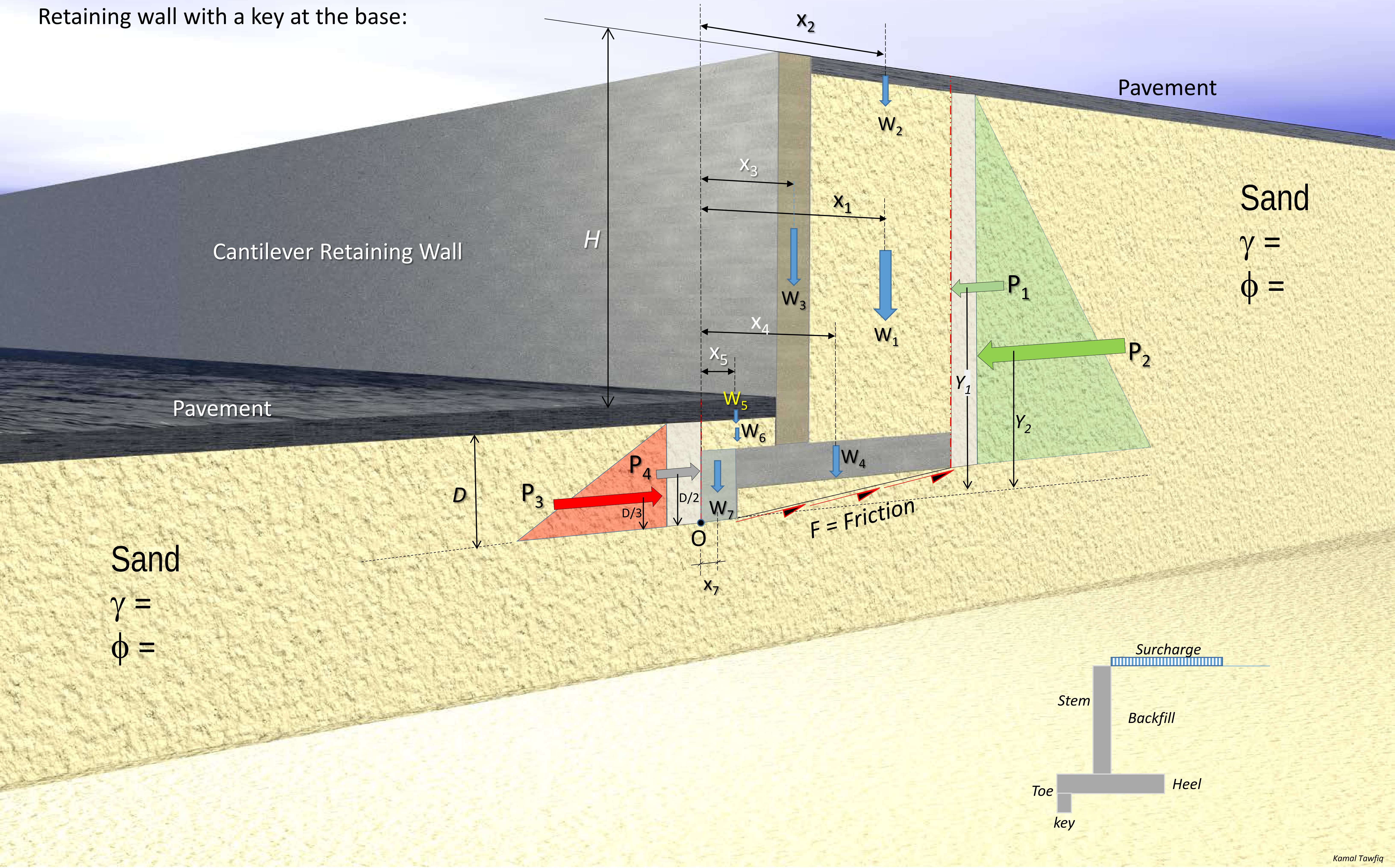
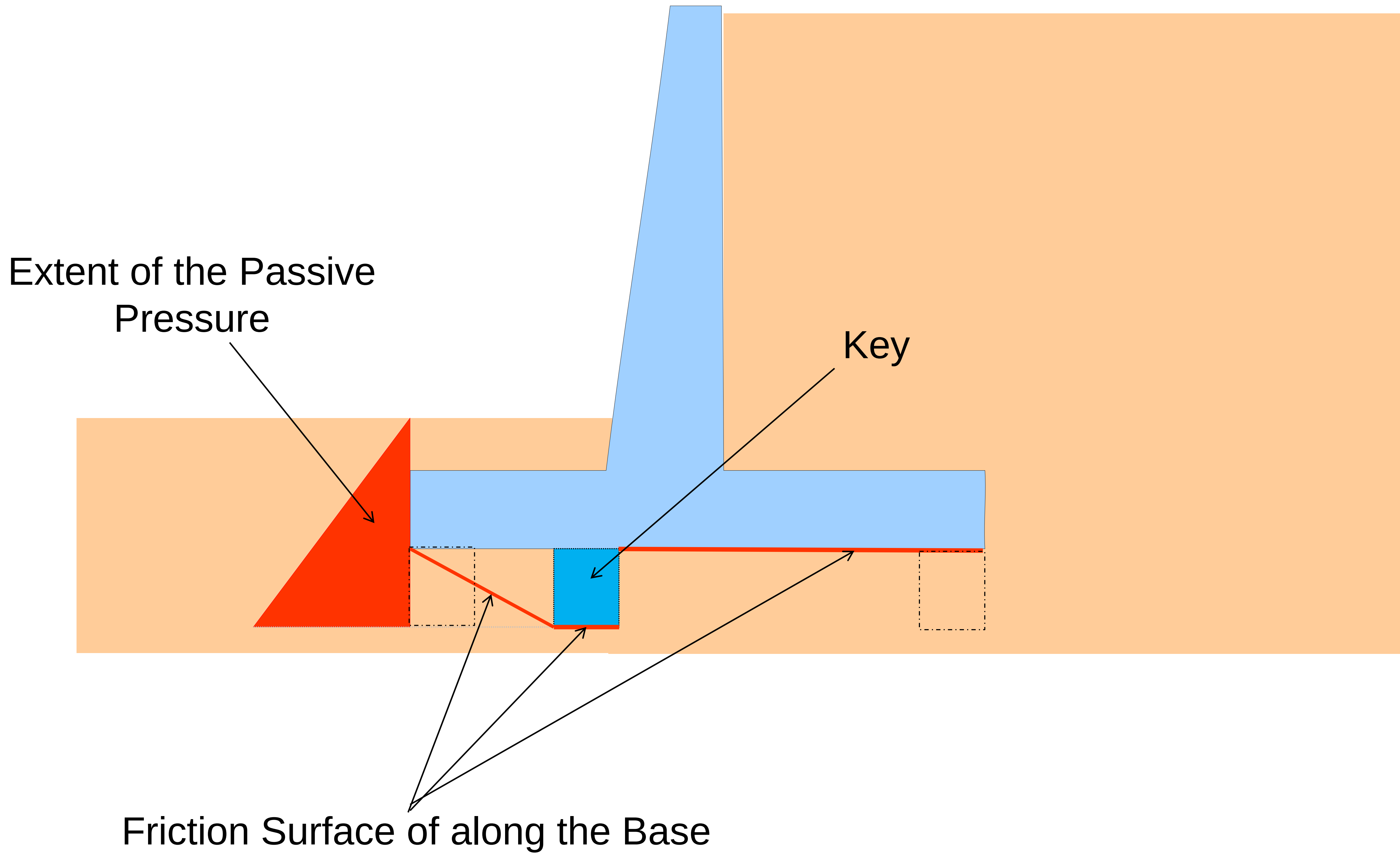
Retaining wall with a key at the base:



Using Key at the Base to Improve Sliding Resistance



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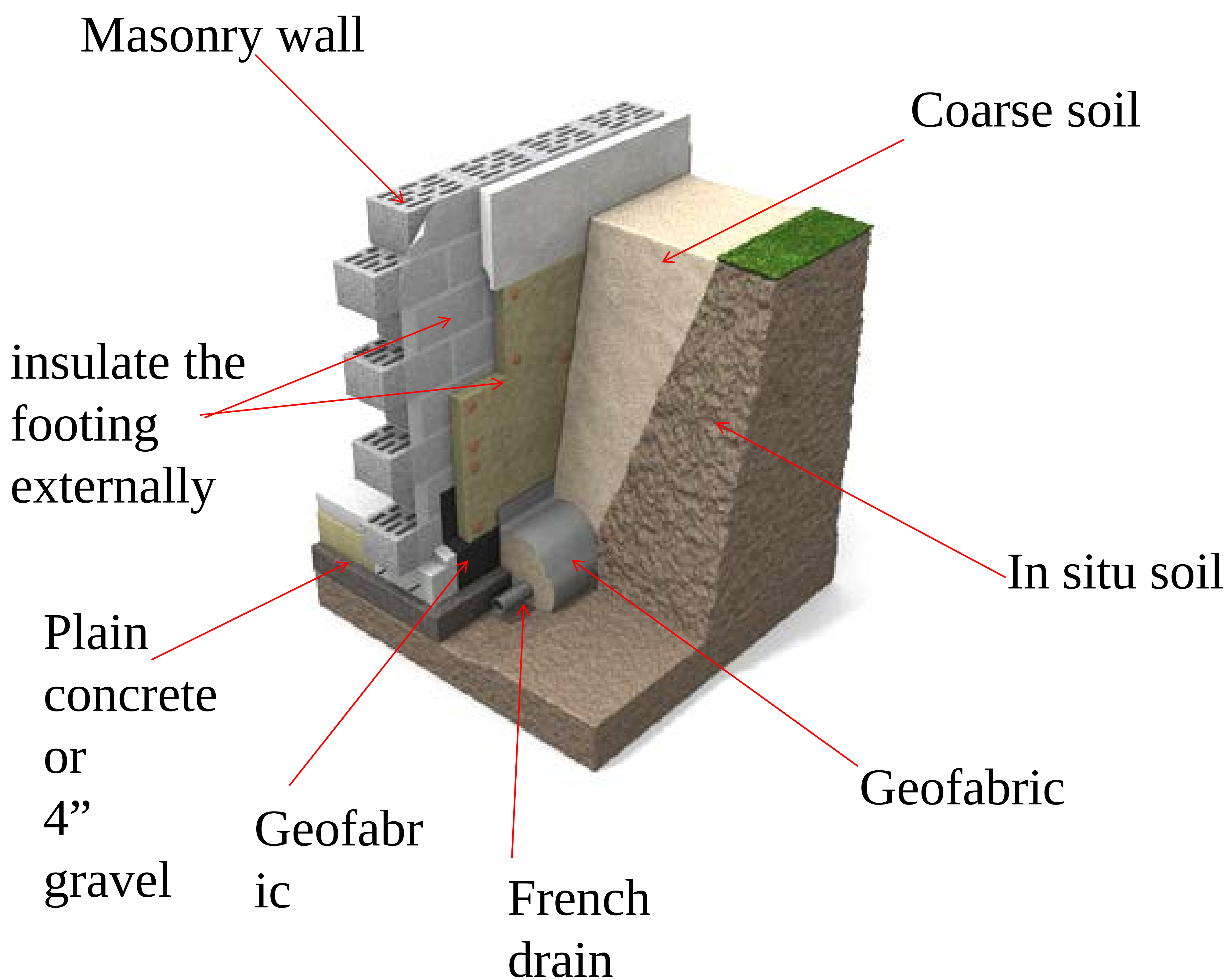
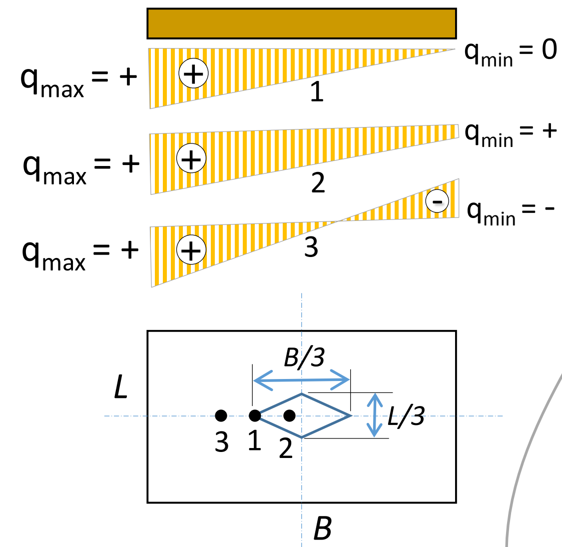

Masonry wall
Coarse soil
insulate the footing externally
In situ soil
Plain concrete or 4” gravel
Geofabric
French drain
Geofabric

Active Earth Pressure in ϕ – Soil

Example -1

Given:
- Vertical retaining wall (Rigid)
- Wall height (H) = 12 ft
- Backfill unit weight (γ) = 115 pcf
- Angle of soil friction (ϕ) = 30º
- Assume wall to be smooth
- Angle of friction between the base and the soil δ = 20º



Determine:
The stability of the wall

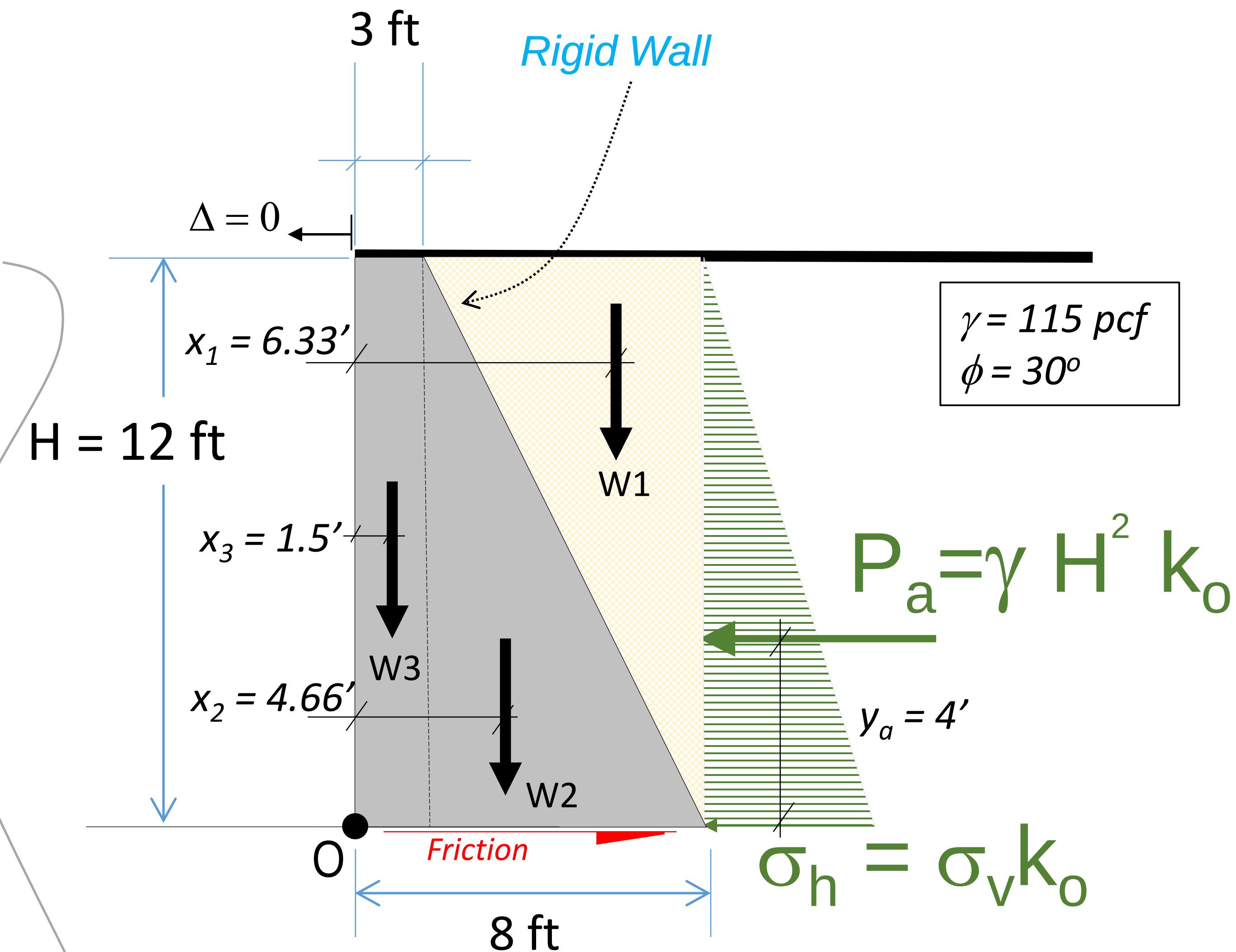
Solution:

$\sigma_h = \sigma_v k_o$ For Rigid Wall use k_o

$P_o = 0.5\ \gamma\ H^2 k_o$

$K_o = 1 - \sin\phi$

$P_o = 0.5 \times 115 \times 12^2 \times 0.5 = 4{,}140$ lb/ft



1- Factor of Safety Against Sliding

$$FS_{(sliding)} = \frac{\sum V \tan(20) + Pp}{P_a} \qquad P_p = 0$$

$$= \frac{[(13350)\tan 20^o]}{4140} = 1.2 > 1.5\ \ Not\ OK$$

2- Factor of Safety Against Overturning

$$FS_{(overturning)} = \frac{\sum M_R}{M_D} = \frac{50908.5}{16560} = 3.1 > 2\ OK$$

3- Factor of Safety Bearing Capacity Failure = $FS_{(BC)}$

$M_{net} = \sum M_R - \sum M_D$ = 50908.5 -13350 = 37558.5 ft.lb/ft

M_{net} = 37,558.5 = $\sum F_y(X)$ = 13350 (X)

$X = (M_{net} / \sum F_y)$ = 2.81 ft

e = (8/2) – 2.81 = 1.18 ft < B/6 or 8/6 = 1.33 (Full contact)

$$q_{max} = \frac{\sum F_y}{B}\left(1 + \frac{6\,e}{B}\right) = \frac{13350}{8}\left(1 + \frac{(6)(1.18)}{8}\right) = 3145.6\ \frac{lb}{ft^2} > q_{all} = 3{,}000\ \frac{lb}{ft^2}$$

$$q_{min} = \frac{\sum F_y}{B}\left(1 - \frac{6\,e}{B}\right) = \frac{13350}{8}\left(1 - \frac{(6)(1.18)}{8}\right) = 192\ \frac{lb}{ft^2}$$

X - Force (lb)/ft)	Vertical Distance (ft)	F_y (lb)/ft	Moment Arm X (ft)	Driving Moment (ft.lb)/ft	Resisting Moment (ft.lb)/ft
P_a= 4,140	4			4,140 x 4 = 16,560	
		W_1= 0.5x5x12x115 = 3,450	6.33		3,450x6.33=21,838.5
		W_2 =0.5x5x12x150 = 4,500	4.66		4,500x4.66 = 20,970
		W_3 = 3x12x150 = 5400	1.5		5,400 x 1.5 = 8,100
P_p = 0	0				o
		13,350		**16,560**	**50,908.5**

Kamal Tawfiq

Active & Passive Earth Pressure in ϕ – Soil

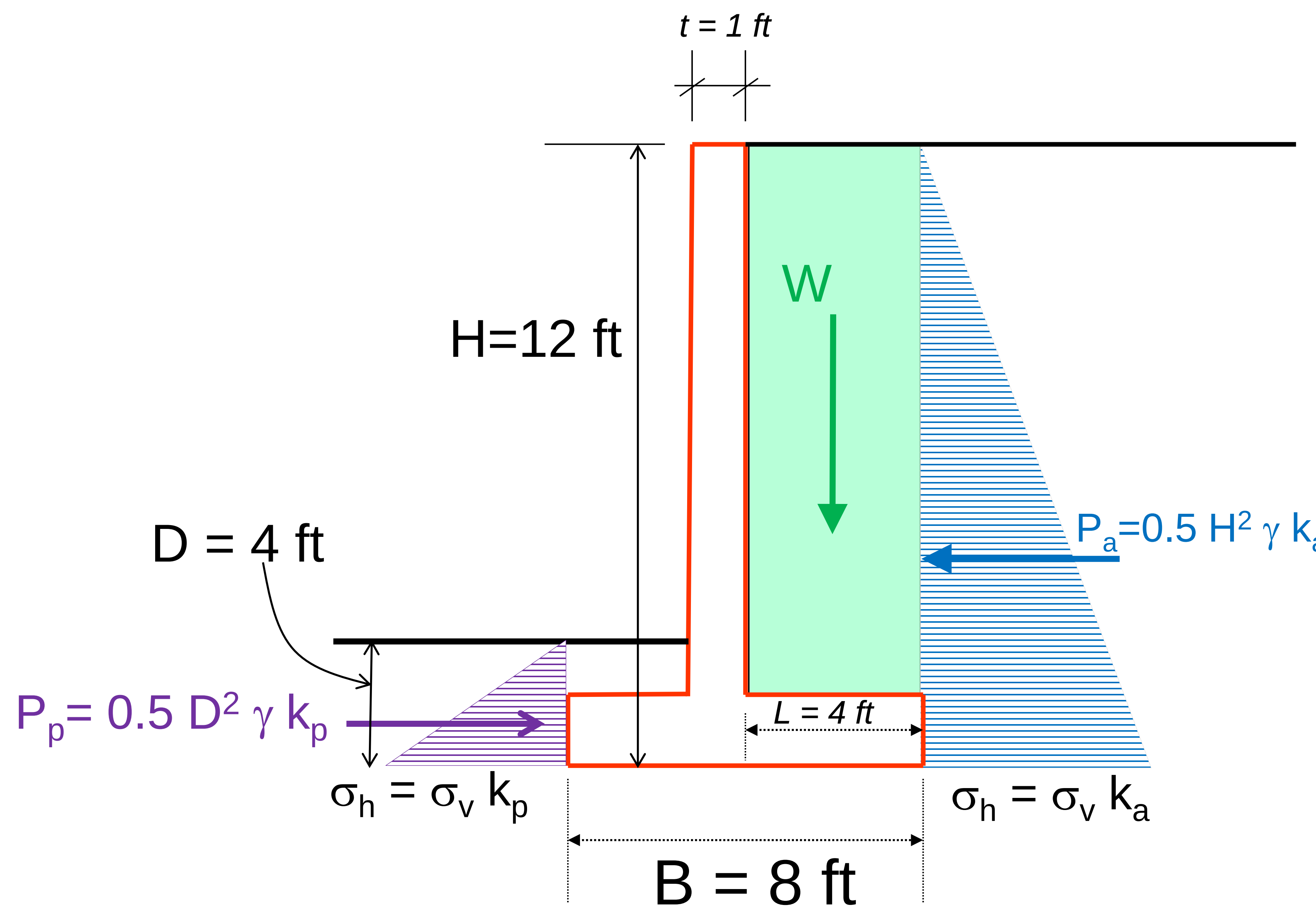
Example -2

Given:

- Vertical retaining wall (flexible)
- Wall height (H) = 12 ft
- Backfill unit weight (γ) = 115 pcf
- Angle of soil friction (ϕ) = 30°
- Assume wall to be smooth
- $\gamma_{concrete} = 150\ lb/ft^3$
- D = 4 ft

Find:

- Resultant Force of the Wall



Solution:

$$\sigma_h = \sigma_v\, k_a$$

$$K_a = \frac{1 - \sin\phi}{1 + \sin\phi} \qquad K_p = \frac{1 + \sin\phi}{1 - \sin\phi}$$

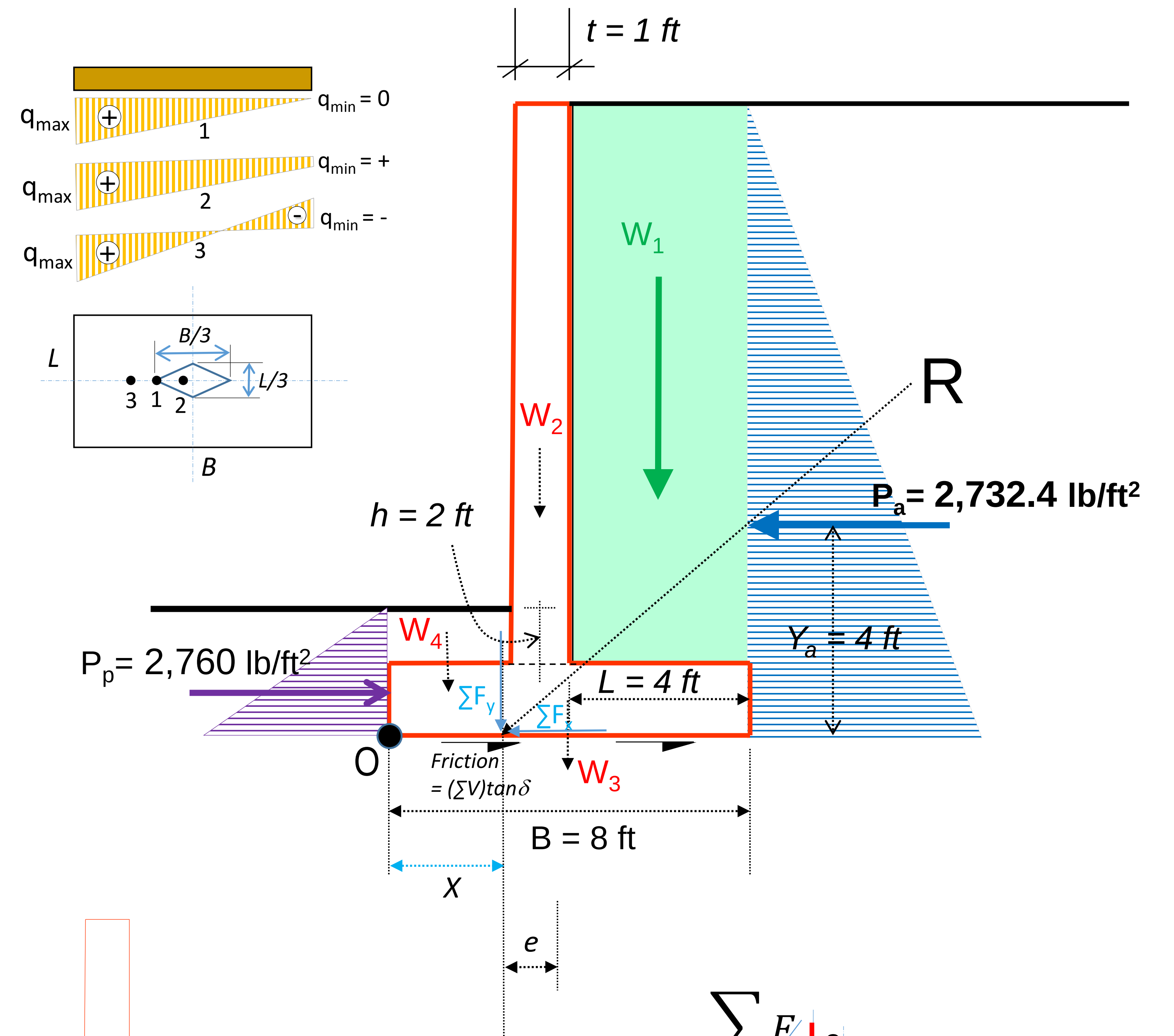
$$P_a = 0.5\, \gamma\, H^2\, k_a$$

$$P_a = 0.5 \times 12^2 \times 115 \times 0.33 = 2{,}732.4\ lb/ft^2$$

$$P_p = 0.5\, D^2\, \gamma\, k_p$$

$$P_p = 0.5 \times 4^2 \times 115 \times 3 = 2{,}760\ lb/ft^2$$

F_x (lb)/ft	Y (ft)	F_y (lb)/ft	Moment Arm X (ft)	Driving Moment (ft.lb)/ft	Resisting M (ft.lb)/ft
P_a= 2,732.4	4			2,732.4x4 = 10,929.6	
		W_1= 4x10x115 = 4,600	6		4600x6=27,600
		W_2 =1x10x150 = 1,500	3.5		1,500x3.5=5,250
		W_3 = 8x1x150=1,200	4		1,200x4=4,800
		W_4 =2x3x115 = 690	1.5		690x1.5= 1,035
P_p= 2,760	1.33				2,760x1.33= 3,680
		7,990		**10,929.6**	**42,365**



1- Factor of Safety Against Sliding = $FS_{(sliding)} = \frac{\sum F_y \tan(20)+Pp}{P_a} = \frac{[(7{,}990)\tan 20^o]+2{,}760}{2{,}732.4} = 2.1 > 1.5\ OK$

2- Factor of Safety Against Overturning = $FS_{(overturning)} = \frac{\sum M_{Resisting}}{M_{Driving}} = \frac{42{,}365}{10{,}929.6} = 3.8 > 2\ OK$

3- Factor of Safety Bearing Capacity Failure = $FS_{(BC)}$

$M_{net} = \sum M_r - \sum M_o$ = 42,365 -10,929.6 = 31,435.4 ft.lb/ft

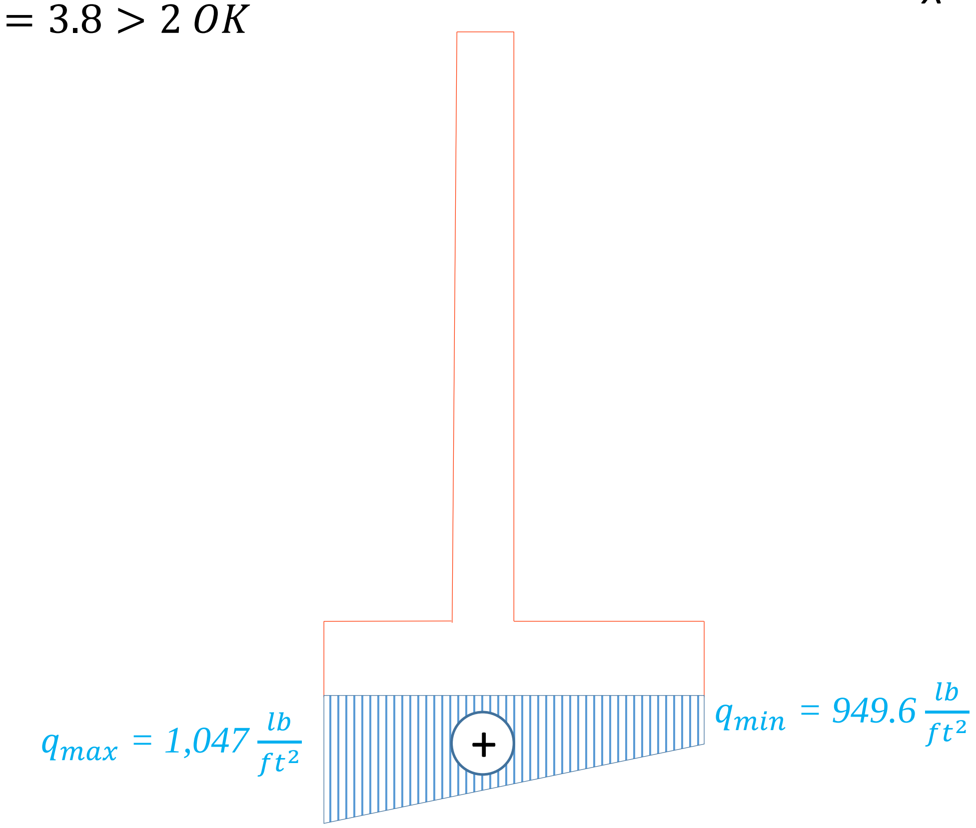
M_{net} = 31,435.4 = $\sum F_y(X)$ = 7,990.(X)

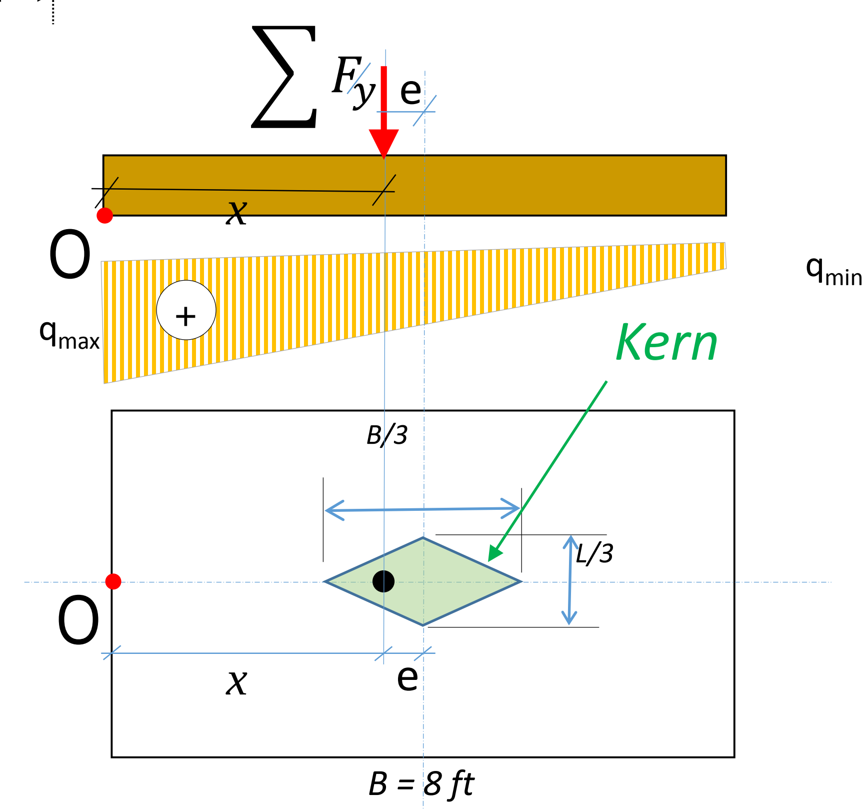
$X = (M_{net} / \sum F_y)$ = 3.93 ft

e = (8/2) – 3.93 = 0.0656 ft < B/6 or 8/6 = 1.33 (Full contact)

$$q_{max} = \frac{\sum F_y}{B}\left(1+\frac{6\,e}{B}\right) = \frac{7{,}990}{8}\left(1+\frac{(6)(0.0656)}{8}\right) = 1{,}047.8\,\frac{lb}{ft^2} < \quad q_{all} = 3{,}000\,\frac{lb}{ft^2}$$

$$q_{min} = \frac{\sum F_y}{B}\left(1-\frac{6\,e}{B}\right) = \frac{7{,}990}{8}\left(1-\frac{(6)(0.0656)}{8}\right) = 949.6\,\frac{lb}{ft^2}$$

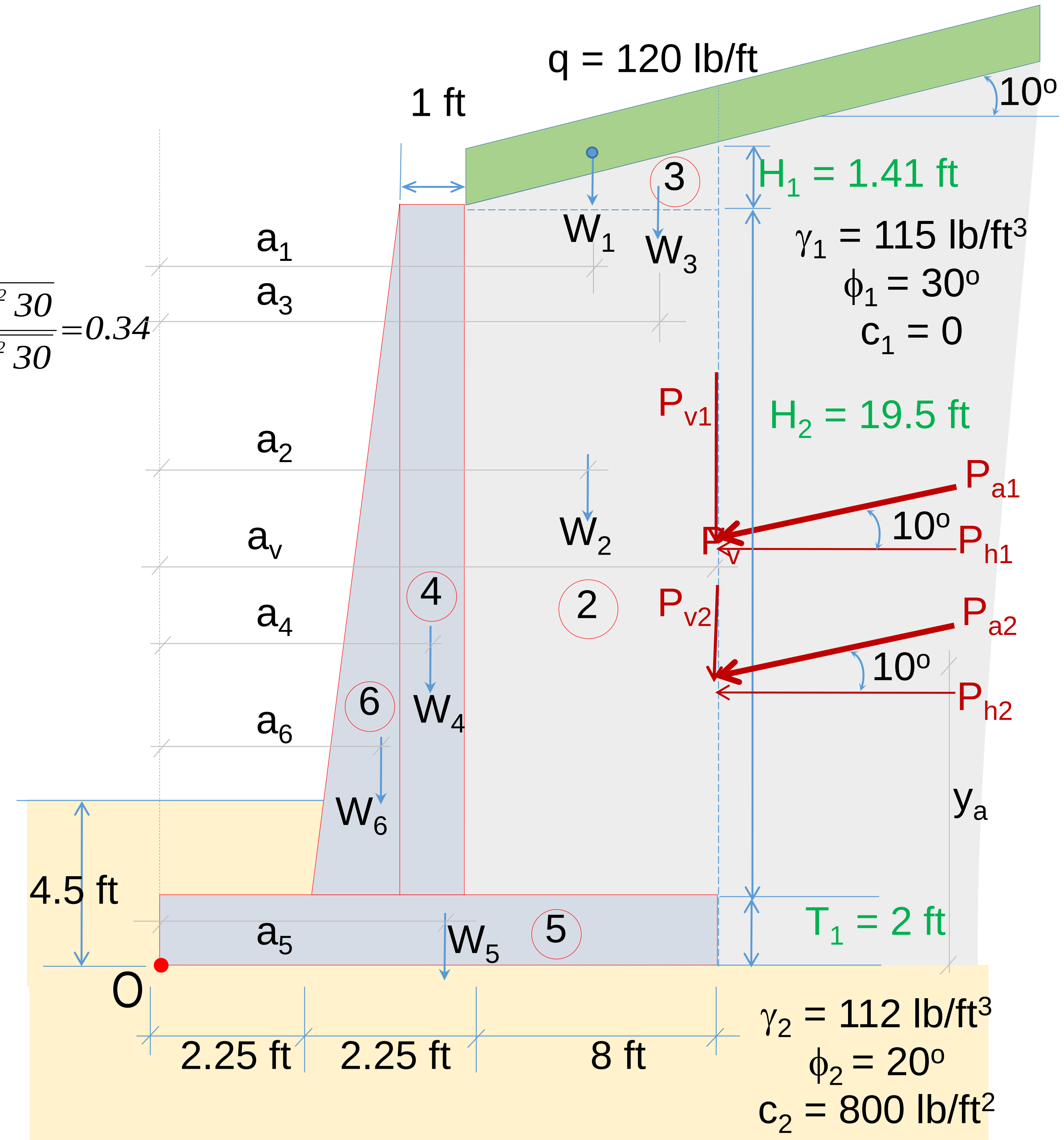




Example 1

Given

The cross section of a cantilever retaining wall is shown in Figure 1. Calculate the factors of safety with respect to overturning, sliding, and bearing capacity.



Solution

From the figure,

$H^* = H_1 + H_2 + T_1 = 8 \tan 10° + 19.5 + 2 = 22.91$ ft

The Rankine active force per unit length of wall =

$$K_a = \cos\alpha \frac{\cos\alpha - \sqrt{\cos^2\alpha - \cos^2\phi}}{\cos\alpha + \sqrt{\cos^2\alpha - \cos^2\phi}} \qquad K_a = \cos 10 \frac{\cos 10 - \sqrt{\cos^2 10 - \cos^2 30}}{\cos 10 + \sqrt{\cos^2 10 - \cos^2 30}} = 0.34$$

$$P_a = \textit{Lateral Pressure from Surcharge} + \textit{Lateral Pressure from Soil}$$

$$P_{a1} = q H^* k_a$$

$$P_{a2} = \frac{1}{2}\gamma H^{*2} k_a$$

$$P_{a1} = 120x22.9x0.34 = 934.32\, lb/ft$$

$$P_{v1} = 934.32 \sin(10^o) = 162.24\ lb/ft$$

$$P_{h1} = 934.32 \cos(10^o) = 920.13\ lb/ft$$

$$Y_{a1} = \frac{22.9}{2} = 11.45\ ft$$

$$P_{a2} = 0.5x115x22.9^2x0.34 = 10252.22 = 11186.54\, lb/ft$$

$$P_{v2} = 10{,}252.2 \sin(10^o) = 1780.28\ lb/ft$$

$$P_{h2} = 10{,}252.2 \cos(10^o) = 10096.45\ lb/ft$$

$$Y_{a1} = \frac{22.9}{3} = 7.63\ ft$$

Driving Pressure $(lb/ft^2)/ft$	Resisting Pressure $(lb/ft^2)/ft$	Weight/Unit Length (lb/ft)	Moment Arm from Point O (ft)	Driving Moment (ft.lb/ft)	Resisting Moment (ft.lb/ft)
P_{h1} = 920.13			11.45	920.13x11.45 = 10535.49	
P_{h2} = 10096.45			7.64	10096.45x7.64 = 77136.88	
		W_1 = 120 x 8 = 960	8.5		960x8.5 = 8,160
		W_2 = 8X19.2X112 = 17,203.2	8.5		17,203.2x8.5 = 146,227.2
		W_3 = 0.5X1.41X8X112 = 631.7	9.83		631.7x9.83 = 6,209.6
		W_4 = 1X19.5X150 = 2,925	4.0		2925x4 = 11,700
		W_5 = 12.5X2X150 = 3,750	6.25		3750x6.25 = 23,437.5
		W_6 = 0.5X1.25X19.2X150 = 1,800	3.08		1800x3.08 = 5,544
		∑Pv = 162.24+1780.28 = 1,942.52	12.5		1942.52x12.5 = 24,281.5
$\sum P_h$ = 11,016.58	0	$\sum F_y$ = 29,212.4		$\sum M_D$ = 87,672.37	$\sum M_R$ = 225,559.86

1- Factor of Safety Against Sliding = $FS_{(sliding)} = \frac{\sum F_y \tan(20)+Pp}{P_a} = \frac{[(29{,}212.4)\tan 20^o]+0}{11{,}016.58} = 0.96 < 1.5 \ \ Not\ OK$

Add Passive Resistance

$P_p = 0.5 \times 4.5^2 \times 115 \times 3 = 3493.13$ lb/ft

2- Factor of Safety Against Sliding = $FS_{(sliding)} = \frac{\sum F_y \tan(20)+Pp}{P_a} = \frac{[(29{,}212.4)\tan 20^o]+3493.13}{11{,}016.58} = 1.28 < 1.5 \ \ Not\ OK$

3- Factor of Safety Against Overturning = $FS_{(overturning)} = \frac{\sum M_R}{\sum M_D} = \frac{225{,}559.86}{87{,}672.37} = 2.57 > 20 \quad OK$

4- Factor of Safety Bearing Capacity Failure = $FS_{(BC)}$ =

$M_{net} = \sum M_R - \sum M_D = 225{,}559.86 - 87{,}672.37 = 137{,}887.5$ ft.lb/ft

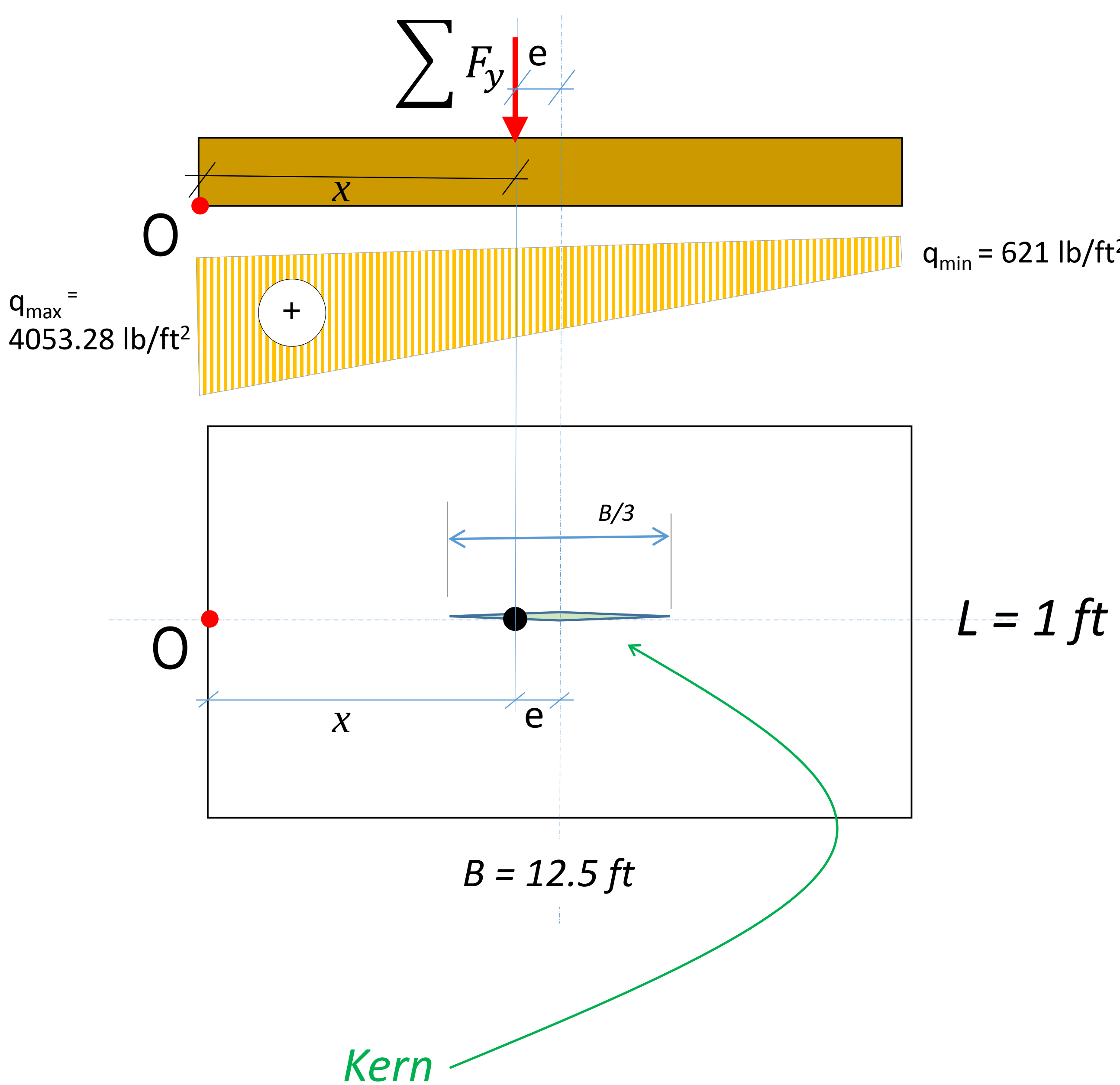
$M_{net} = 137{,}887.5 = \sum F_y(X) = 29{,}212.4\ (X)$

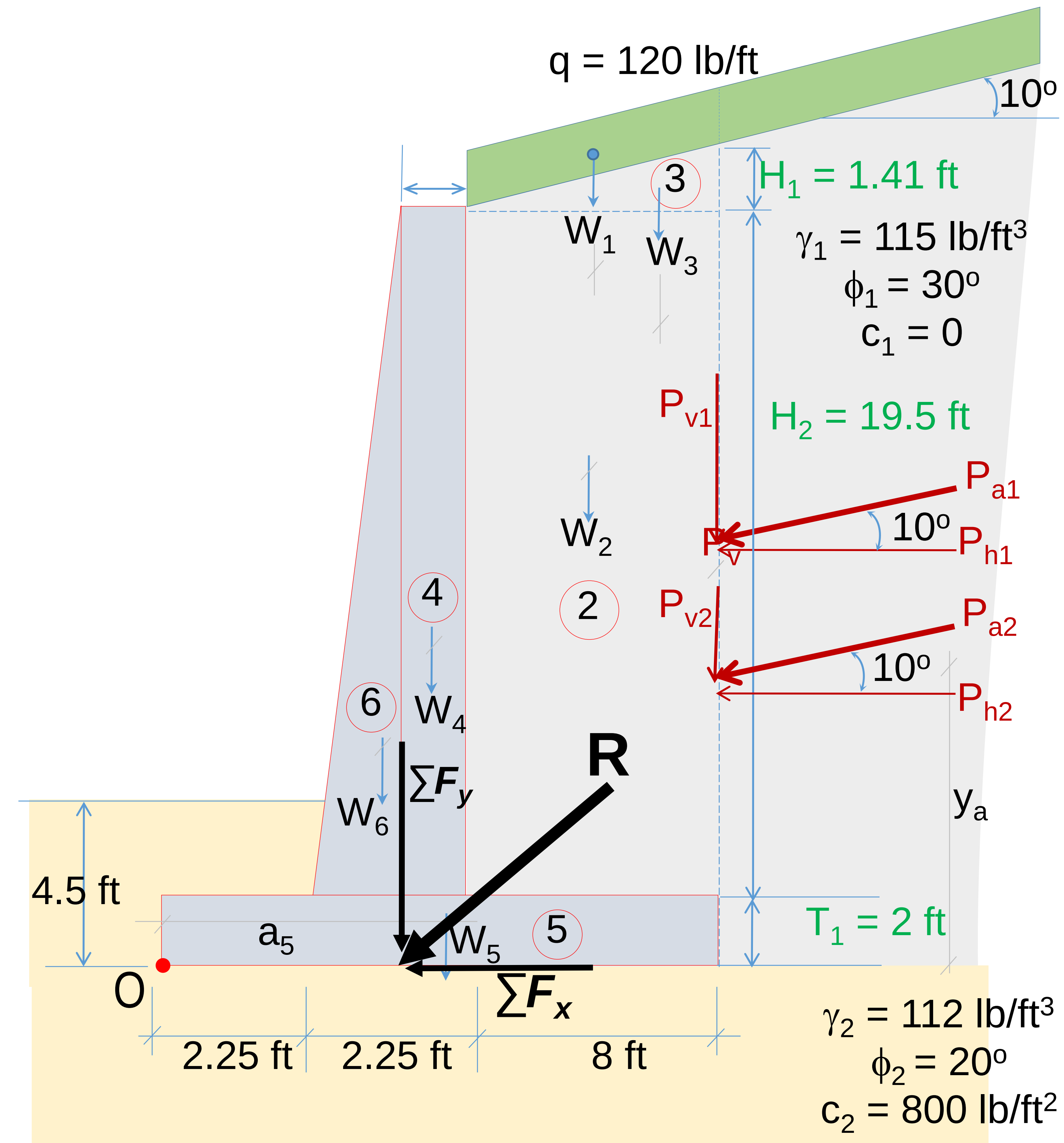
$X = (M_{net} / \sum F_y) = 4.72$ ft

e = (12.5/2) – 4.72 = 1.53 ft < B/6 or 12.5/6 = 2.083 (Full contact)

$$q_{max} = \frac{\sum F_y}{B}\left(1 + \frac{6\,e}{B}\right) = \frac{29{,}212.4}{12.5}\left(1 + \frac{(6)(1.53)}{12.5}\right) = 4053.28\,\frac{lb}{ft^2} > \quad q_{all} = 3{,}000\,\frac{lb}{ft^2}$$ No good

$$q_{min} = \frac{\sum F_y}{B}\left(1 - \frac{6\,e}{B}\right) = \frac{29{,}212.4}{12.5}\left(1 - \frac{(6)(1.53)}{12.5}\right) = 621\,\frac{lb}{ft^2}$$





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