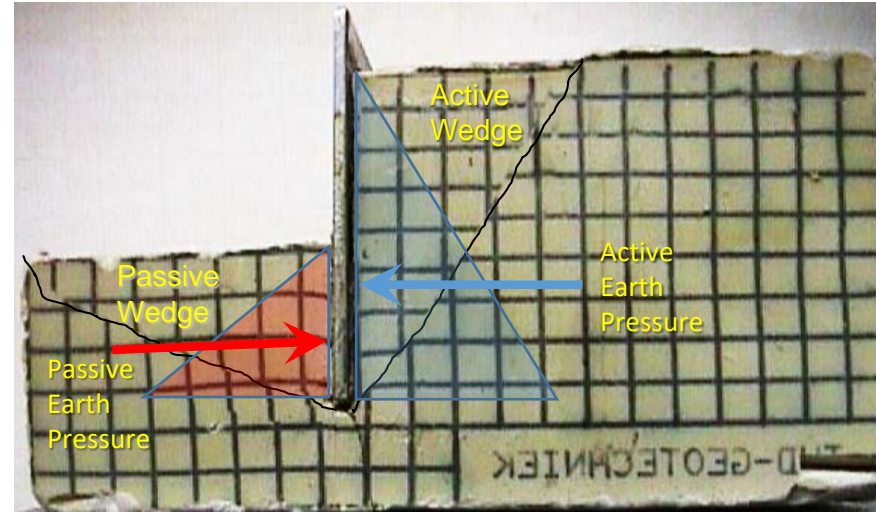
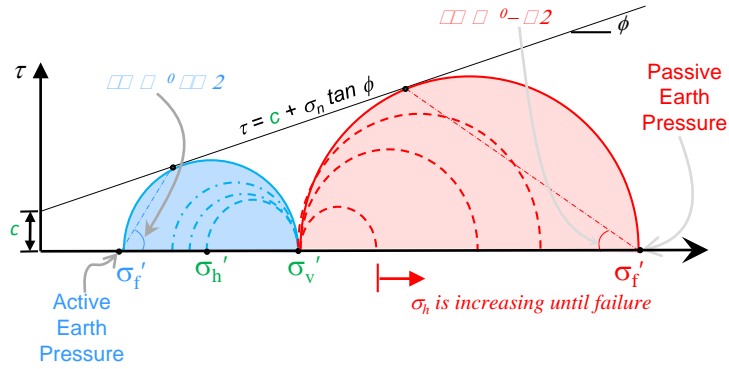
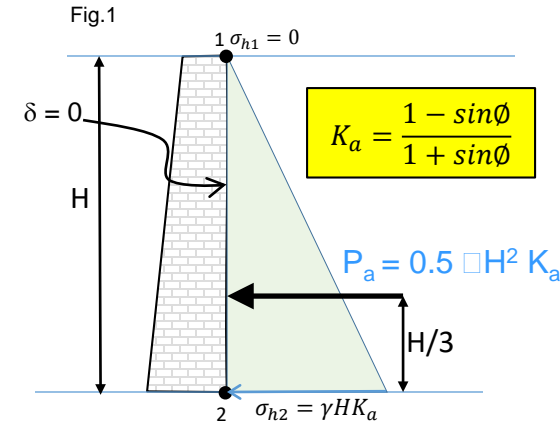


# Rankine's Earth Pressure Method for (c-φ) Soil

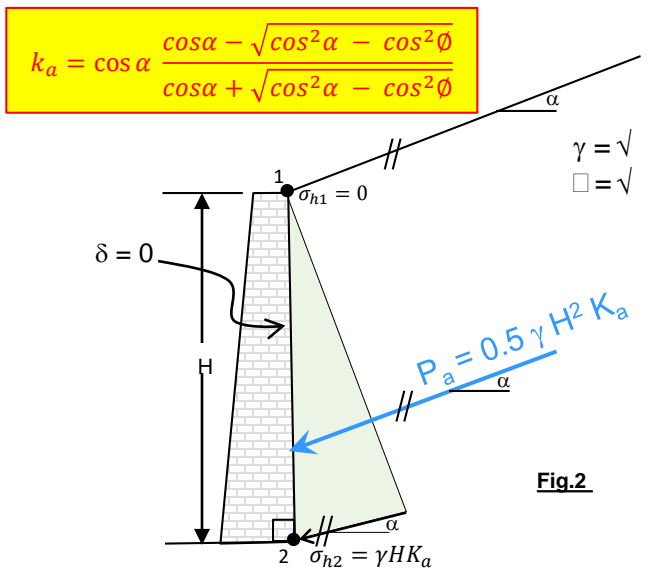
Rankine's Active and Passive Earth Pressure in (c-φ) Soil



Rankine's Active Earth Pressure in (φ) Soil



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



## Active Earth Pressure

$$\sigma_f' = \sigma_v' \tan^2 \left( 45^\circ - \frac{\phi}{2} \right) + 2c \tan \left( 45^\circ - \frac{\phi}{2} \right)$$

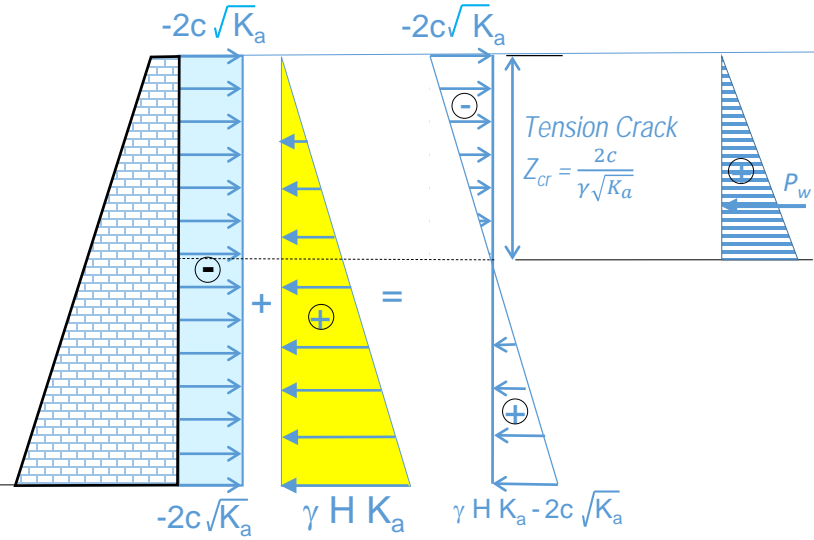
Or

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

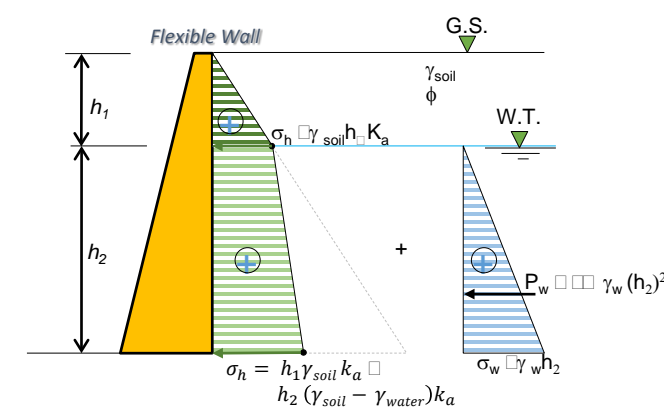
$$K_a = \tan^2 \left( 45^\circ - \frac{\phi}{2} \right) = \frac{1 - \sin \phi}{1 + \sin \phi}$$

Coefficient of active earth pressure

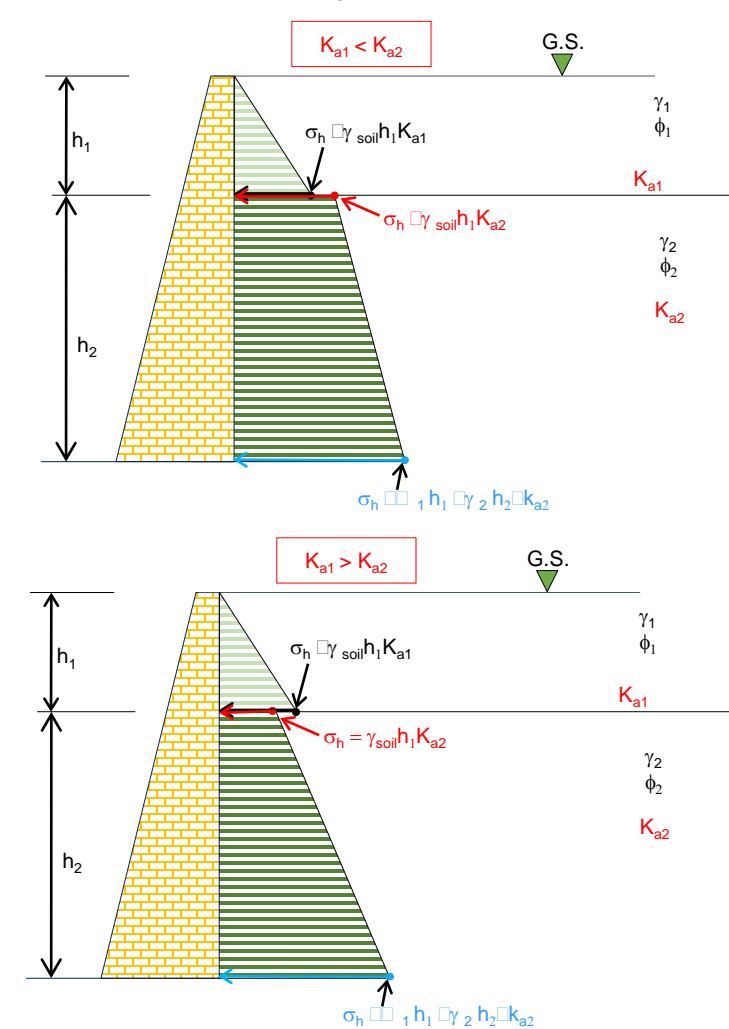
Effect of Cohesion of the Rankine's Active and Passive Earth Pressure



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



Effect of Two Soil Layers on Active Earth Pressure



## Passive Earth Pressure

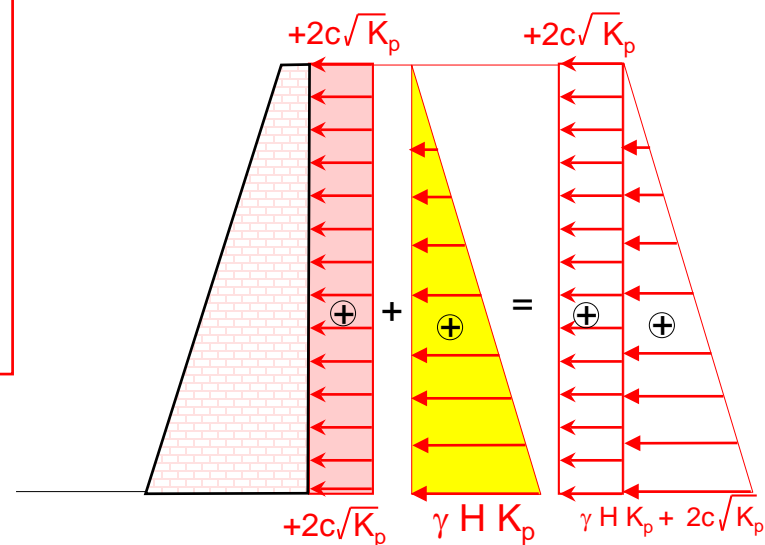
$$\sigma_f' = \sigma_v' \tan^2 \left( 45^\circ + \frac{\phi}{2} \right) + 2c \tan \left( 45^\circ + \frac{\phi}{2} \right)$$

Or

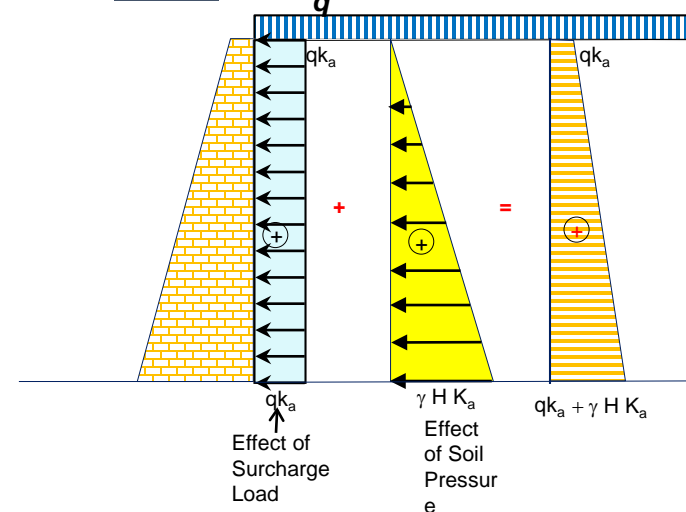
$$\sigma_f' = \sigma_v' K_p + 2c \sqrt{K_p}$$

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

Coefficient of passive earth pressure



Effect of Surcharge (q) Load on Active Earth Pressure



# COULOMB'S WEDGE THEORY

**W** = weight of the soil wedge  
**R** = resultant of the shear and normal forces on the failure surface BC  
**P<sub>a</sub>** = the active force per unit length of the wall. The direction of P<sub>a</sub> is inclined at an angle  $\psi$  to the normal drawn and the face of the wall that supports the soil  
 **$\delta$**  = the angle of friction between the soil and the wall

$$W = \gamma (\text{area of wedge } ABC)$$

From the triangles of forces,

$$\frac{P_a}{\sin(\theta - \phi)} = \frac{W}{\sin(180^\circ - \psi - \theta + \phi)}$$

$$P_a = \frac{W \sin(\theta - \phi)}{\sin(180^\circ - \psi - \theta + \phi)}$$

Substituting for W,

$$P_a = \frac{1}{2} \cdot \frac{\gamma H^2}{\sin^2 \alpha} \cdot \frac{\sin(\theta - \phi)}{\sin(180^\circ - \psi - \theta + \phi)} \cdot \frac{\sin(\theta + \alpha) \cdot \sin(\alpha + \beta)}{\sin(\theta - \beta)}$$

The maximum value of P<sub>a</sub> is obtained by equating the first derivative of P<sub>a</sub> with respect to  $\theta$  to zero; or

$(\partial P_a) / \partial \theta = 0$ , and substituting the corresponding value of  $\theta$ .

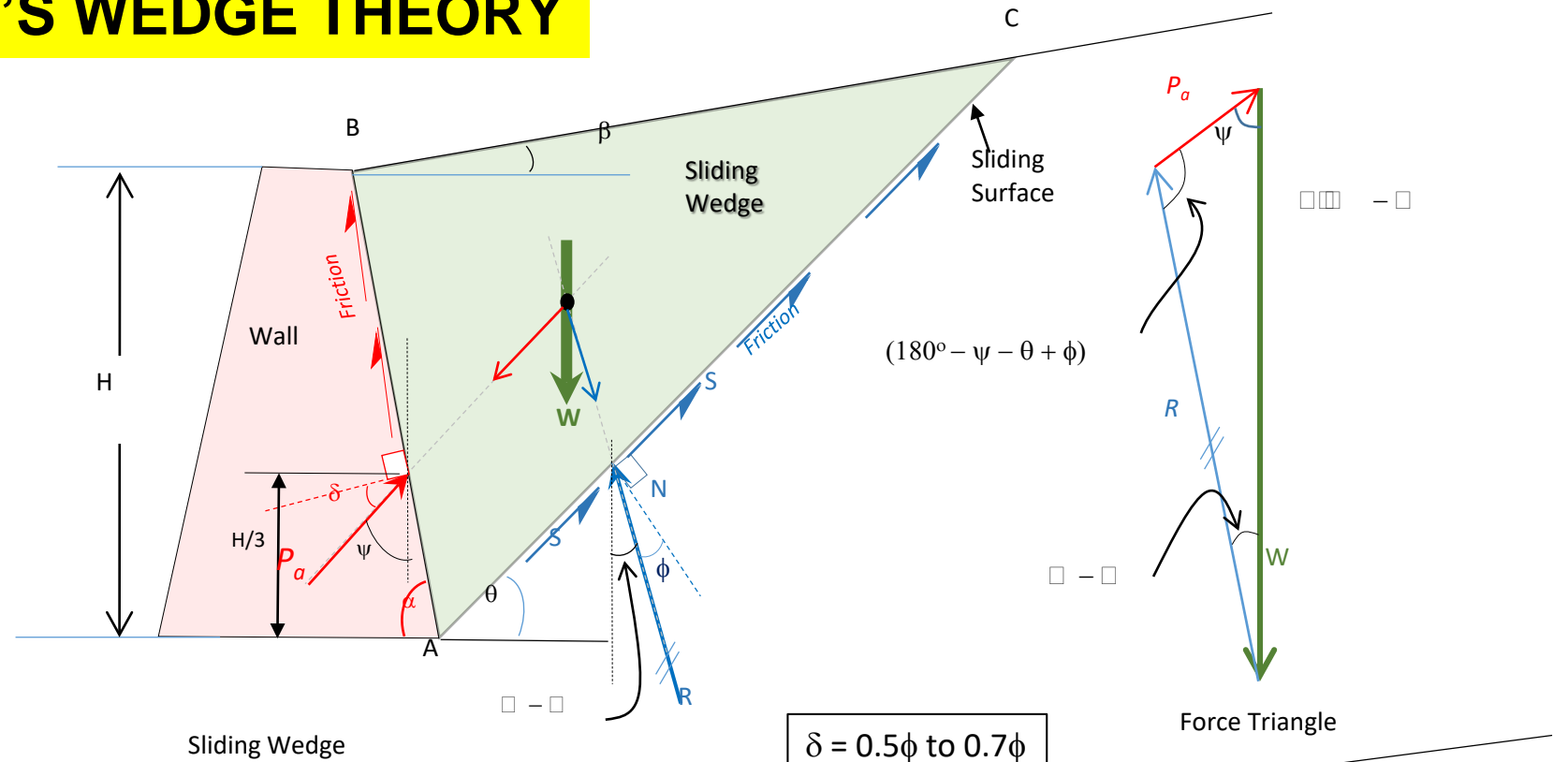
The value of P<sub>a</sub> so obtained is written as

$$P_a = \frac{1}{2} \cdot \gamma H^2 \cdot \frac{\sin^2(\alpha + \phi)}{\sin^2 \alpha \sin(\alpha - \delta) \left[ 1 + \sqrt{\frac{\sin(\phi + \delta) \sin(\phi - \beta)}{\sin(\alpha - \delta) \sin(\alpha + \beta)}} \right]^2}$$

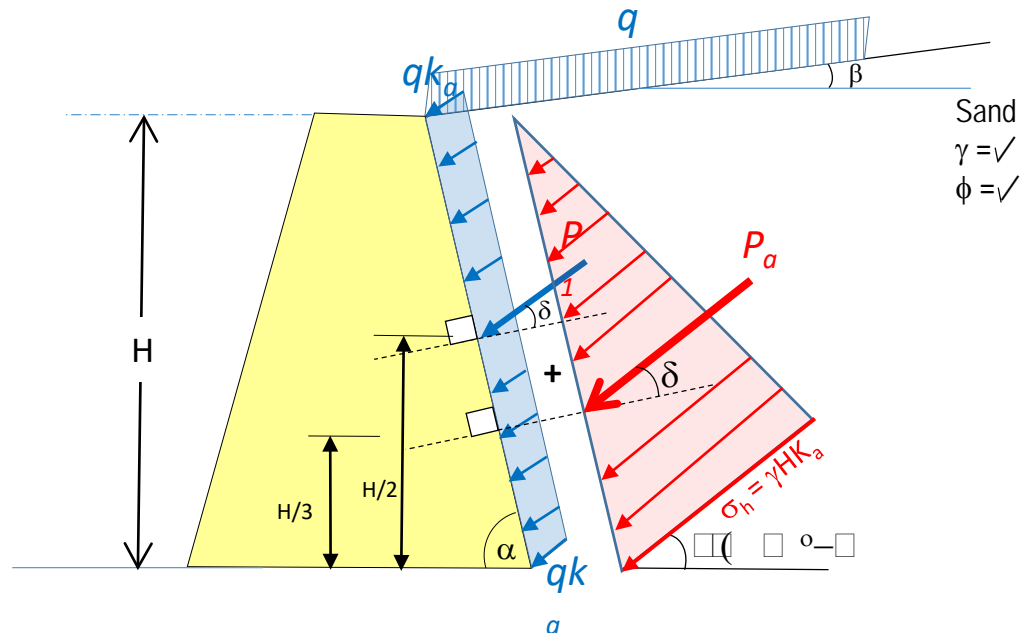
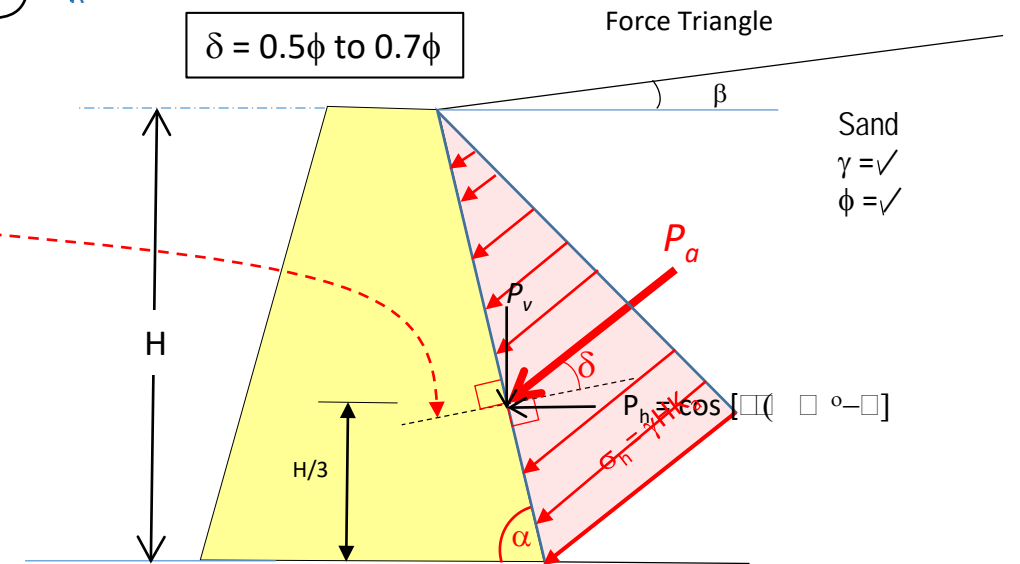
This is usually written as

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

Where  $K_a$  being the coefficient of active earth pressure = 
$$\frac{\sin^2(\alpha + \phi)}{\sin^2 \alpha \sin(\alpha - \delta) \left[ 1 + \sqrt{\frac{\sin(\phi + \delta) \sin(\phi - \beta)}{\sin(\alpha - \delta) \sin(\alpha + \beta)}} \right]^2}$$



- Draw this perpendicular line first
- Then draw P<sub>a</sub> with an angle =  $\alpha$





# Earth Retaining Walls

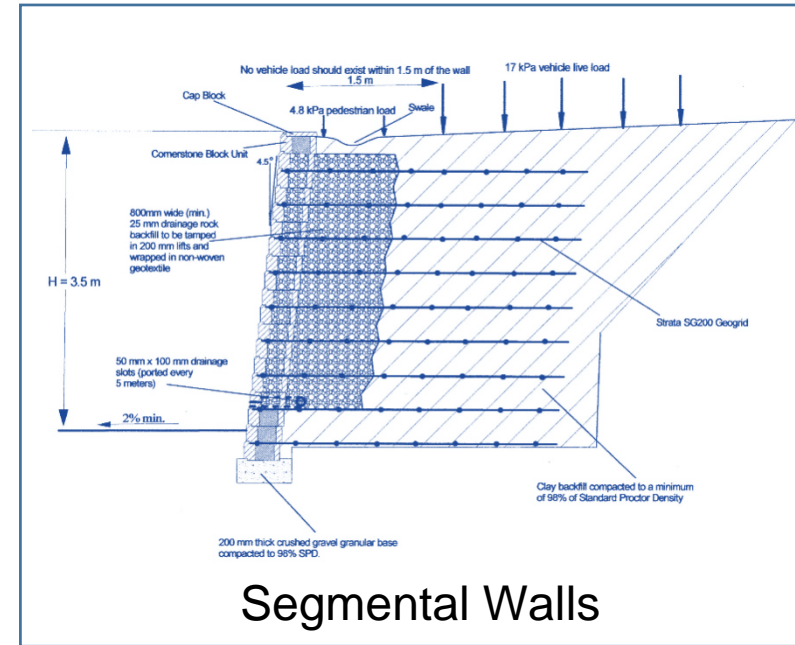
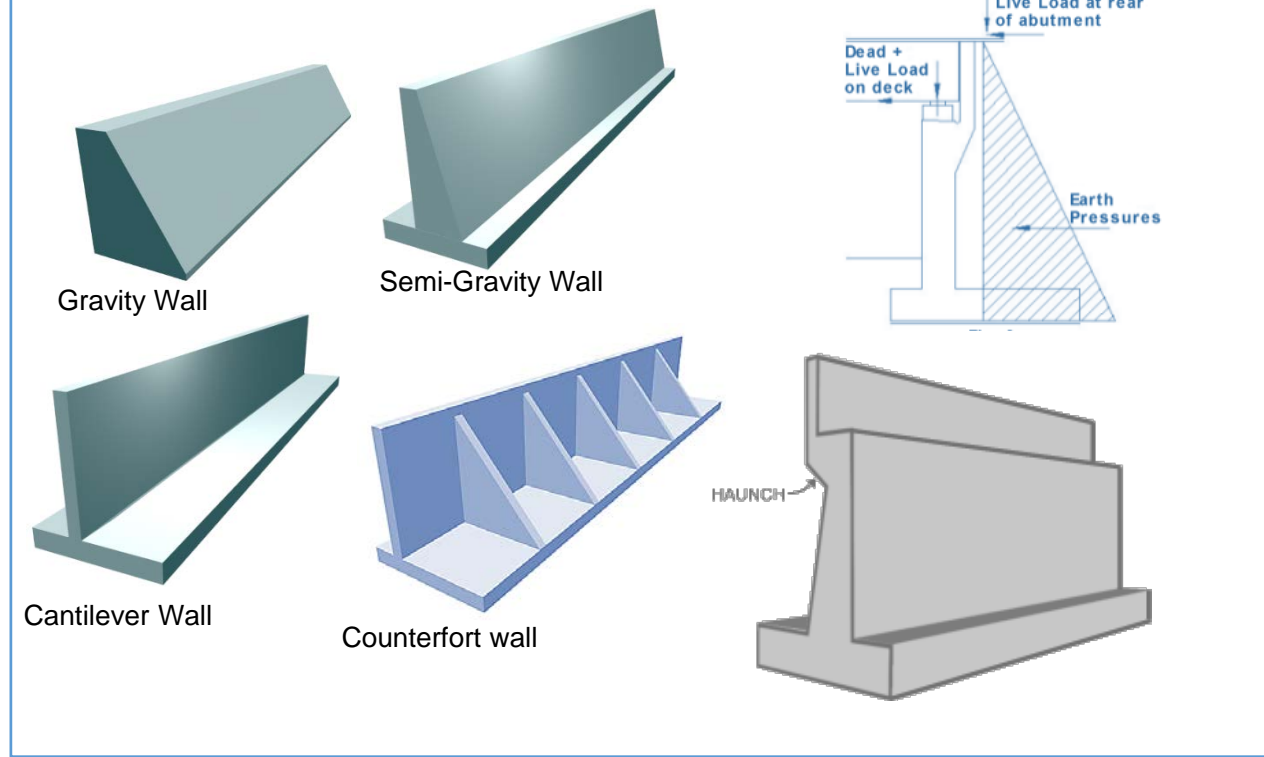




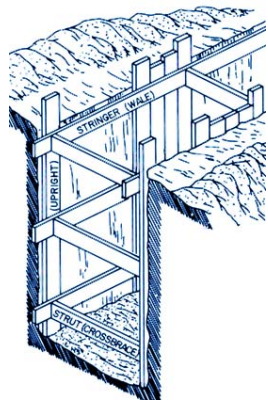
# Design of Retaining Wall

## Types of Earth Retaining Walls

### I- Permanent Walls



### II- Temporary Walls



Braced cuts



Sheet pile wall



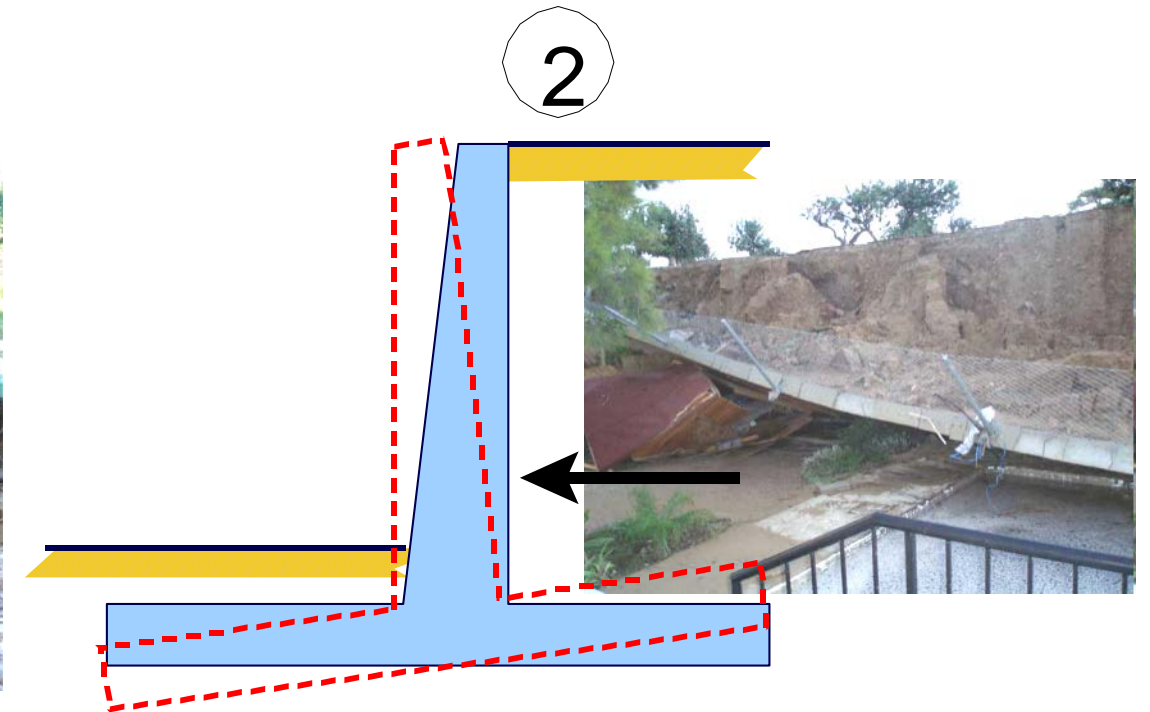
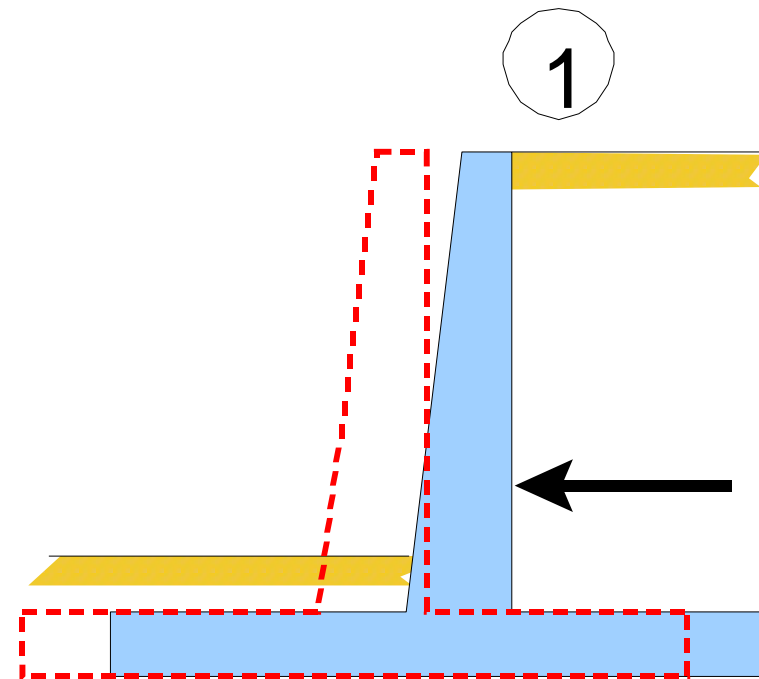
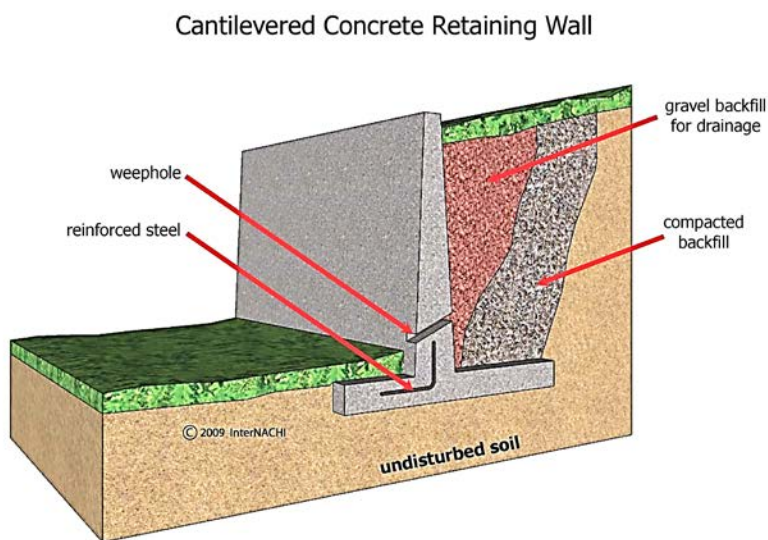


# Design of Retaining Wall

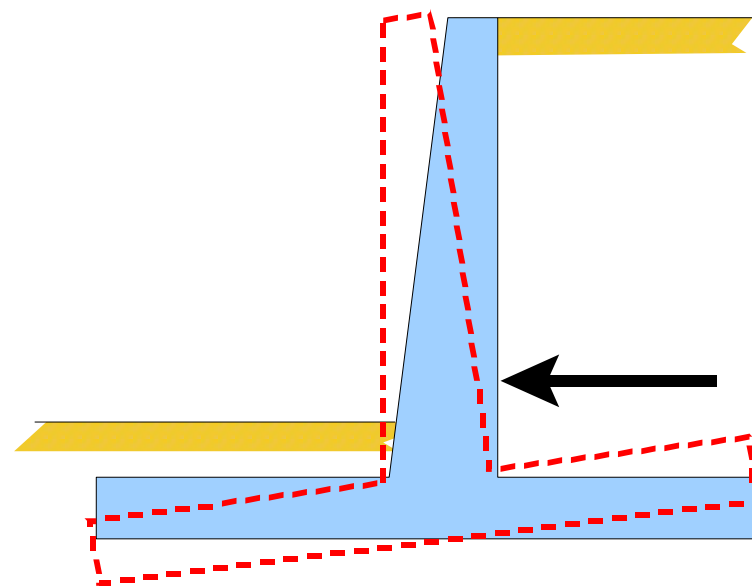
- 1- External Stability
- 2- Internal Stability

## 1. External Stability

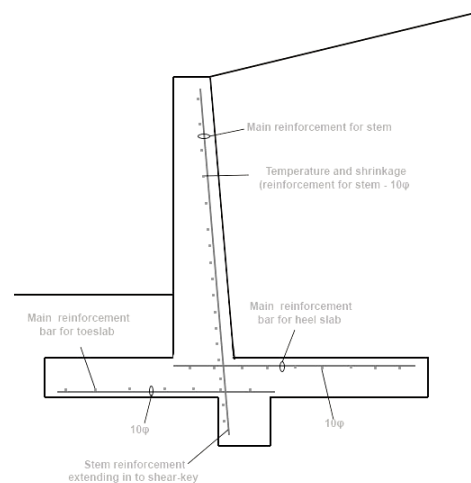
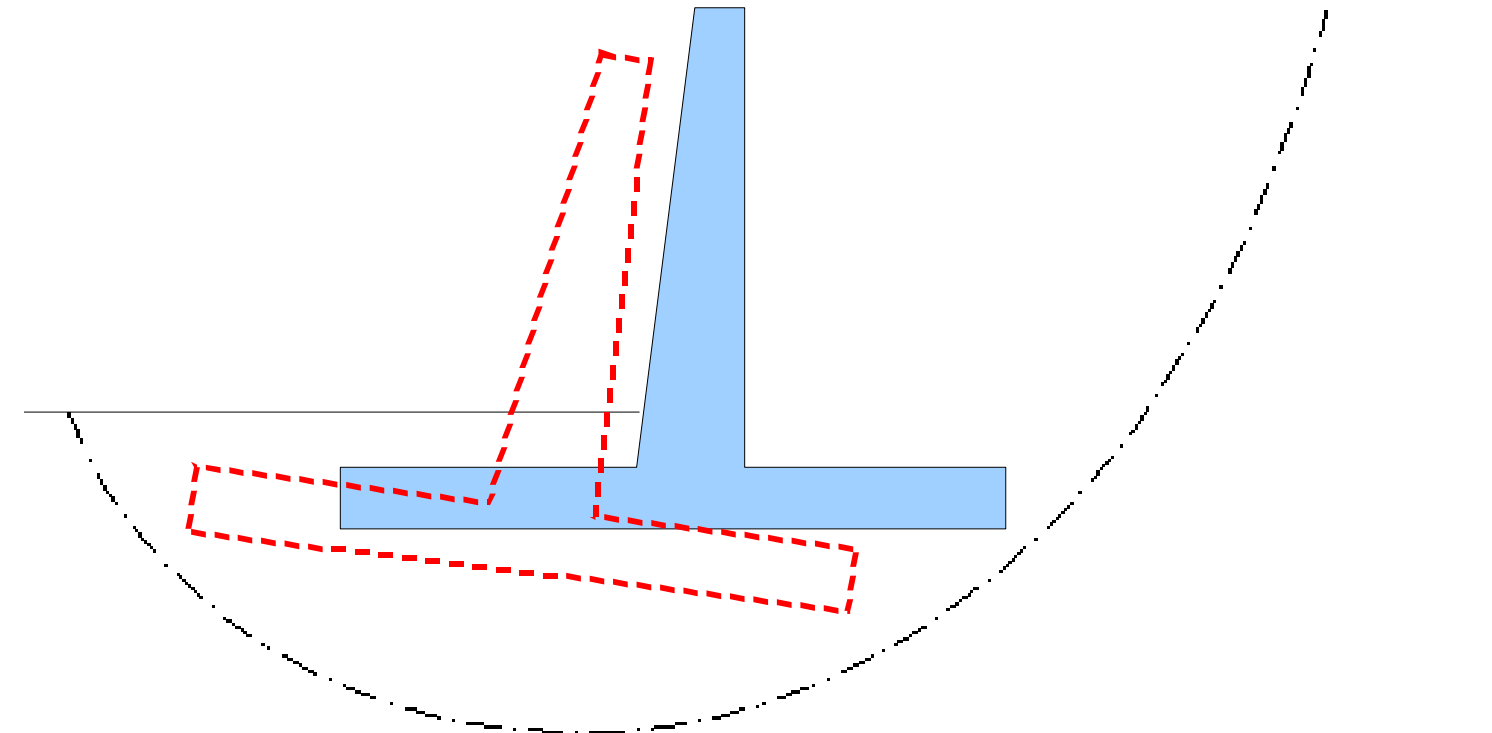
- 1- Sliding
- 2- Overturning
- 3- Settlement
- 4- Overall Failure



3



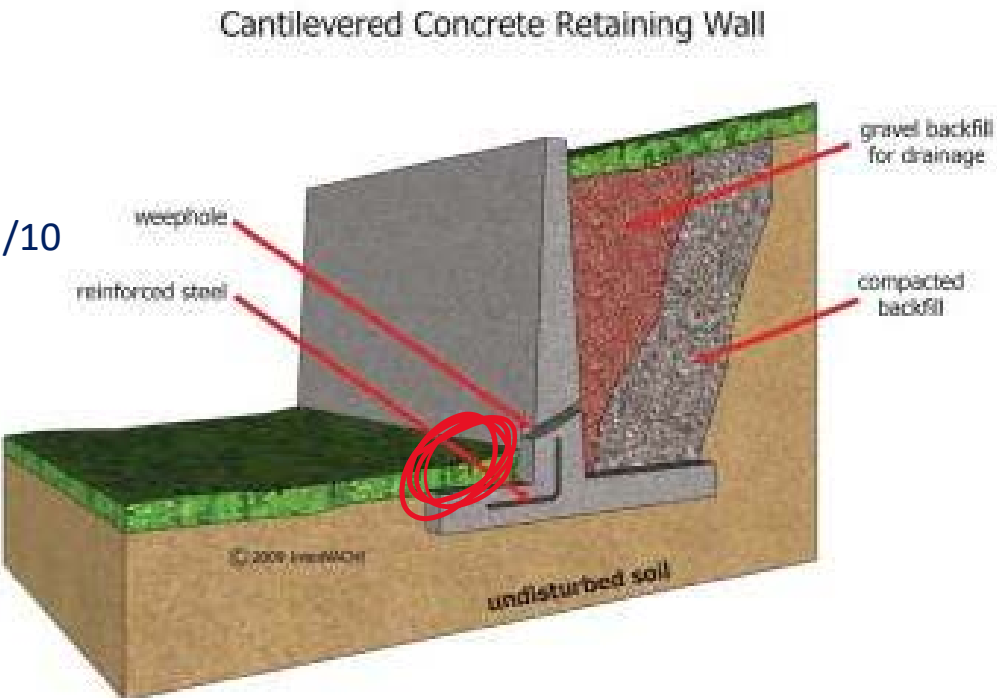
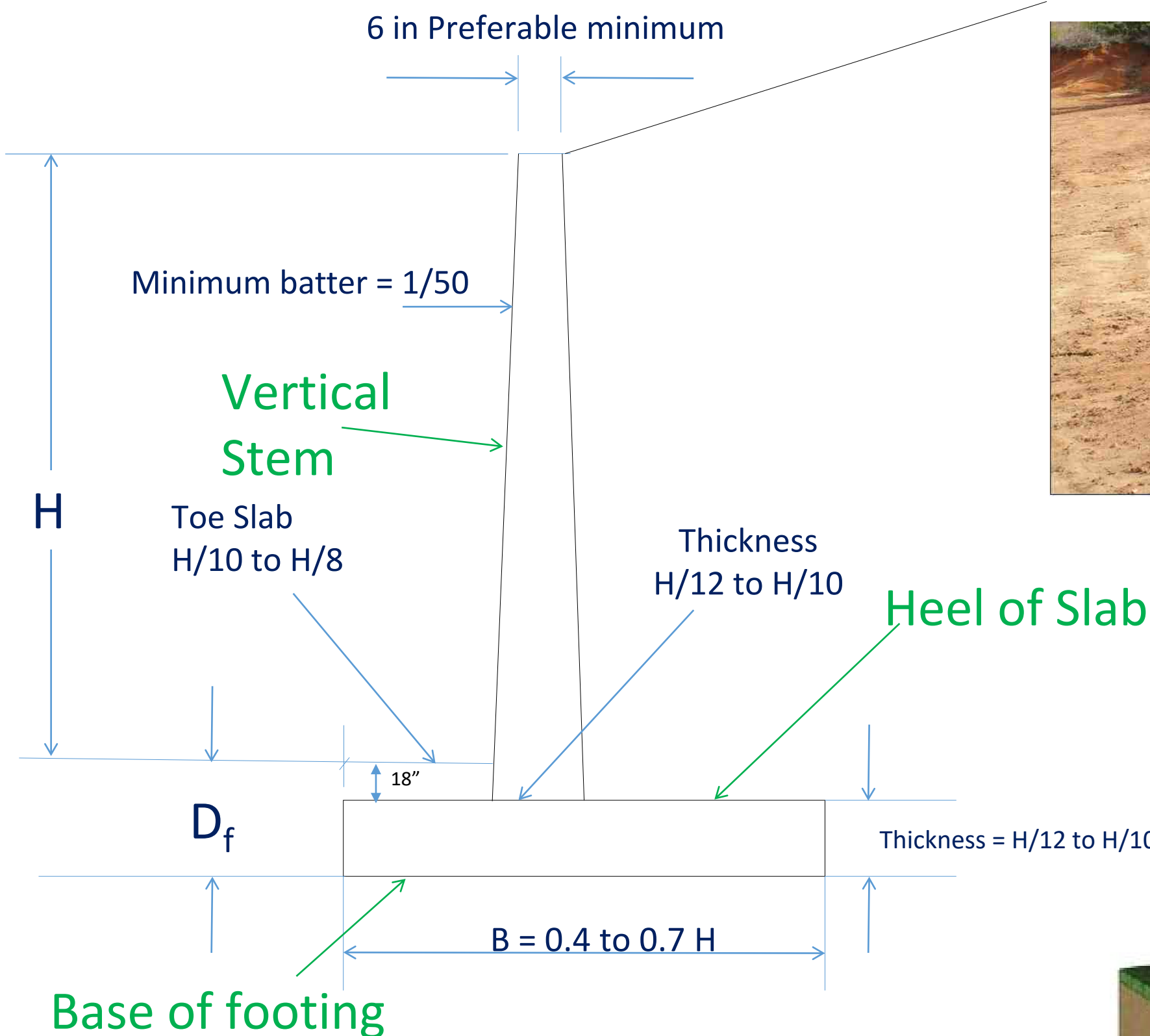
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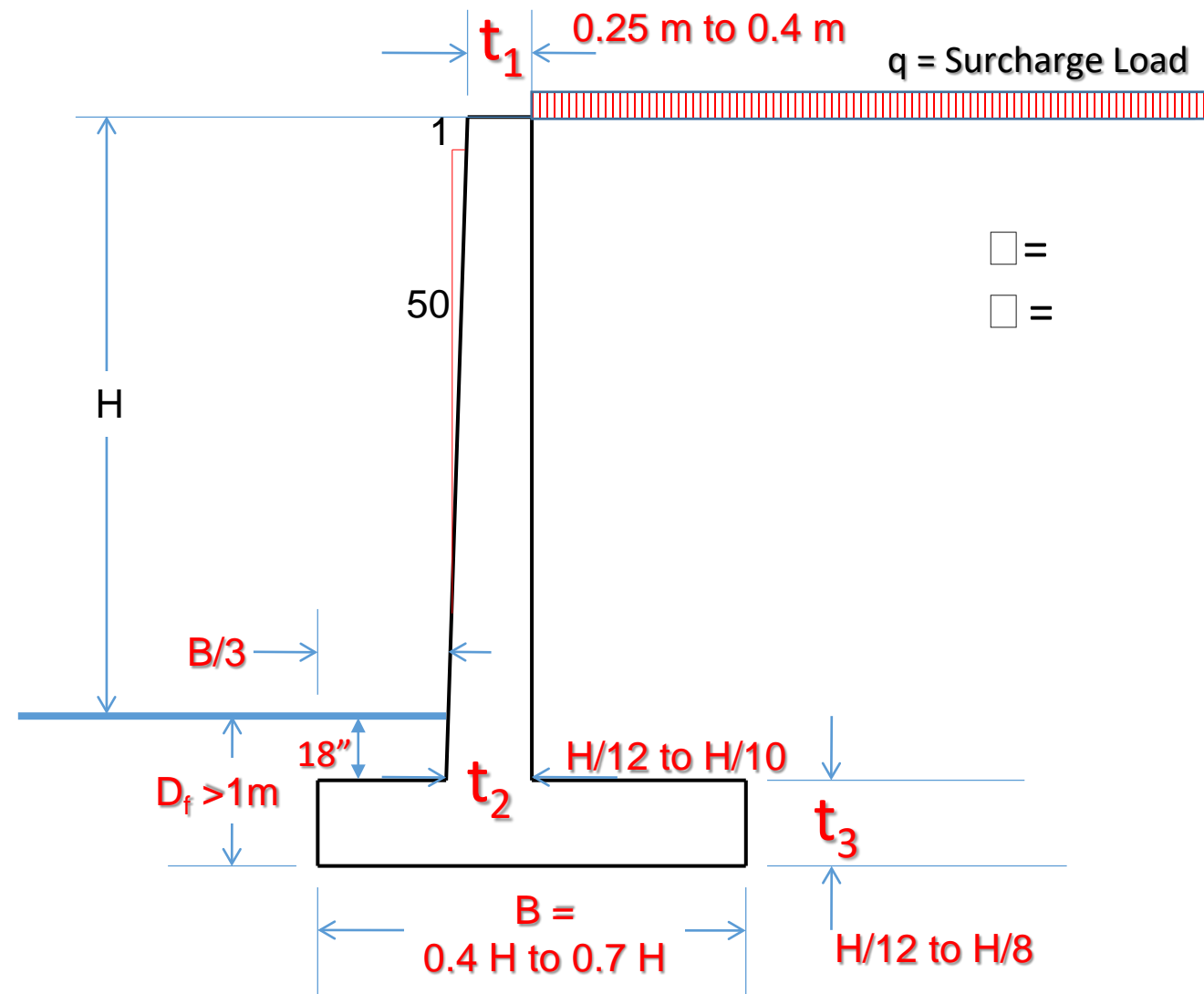
## Internal Stability

Steel Reinforcement and Thicknesses

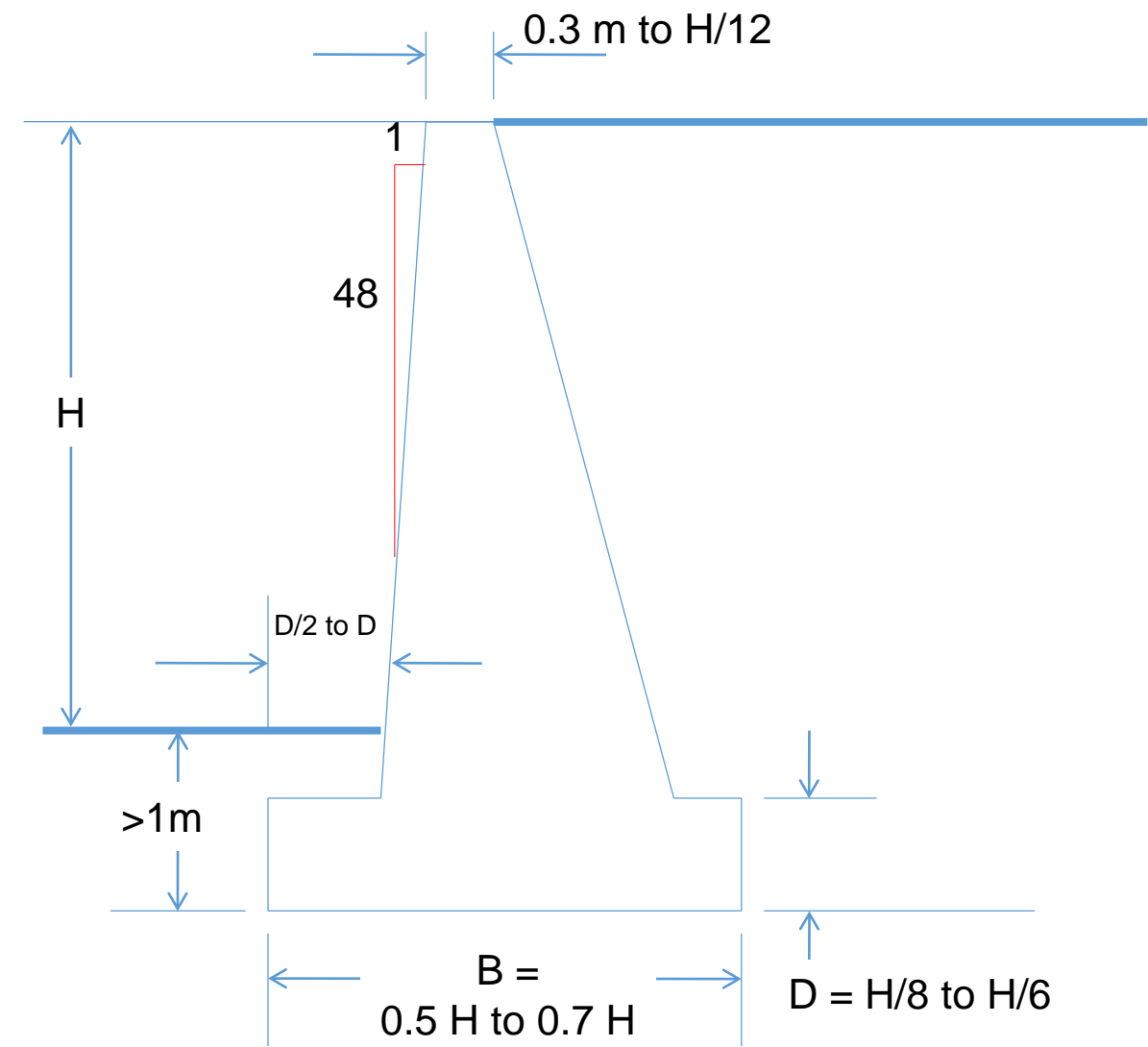
# Common Proportions of Cantilever Wall



# Approximate Dimensions



Cantilever Retaining Wall



Gravity Retaining Wall

# Sample of Excel Spreadsheet Analysis and Deign of Cantilever Retaining Walls

**Note:**  
Assume the Bearing Capacity of the Foundation,  $q_{all} = 3000$  psf

AN20
fx

Name:	PROJECT TITLE:	SHEET No.:
ID:	DESCRIPTION: Retaining Wall	DATE:
	LOCATION:	DATE:

DESIGN OF CANTILEVER RETAINING WALL PER ACI318-05

SECTION A-A & B-B

**b) Geometry input**

B =	7.00 m	22.97 ft
b <sub>1</sub> =	1.50 m	4.92 ft
D <sub>f</sub> =	2.50 m	8.20 ft
t <sub>s</sub> =	1.50 m	4.92 ft
h <sub>e</sub> =	11.10 m	36.42 ft
a =	0.00 m	0.00 ft
t <sub>1</sub> =	1.00 m	3.28 ft
t <sub>2</sub> =	0.50 m	1.64 ft
b <sub>2</sub> =	4.50 m	14.76 ft
h =	12.60 m	41.34 ft
H =	12.60 m	41.34 ft

**1) Design Inputs**

**a) Material**

Concrete grade	f <sub>c</sub> = 35 Mpa	5076.32 psi
Steel grade	f <sub>y</sub> = 420 Mpa	60915.85 psi
Material factor	φ = 0.9	
Concrete density	γ <sub>c</sub> = 24 kN/m <sup>3</sup>	152.88 lb/ft <sup>3</sup>
Soil density	γ <sub>s</sub> = 18 kN/m <sup>3</sup>	114.66 lb/ft <sup>3</sup>
Angle of repose for soil	θ = 30 degree	30 degree
Coefficient of active earth pressure ka =	$\frac{1-\sin(\theta)}{1+\sin(\theta)}$	0.33 radian
Coefficient of passive earth pressure ka =	$\frac{1-\sin(\theta)}{1+\sin(\theta)}$	0.33 radian

**c) Loading**

Safe Bearing Capacity	f <sub>b,all</sub> = 500 kPa	10442.736 lb/ft <sup>2</sup>
Coeff of friction for Sliding	m = 0.5	0.5
Surcharge pressure	q = 12 kN/m <sup>2</sup>	250.62521 lb/ft <sup>2</sup>

**Design Summary**

**F.S against Overturning** = 2.51 > 1.5 Safe !!

**F.S against Sliding** = 1.33 < 1.5 Not Safe!! Hence Provide shear Key

**Max. bearing pressure** = 372.63 kPa < 500 kPa Hence Safe

**Wall Main reinforcement** = 16 @ 25c/c

**Heel Top Main reinforcement** = 20 @ 75c/c

**Toe bottom main reinforcement** = 16 @ 50c/c

Page 1  
Design Input

Page 2  
Design Output  
(External Stability)  
REQUIRED

Page 3  
Design Output  
(Internal Stability)  
NOT REQUIRED  
IN THIS PROJECT

AN20
fx

Name:	PROJECT TITLE:	SHEET No.:
ID:	DESCRIPTION: Retaining Wall	DATE:
	LOCATION:	DATE:

DESIGN OF CANTILEVER RETAINING WALL PER ACI318-05

SECTION A-A & B-B

**1) Design Inputs**

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Concrete grade	f <sub>c</sub> = 35 Mpa	5076.32 psi
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Material factor	φ = 0.9	
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Coefficient of active earth pressure ka =	$\frac{1-\sin(\theta)}{1+\sin(\theta)}$	0.33 radian
Coefficient of passive earth pressure ka =	$\frac{1-\sin(\theta)}{1+\sin(\theta)}$	0.33 radian

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**Wall Main reinforcement** = 16 @ 25c/c

**Heel Top Main reinforcement** = 20 @ 75c/c

**Toe bottom main reinforcement** = 16 @ 50c/c

**2) Design Output**

**2.1) Stability Calculation**

**a) Check for Overturning**

**Calculation of overturning moment about "O"**

Load	Load (kN)	Distance (m)	Mo (kNm)
H1	478.3	4.2	2000
H2	7.4	6.3	317.5
Total	52		2318 kNm

**Calculation of Restoring Moment about "O"**

Load	Load (kN)	Distance (m)	Mro (kNm)
W1	899.1	4.75	4271
W2	252	3.5	882
W3	133.2	2.25	299.7
W4	86.6	1.833	122.1
W5	54	4.75	256.5
Total	1405 kN		5831.0 kNm

Total Overturning Moment Mo = 2318 kNm  
Total Restoring Moment Mro = 5831.1 kNm  
Factor of Safety = Mro/Mo = 5831.1/2317.9 = **2.51 > 1.5 Safe !!**

**b) Check for Sliding**

Total Horizontal force = 526.7 kN  
Restoring force = m x SW = 0.5 x 1404.9 = 702.5 kN  
Factor Safety = Hr/H = 702.5/526.7 = **1.33 < 1.5 Not Safe!!**  
Hence Provide shear Key

**c) Check for Bearing pressure**

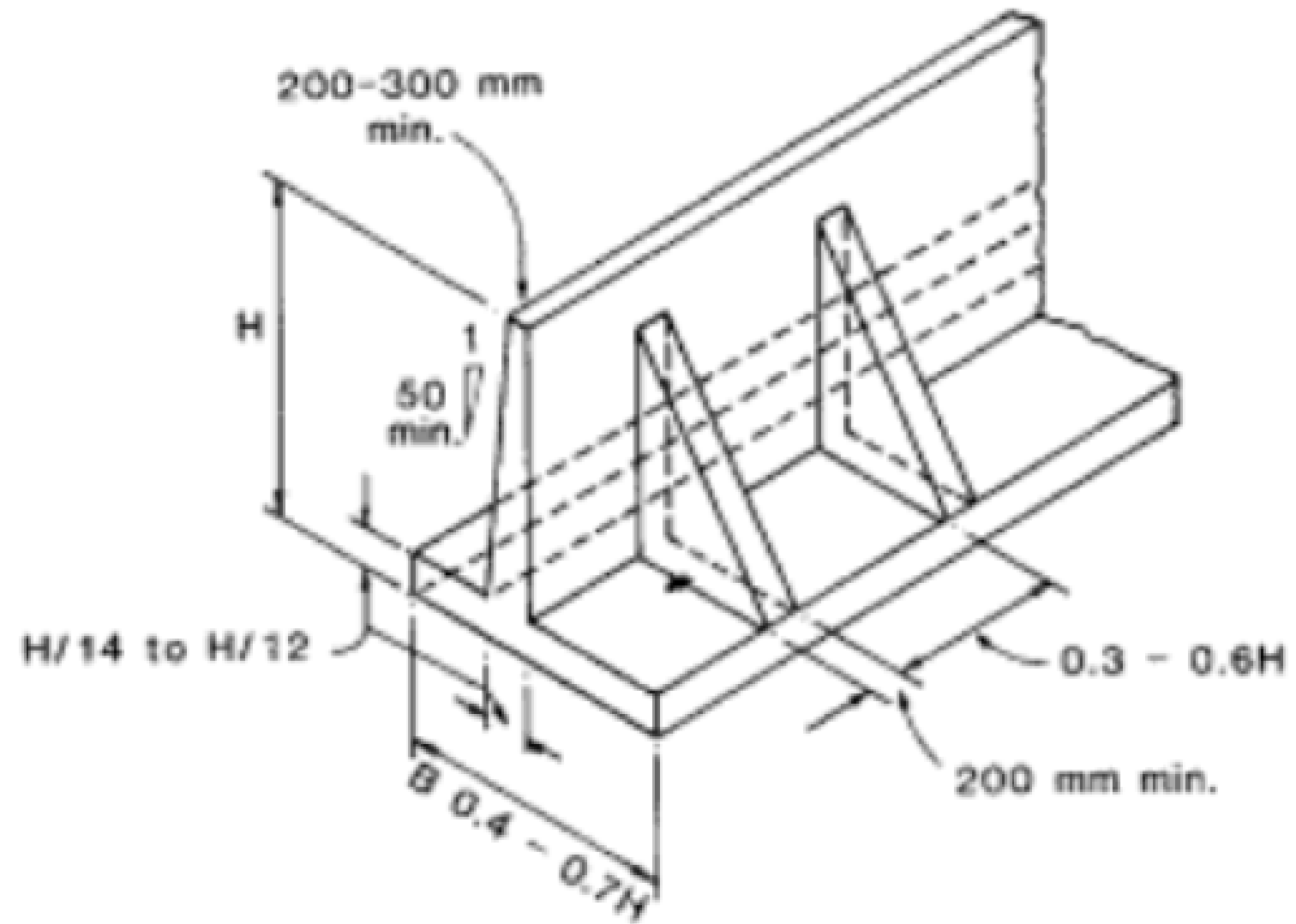
C.G. of Load x = (Mro-Mo)/P = 2.501  
eccentricity e = B/2 - x = 0.999  
fbmax = P/A(1 + 6e/B) = 372.6 kPa < 500 kPa  
fbmin = P/A(1 - 6e/B) = 28.78 kPa > 0  
Hence Safe

**2.2) Structural Design**

**a) Design of Stem (vertical reinforcement - inner face (1))**



# Counterfort Retaining Wall



# Internal Stability

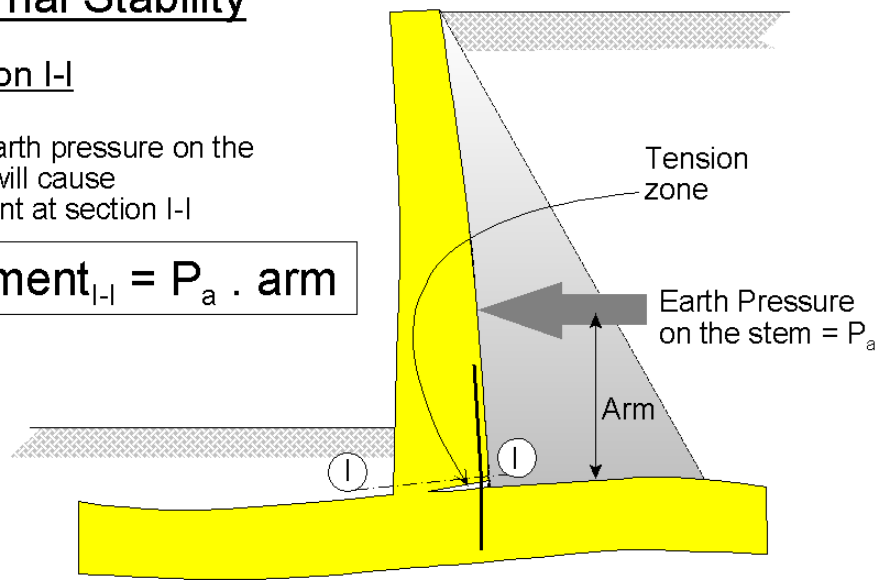
Structural Design  
Steel Reinforcement  
and Thicknesses } Structural Design

## 2- Internal Stability

### Section I-I

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

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

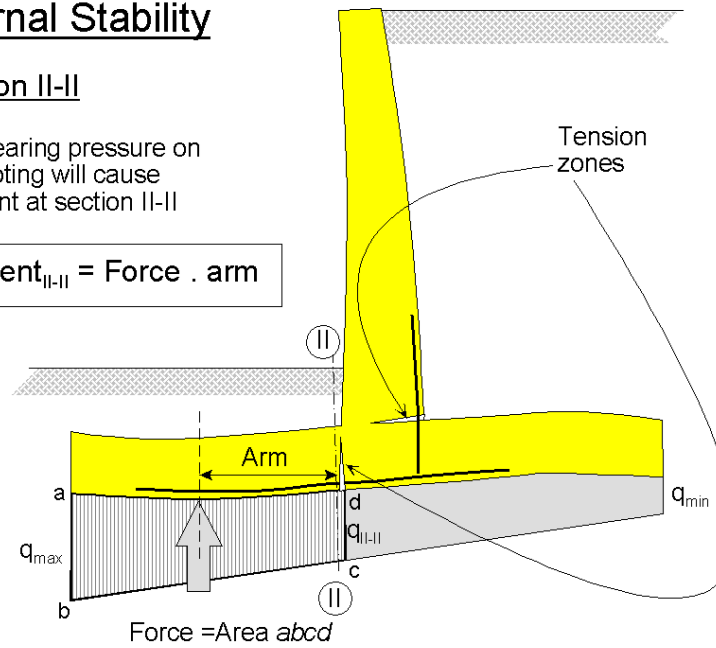


### Internal Stability

#### Section II-II

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

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

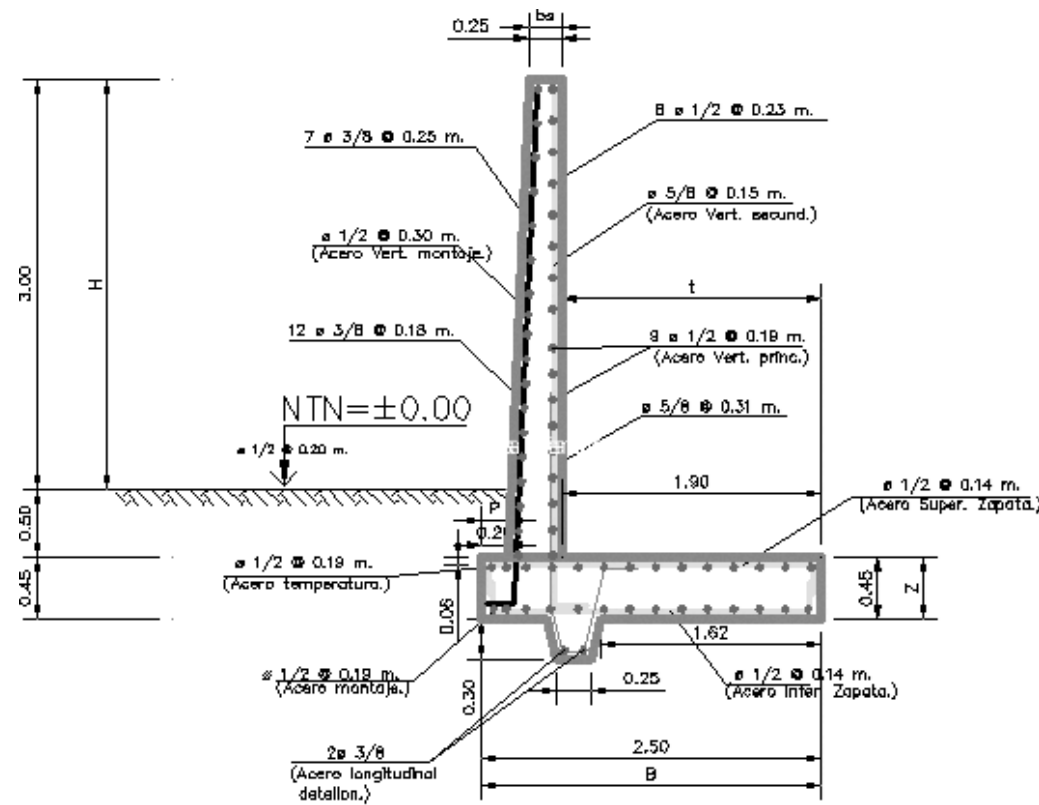
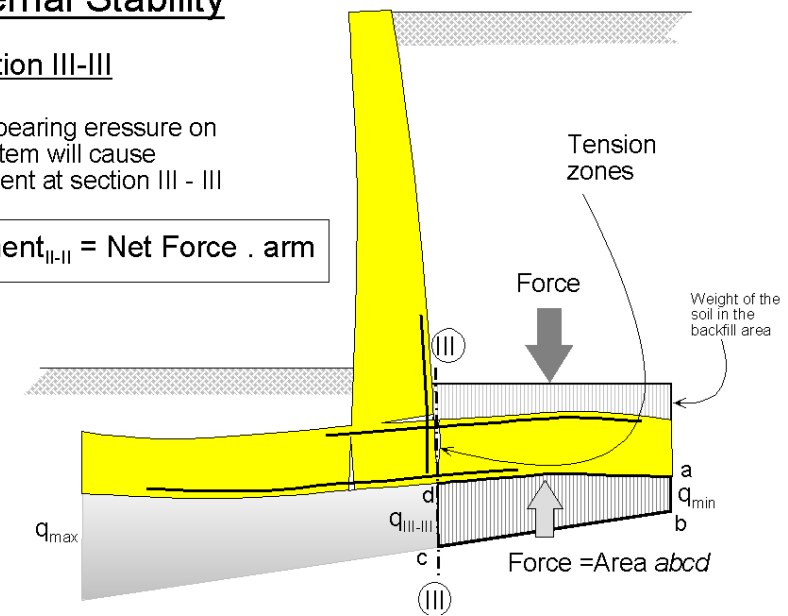


### Internal Stability

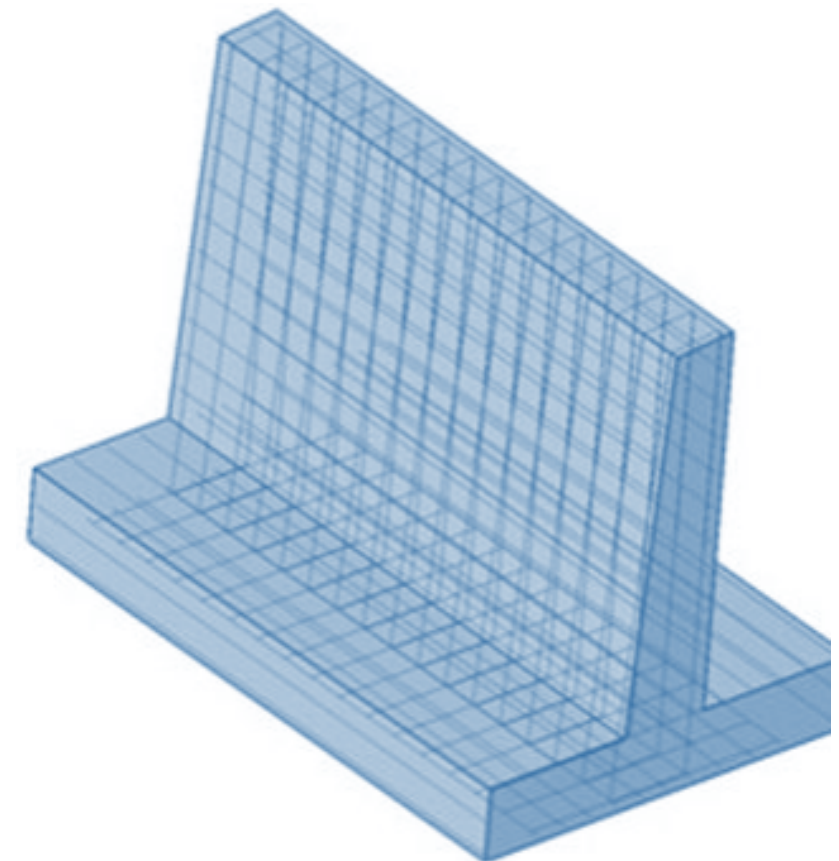
#### Section III-III

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

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



DETALLES DE MURO DE CONTENCIÓN

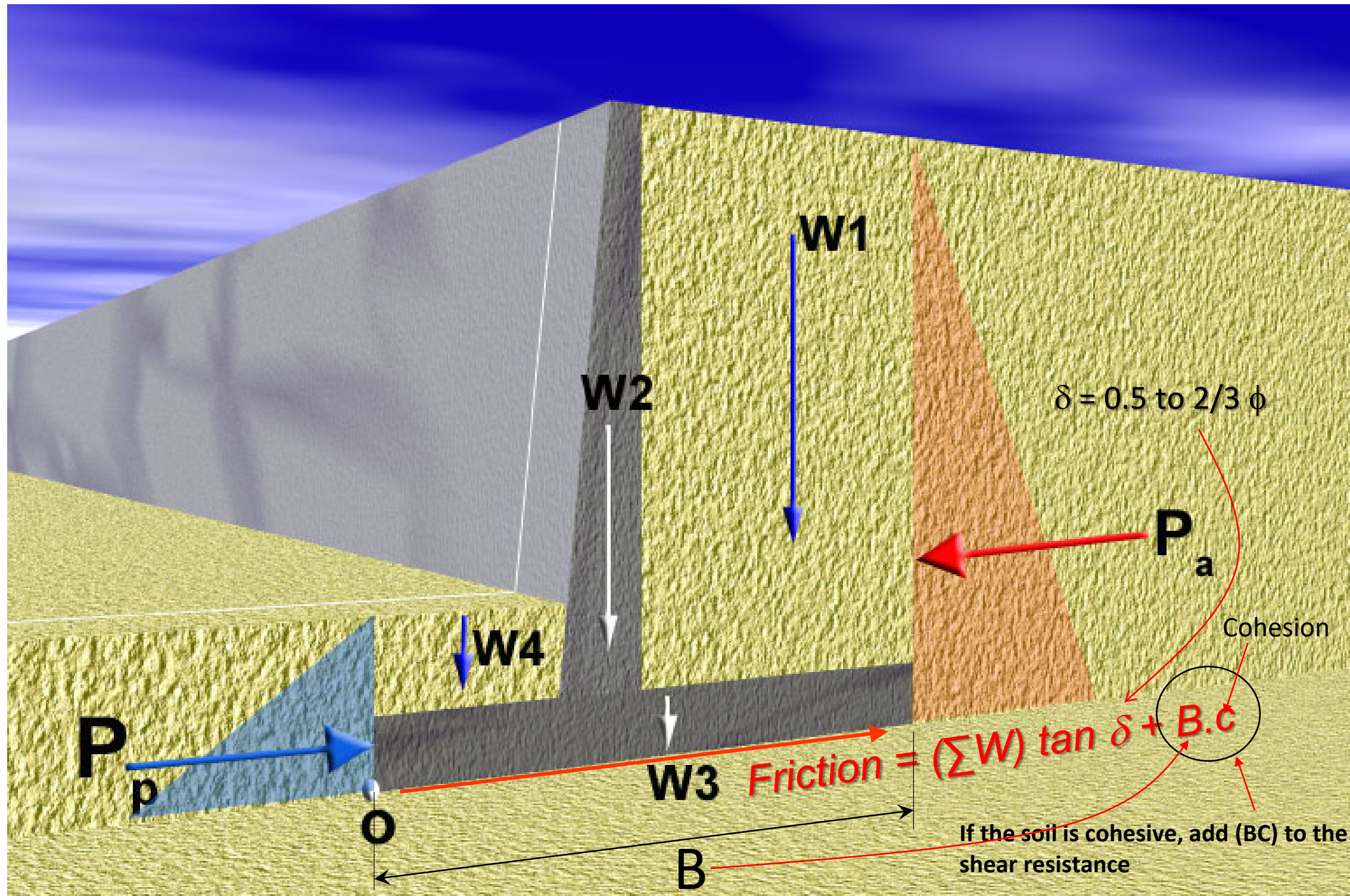




# I. External Stability

## 1- Sliding

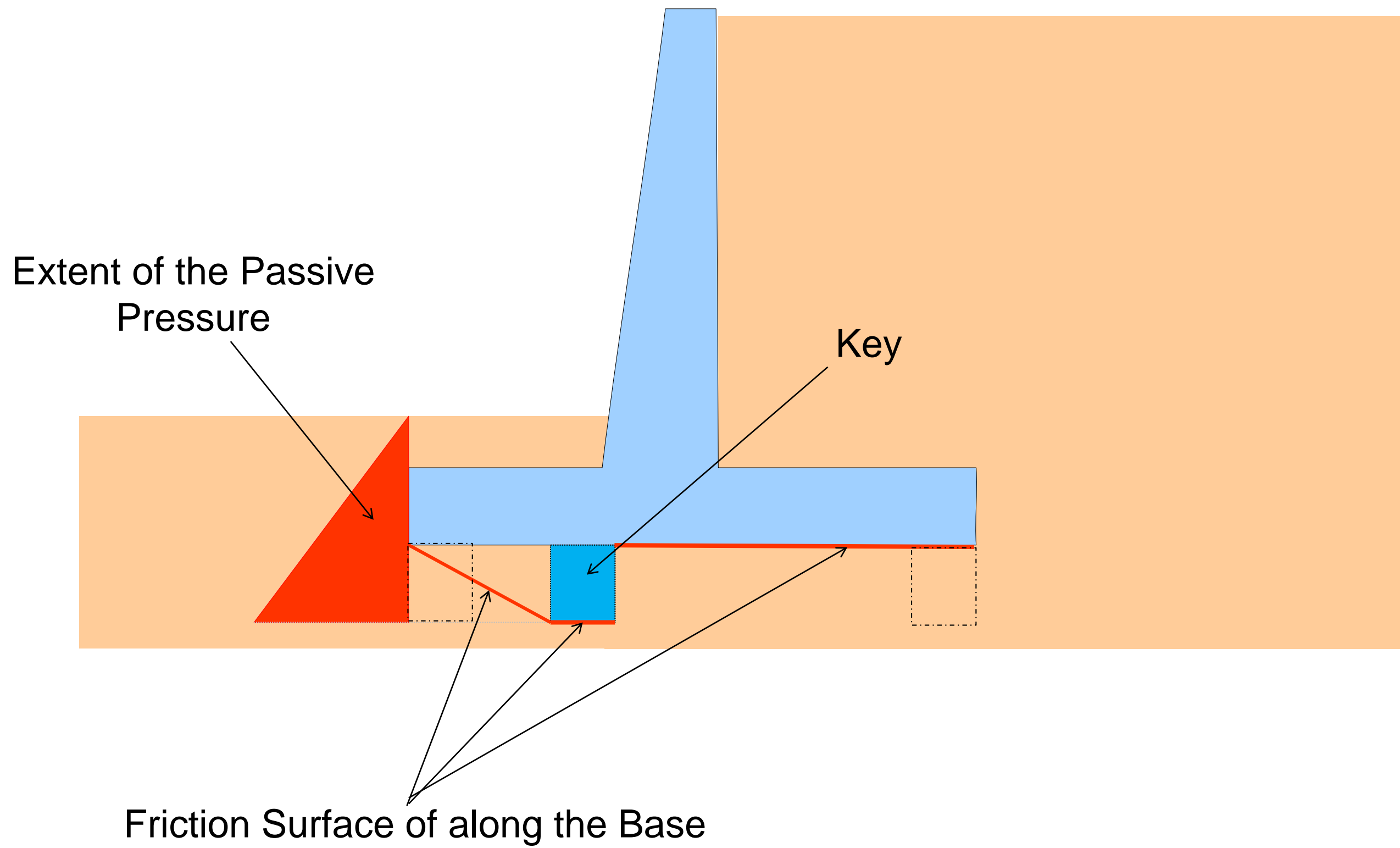
$$\text{Factor of Safety Against Sliding} = \frac{\text{Resisting Force}}{\text{Driving Force}} = \frac{F_R}{F_D}$$



$$F_D = P_a$$

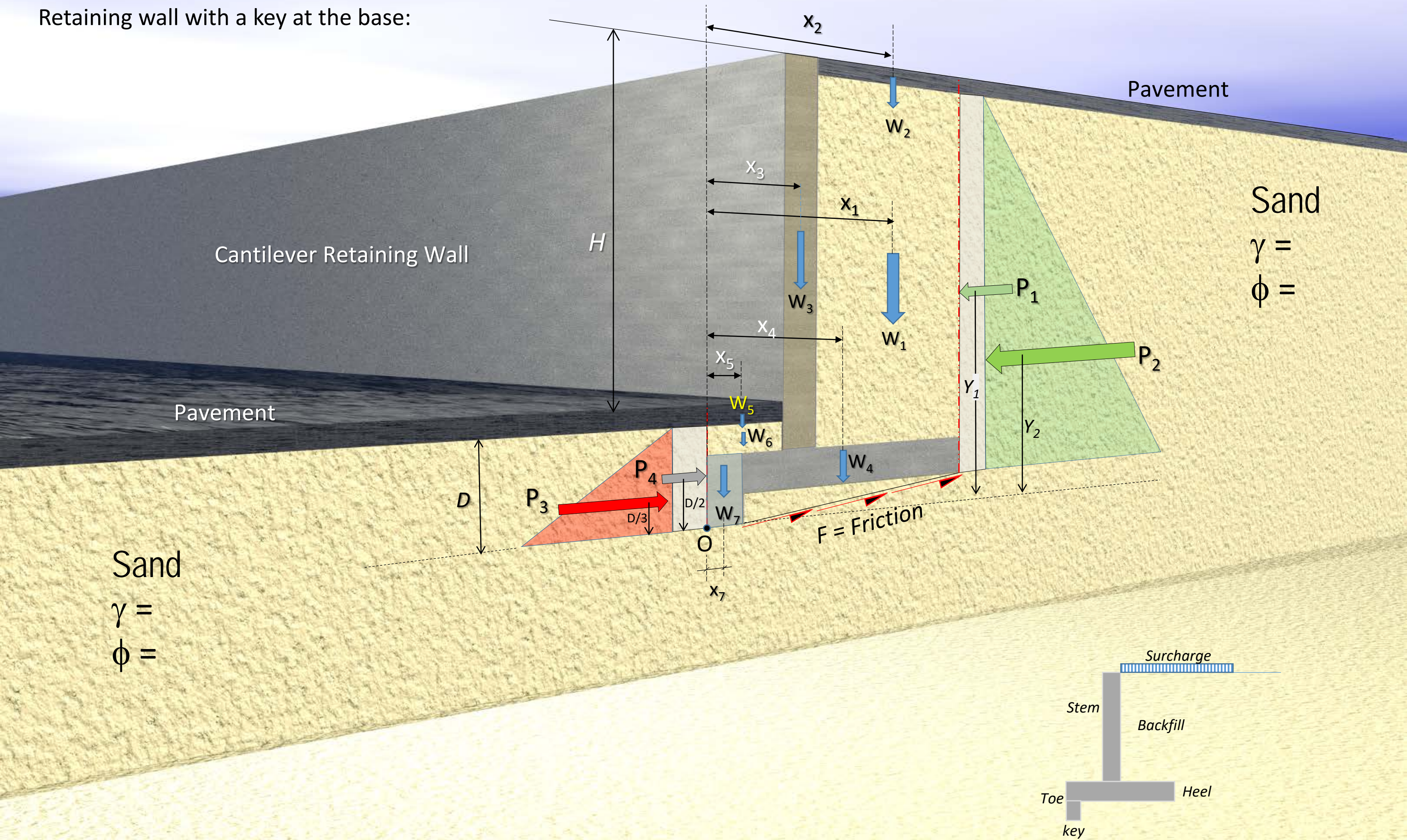
$$F_R = P_p + \text{Friction}$$

# Using Key at the Base to Improve Sliding Resistance

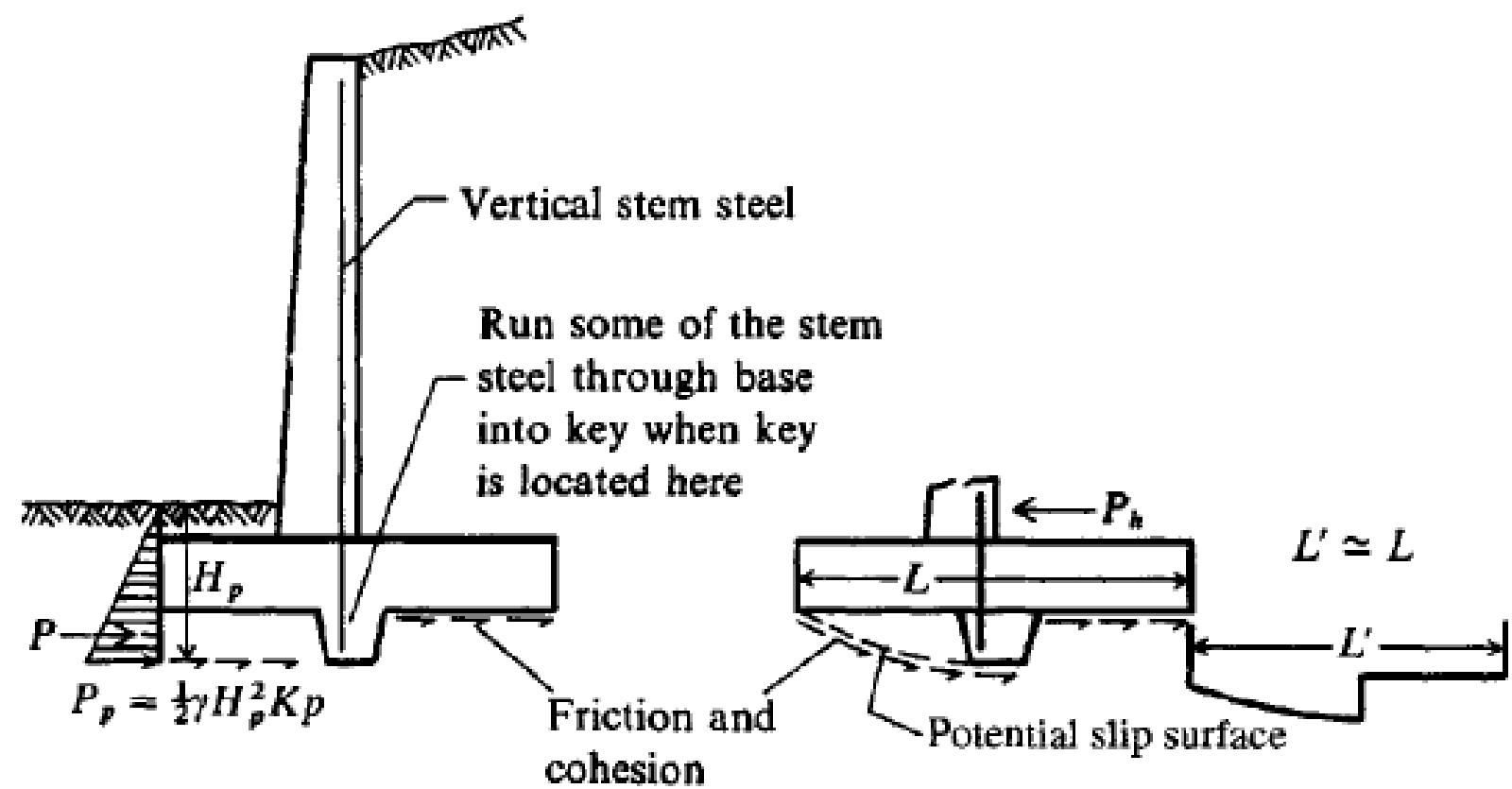




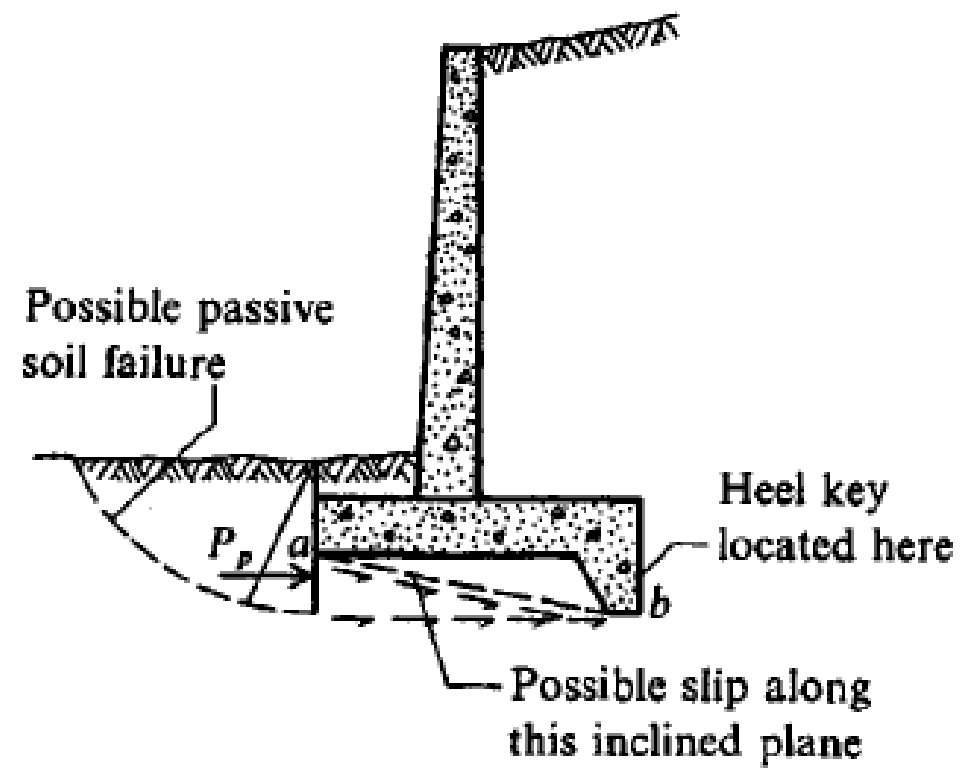
Retaining wall with a key at the base:







- (a) Base key near stem so that stem steel may be extended into the key without additional splicing or using anchor bends.
- (b) Potential sliding surface using the key location of a. There may be little increase in sliding resistance from this key, if the slip surface develops as shown.



- (c) Possible sliding modes when using a heel key.

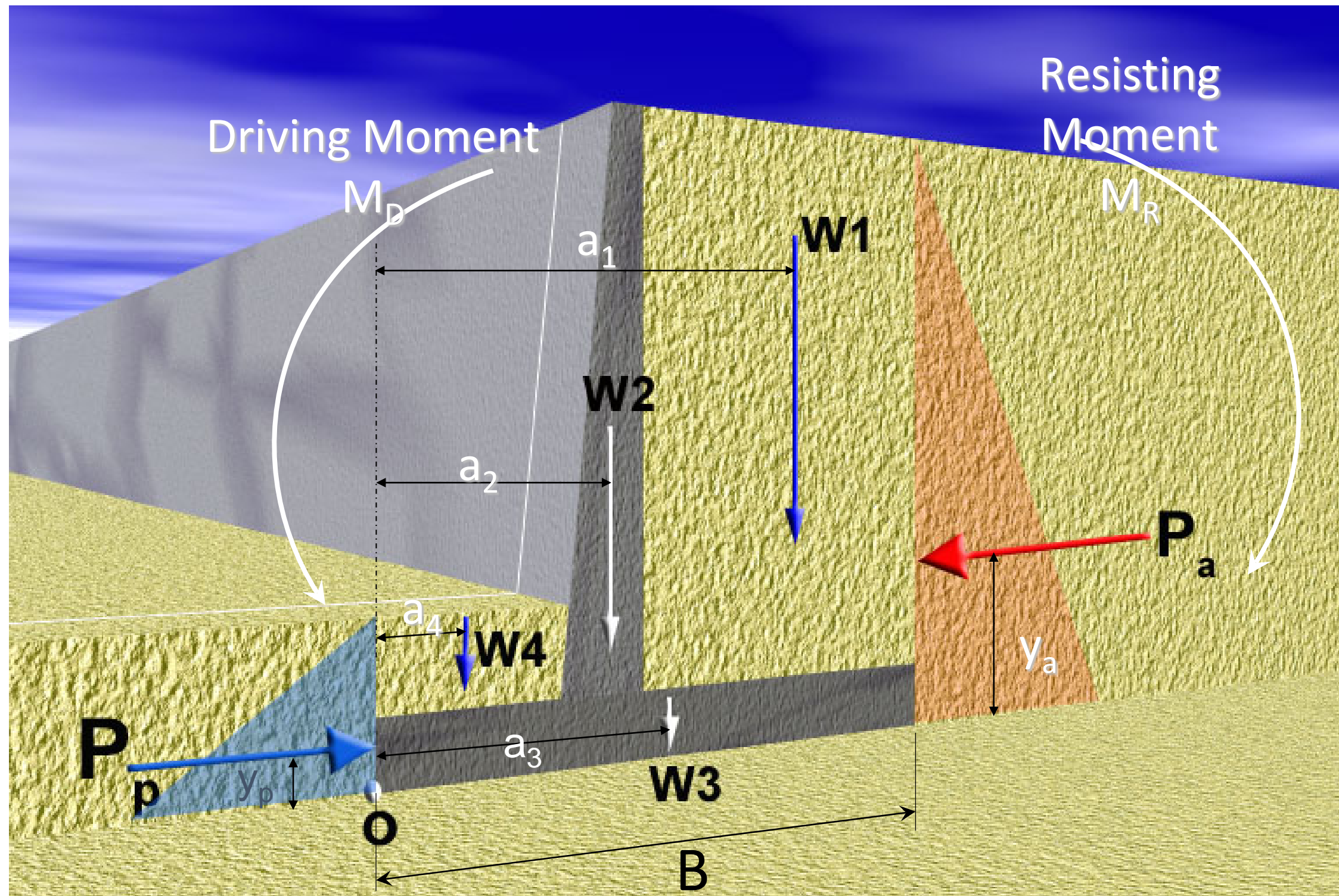
**Figure 12-14** Stability against sliding by using a base key.



# I. External Stability

## 2- Overturning

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



Moment About o

$$M_D = P_a \cdot y_a$$

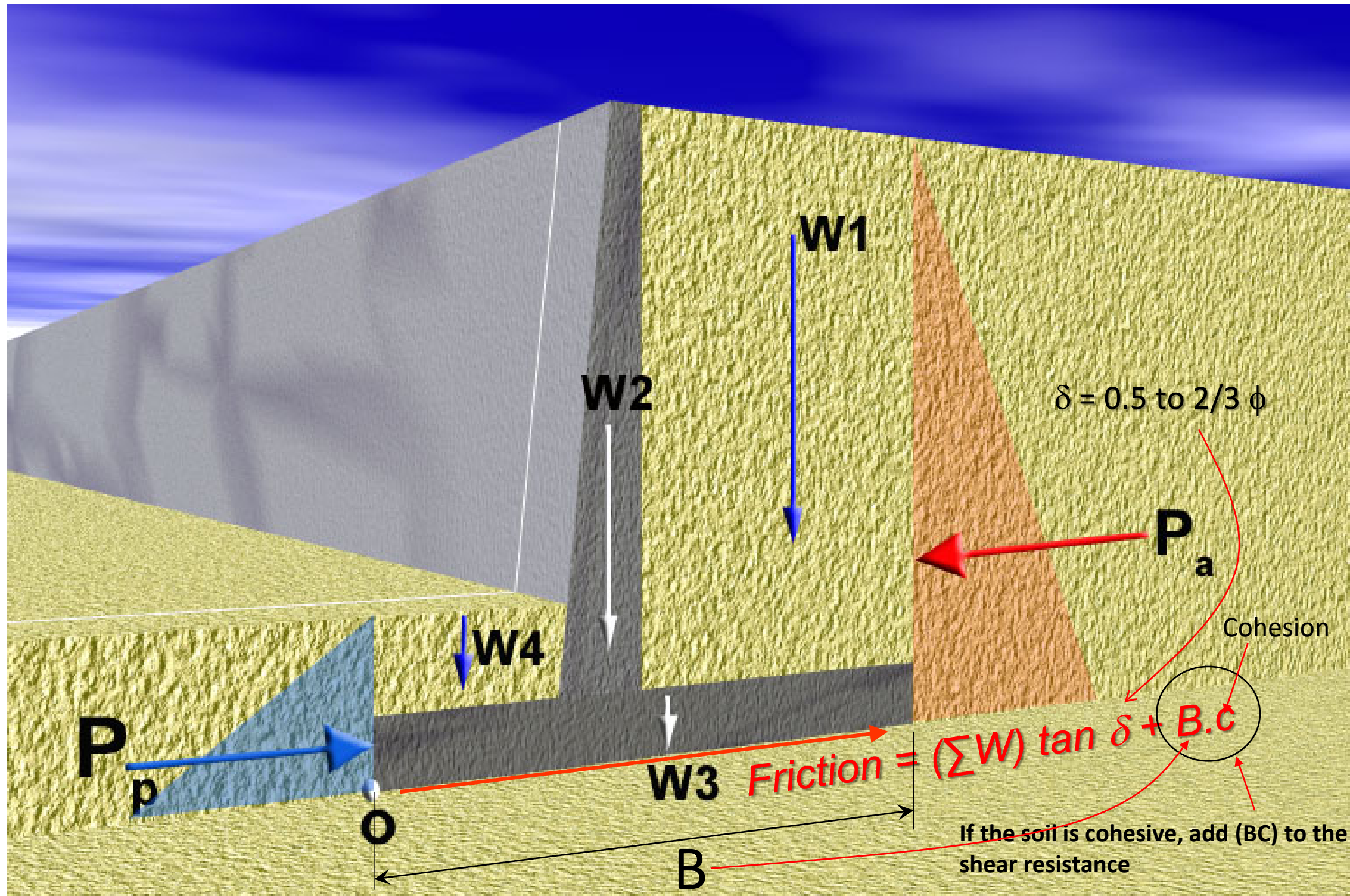
$$M_R = P_p \cdot y_p + W_1 a_1 + W_2 a_2 + W_3 a_3 + W_4 a_4$$

Session Ended 9/30/2020 at 6:15 PM

# I. External Stability

## 1- Sliding

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



$$F_D = P_a$$

$$F_R = P_p + \text{Friction}$$