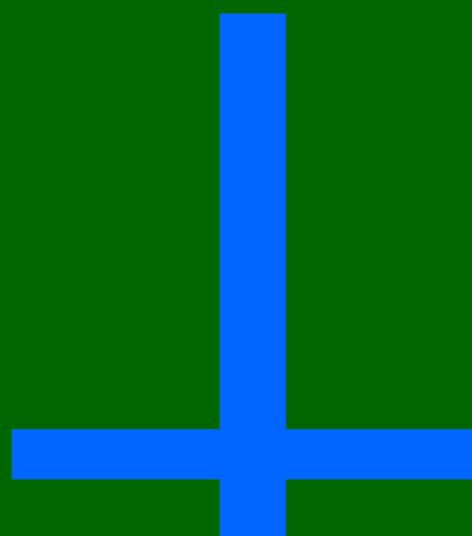
# DESIGN OF CANTILEVER RETAINING WALLS



DR. MUHAMMAD IRFAN UL HASSAN

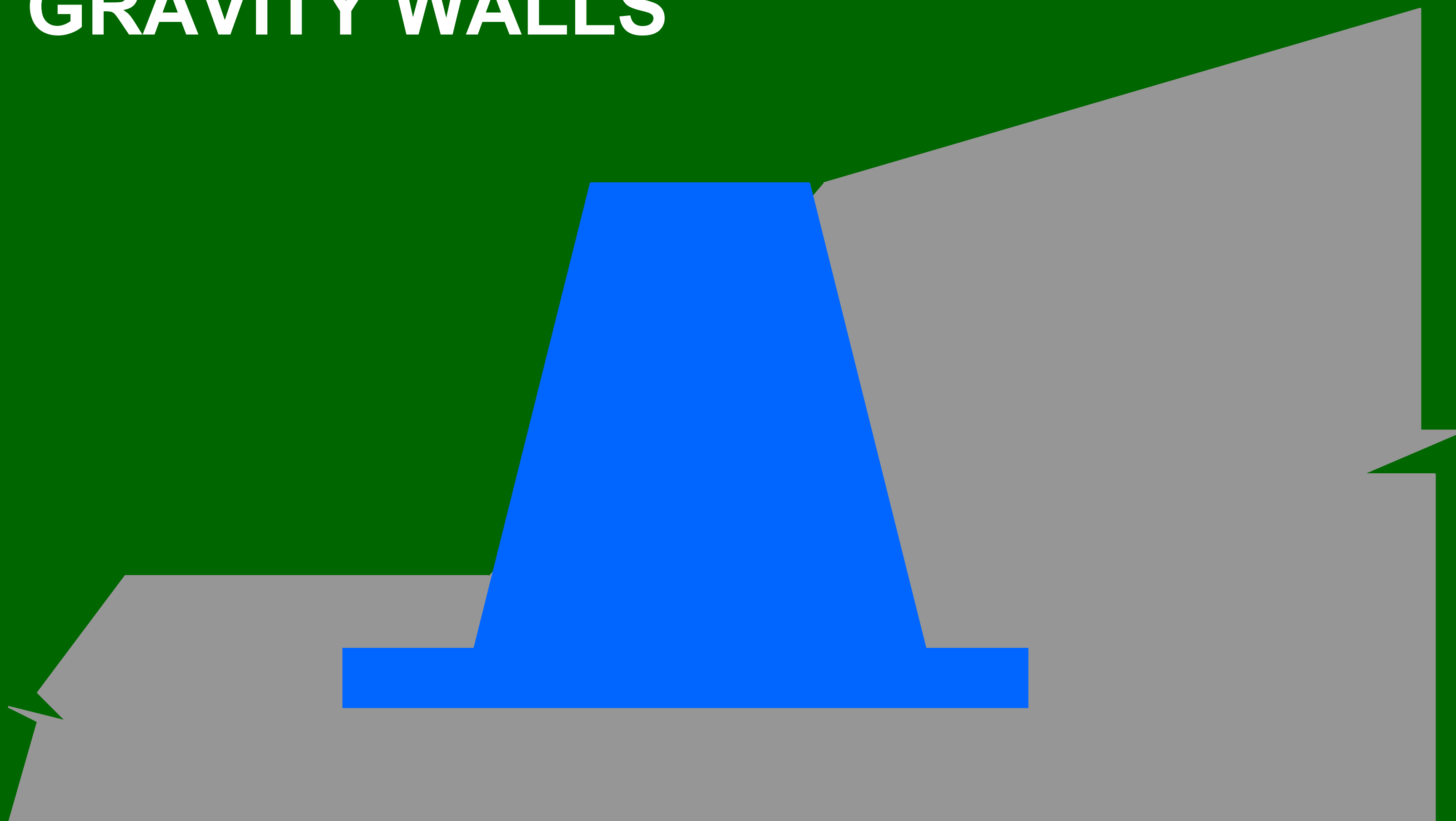
# FUNCTION

To hold back the masses of earth or loose soil where conditions make it impossible to let those masses assume their natural slopes.

## RETAINING WALLS

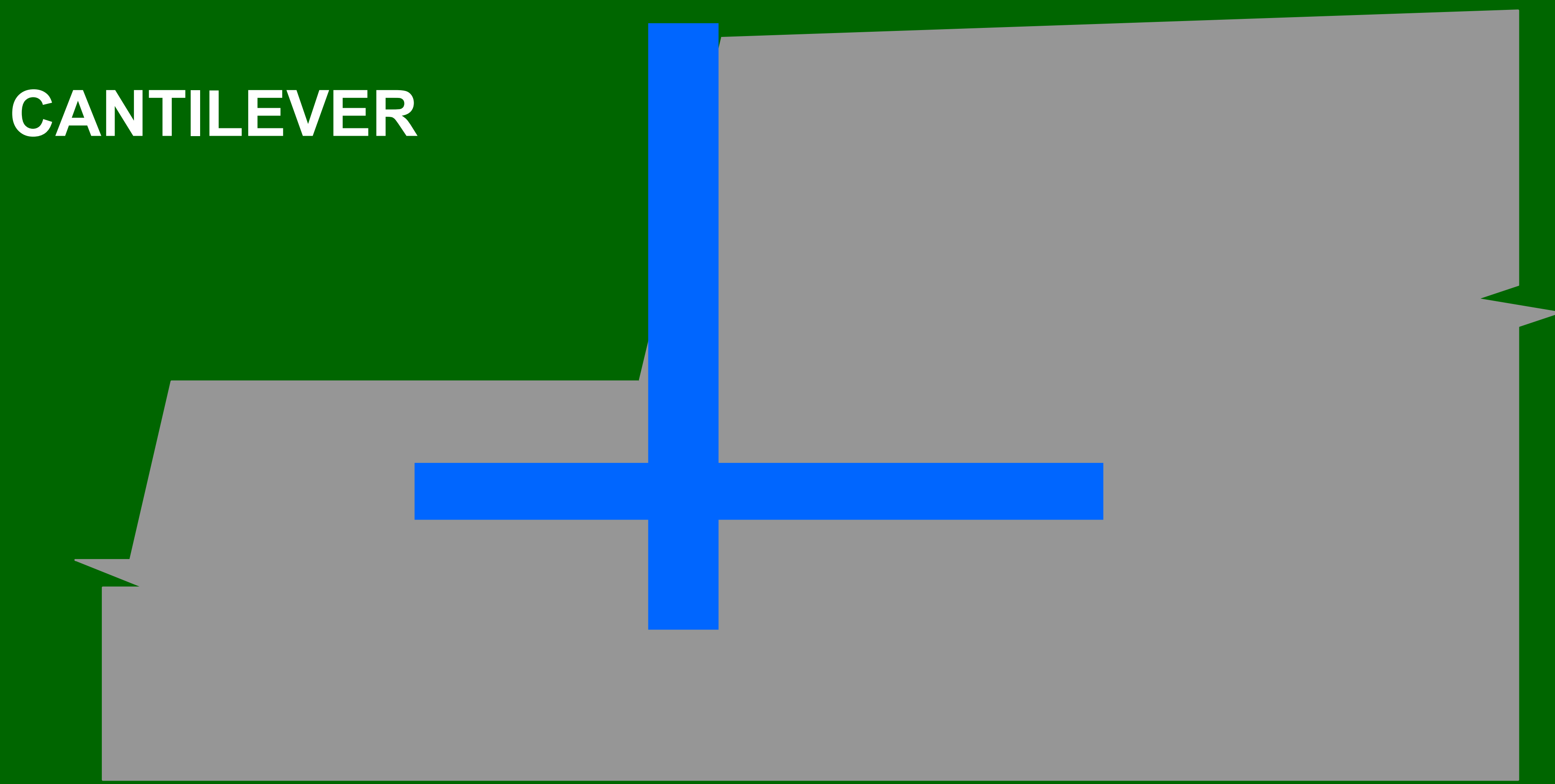
### TYPES

### GRAVITY WALLS



# RETAINING WALLS

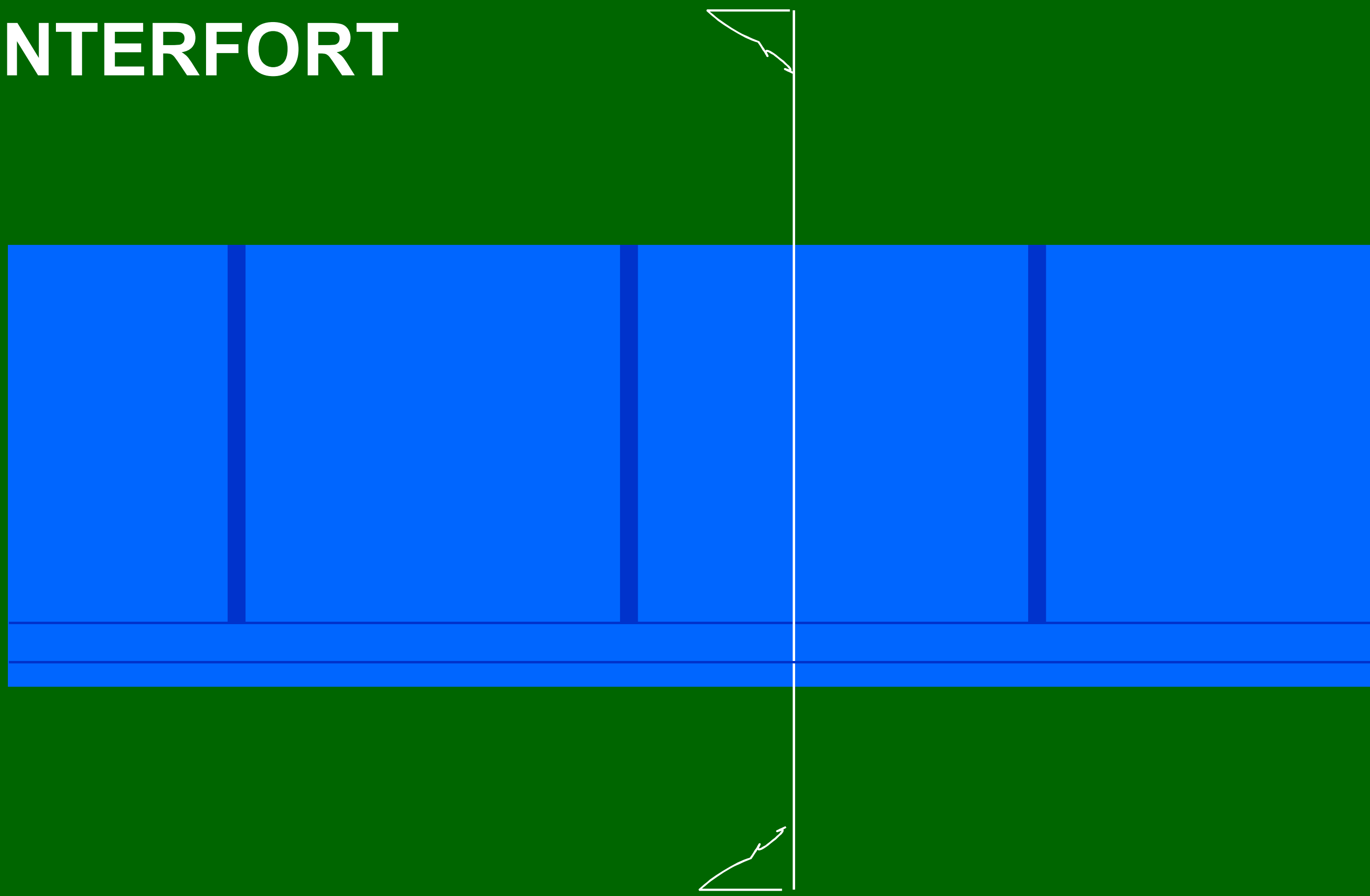
## TYPES



# RETAINING WALLS

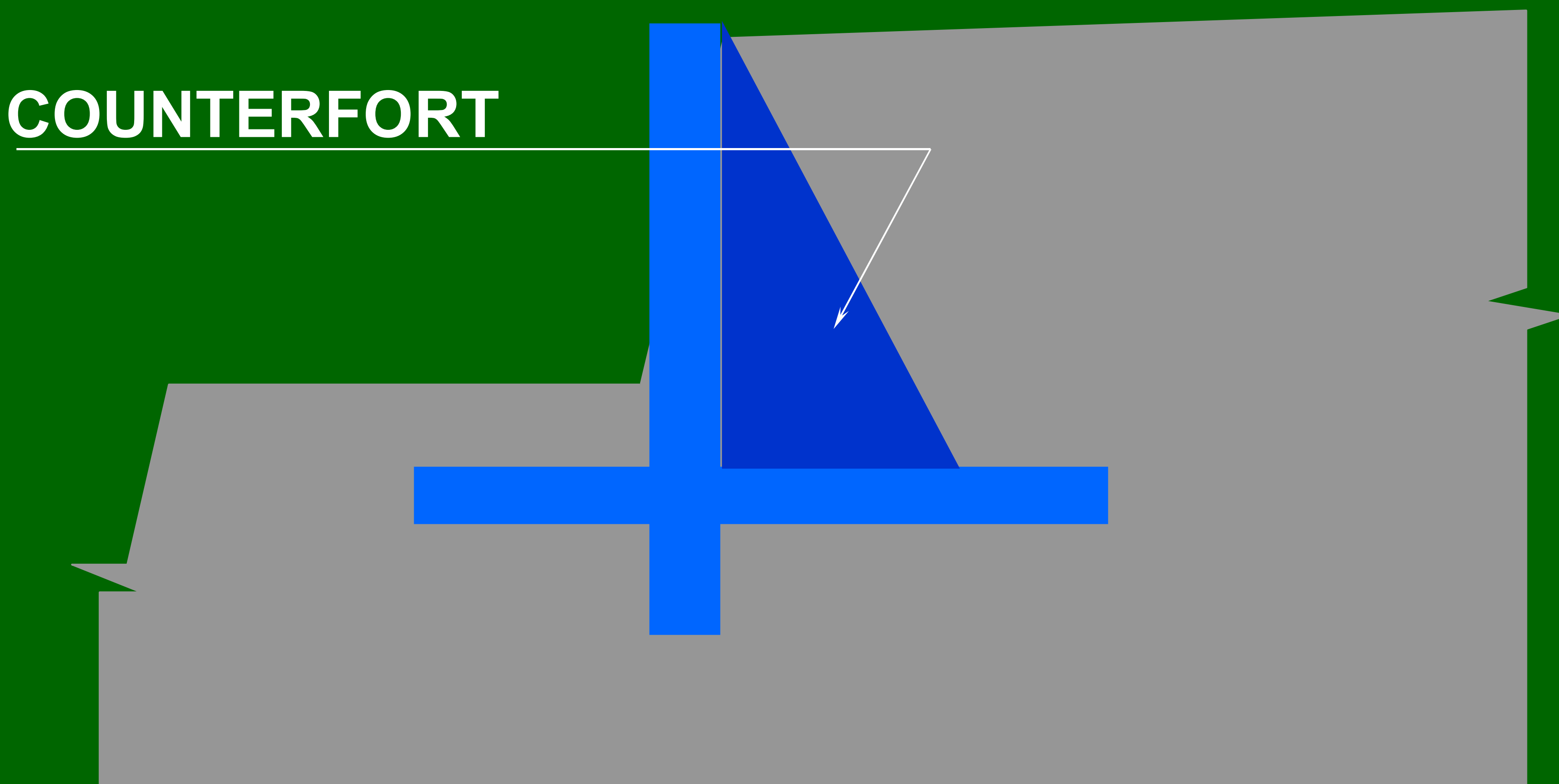
## TYPES

**COUNTERFORT**



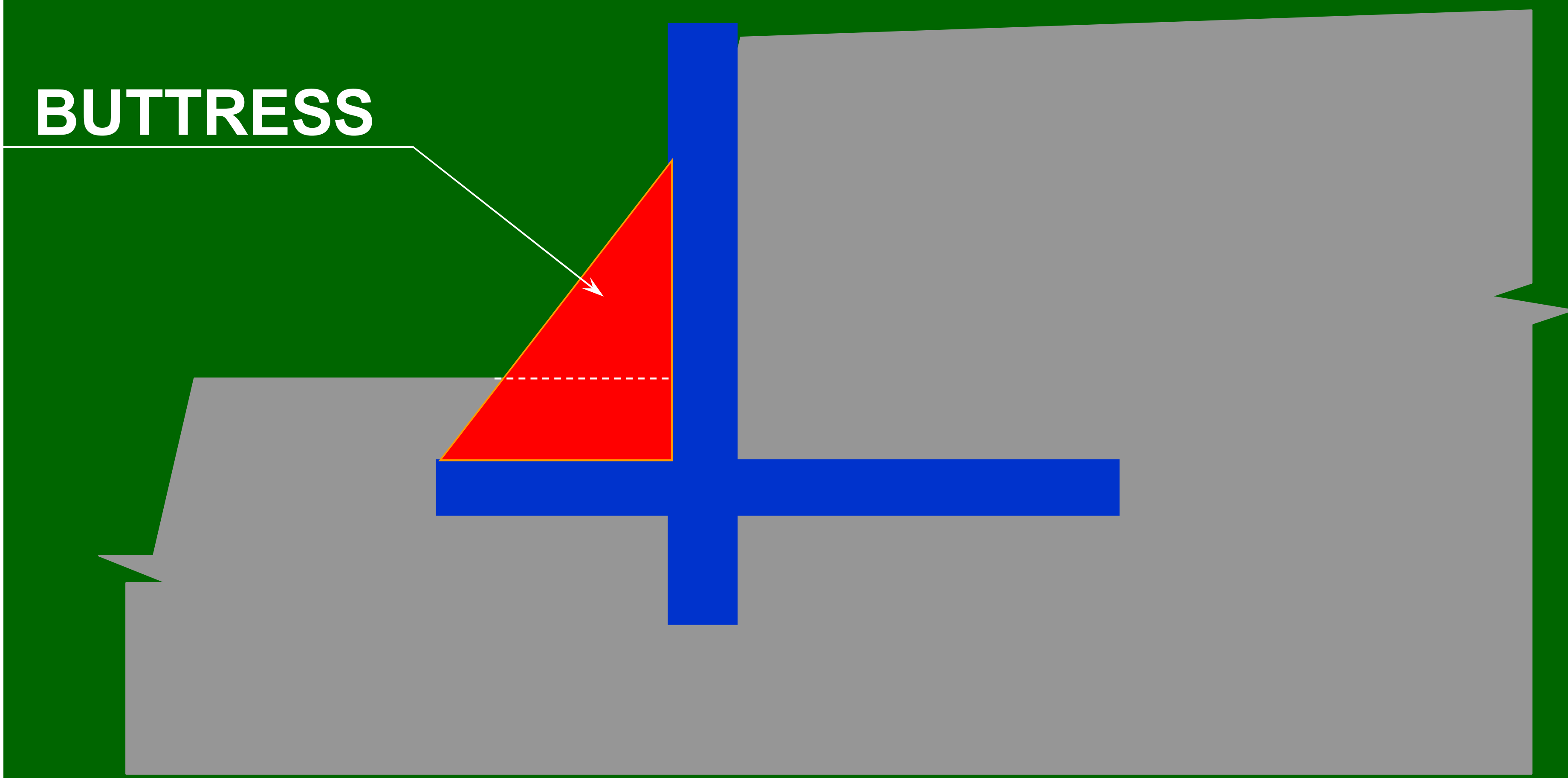
## RETAINING WALLS

### TYPES



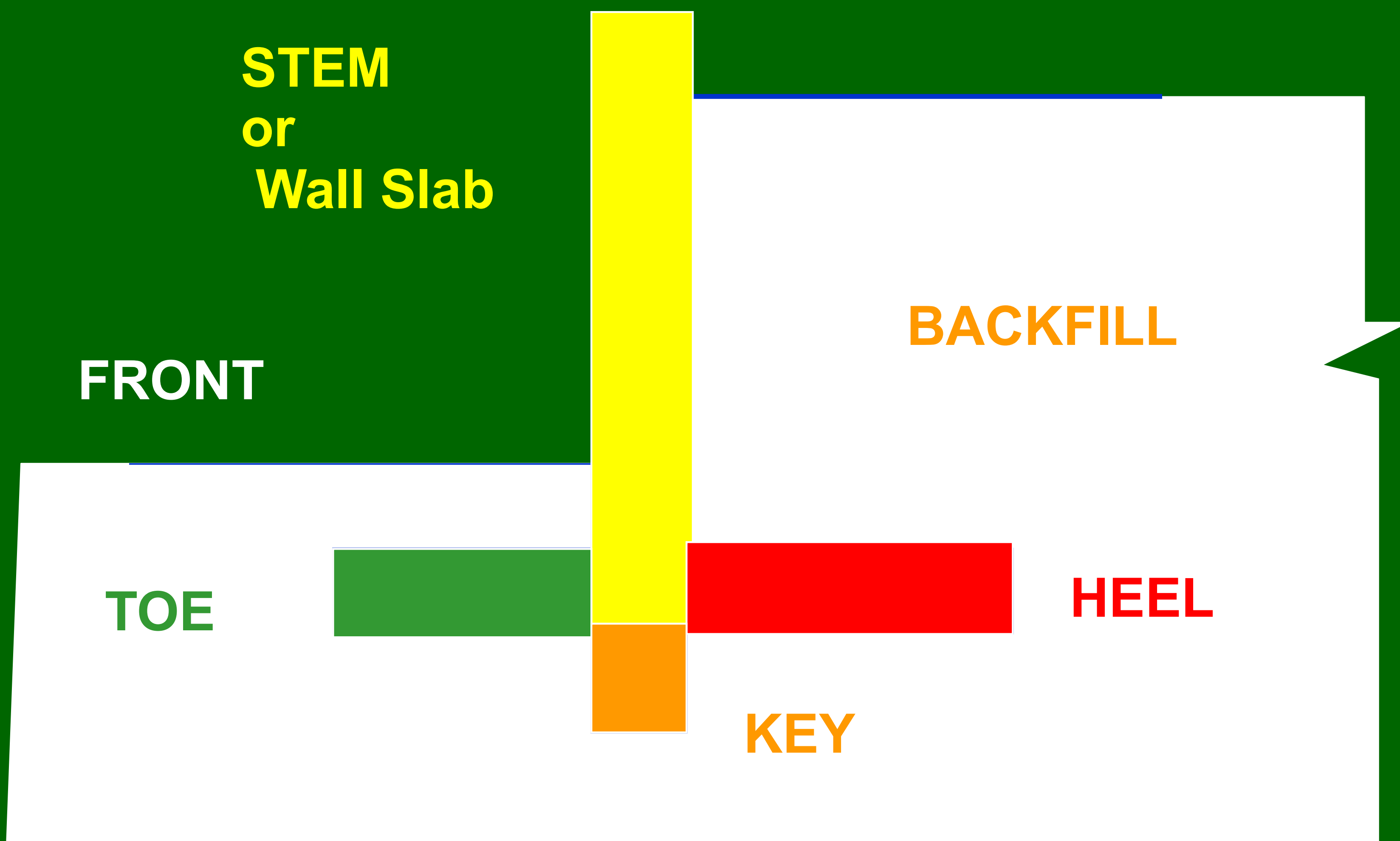
**RETAINING WALLS**

TYPES



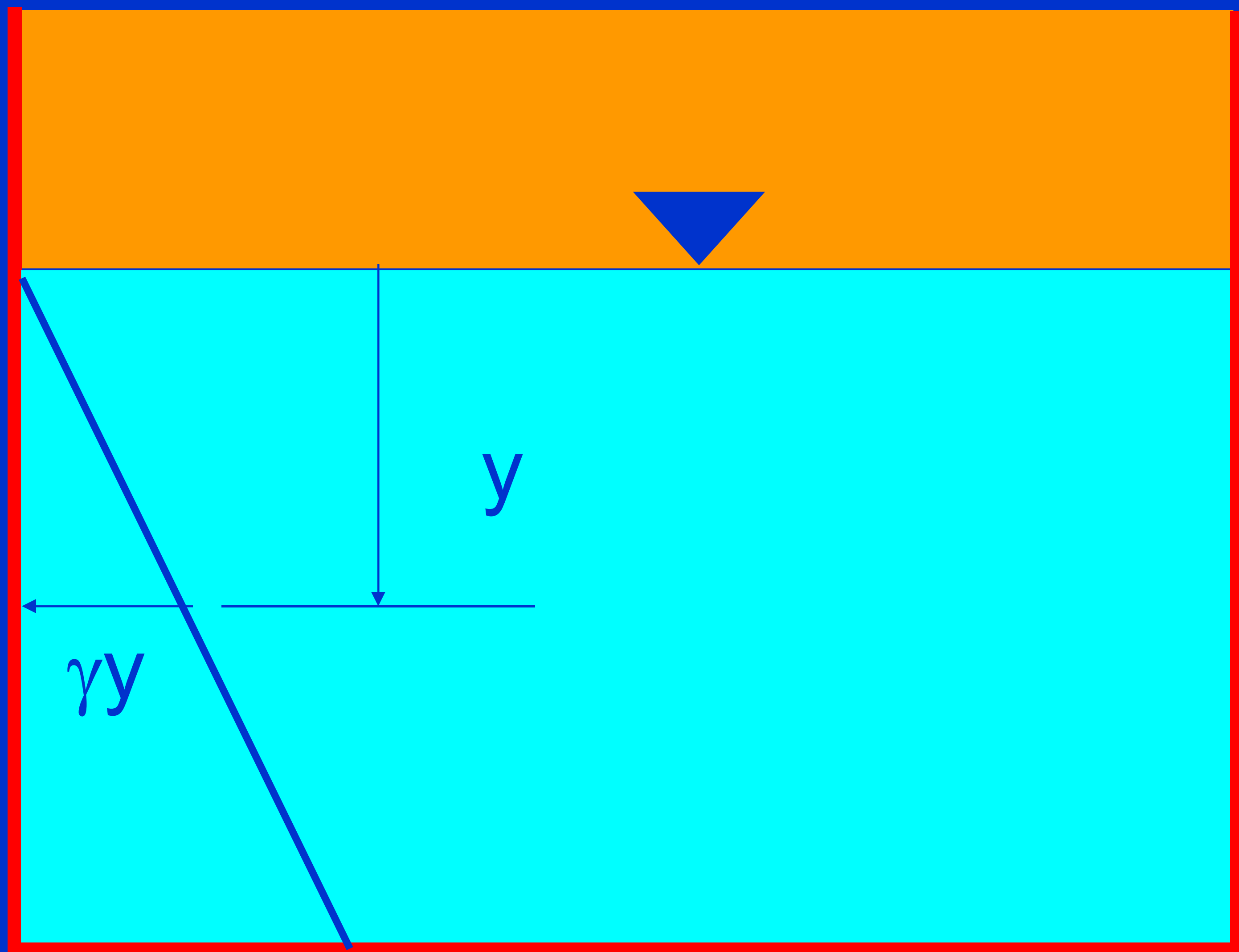
# CANTILEVER RETAINING WALLS

## PARTS



# EARTH PRESSURES

Liquids are frictionless and cohesion less. So in liquid retaining structures the pressures are directly related to the density of the liquid and head.


y
γy

# EARTH PRESSURES

**However, this is not true for soils:**

**Sand, for example, when dry, acts as a frictional material without cohesion and has a well-defined angle of repose .**

# EARTH PRESSURES

If the same sand is now moistened, it develops a certain amount of cohesive strength and its angle of repose increases, somewhat erratically.

# EARTH PRESSURES

Further wetting will break down the internal friction forces until the sand slumps and will hardly stand at any angle at all.

## EARTH PRESSURES

Clay on the other hand when first exposed in situ stands vertically to considerable depths when reasonably dry, but after time will subside, depending on its moisture content.

# EARTH PRESSURES

And clay, in dry seasons, gives up its moisture to atmosphere with subsequent shrinkage, so that at depths less than about 1 or 2 m it may be unreliable as a stop to react the forward movement of a retaining wall.

# EARTH PRESSURES

Thus the lateral pressures from soils can vary very widely depending on the moisture content.

# EARTH PRESSURES

- PRESSURE AT REST
- ACTIVE EARTH PRESSURE
- PASSIVE EARTH PRESSURE

# PRESSURE AT REST

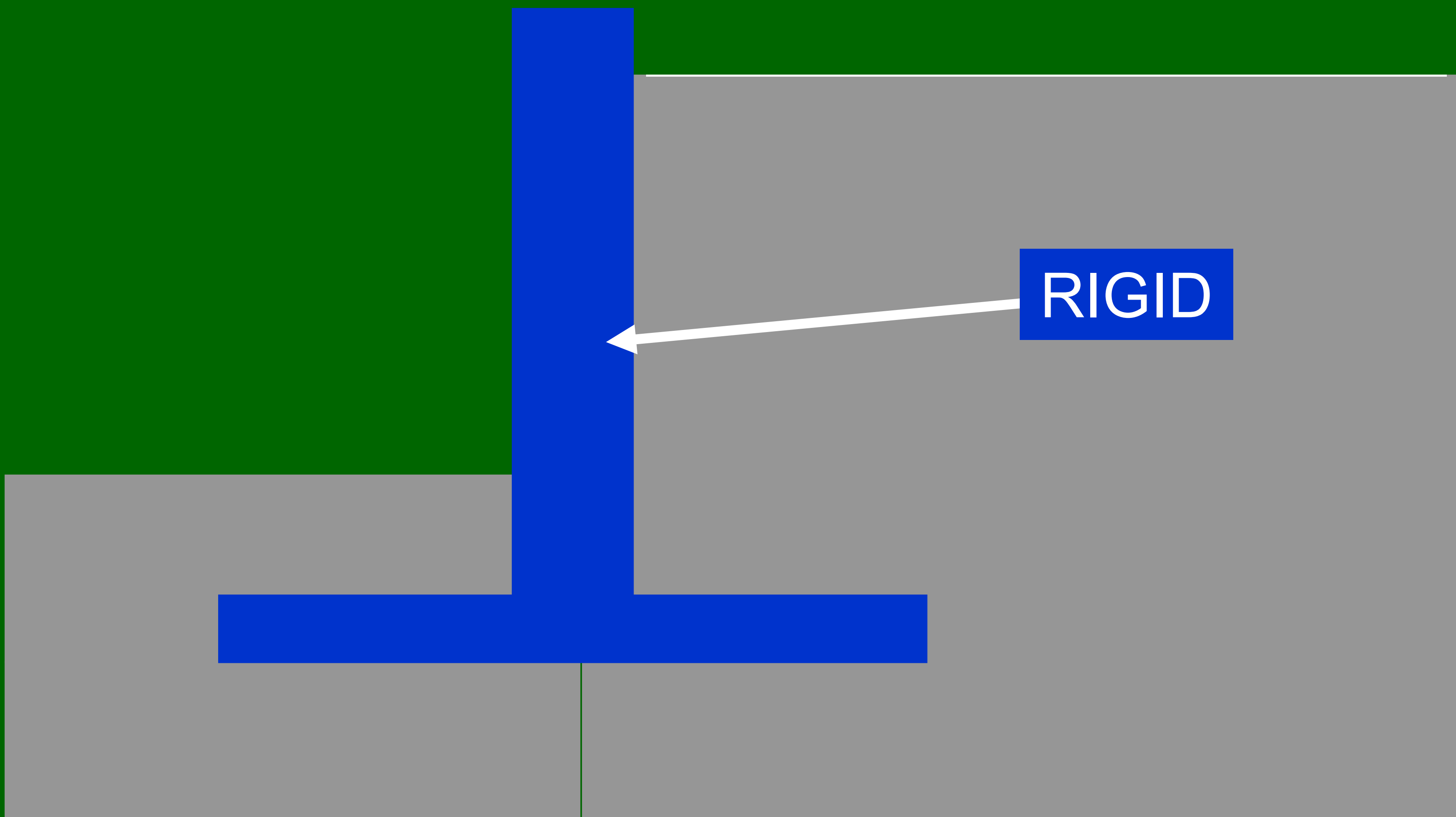
When the soil behind the wall is prevented from lateral movement (towards or away from soil) of wall, the pressure is known as earth pressure at rest.

# PRESSURE AT REST

This is the case when wall has a considerable rigidity.

Basement walls generally fall in this category.

# PRESSURE AT REST



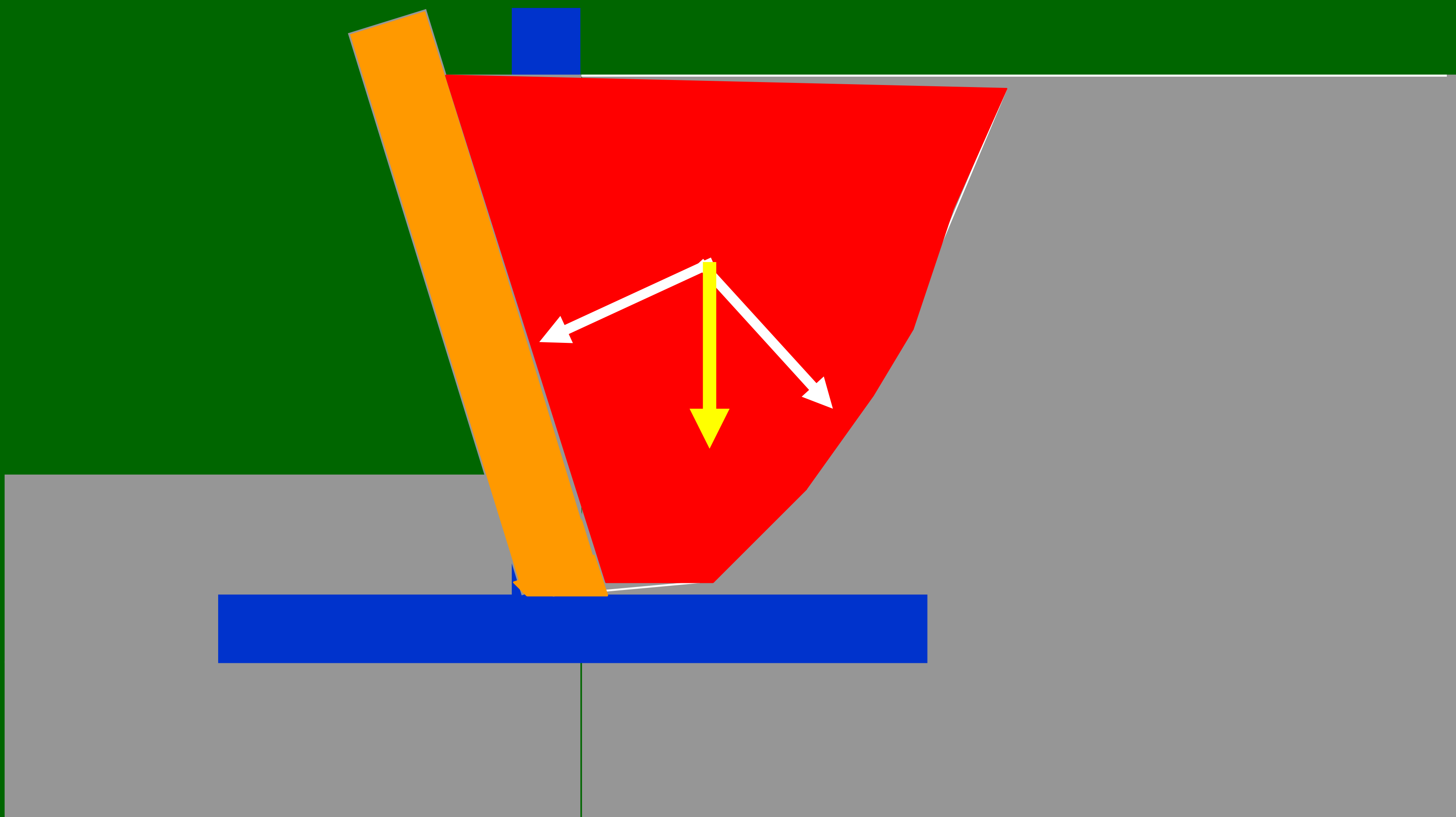
# ACTIVE EARTH PRESSURE

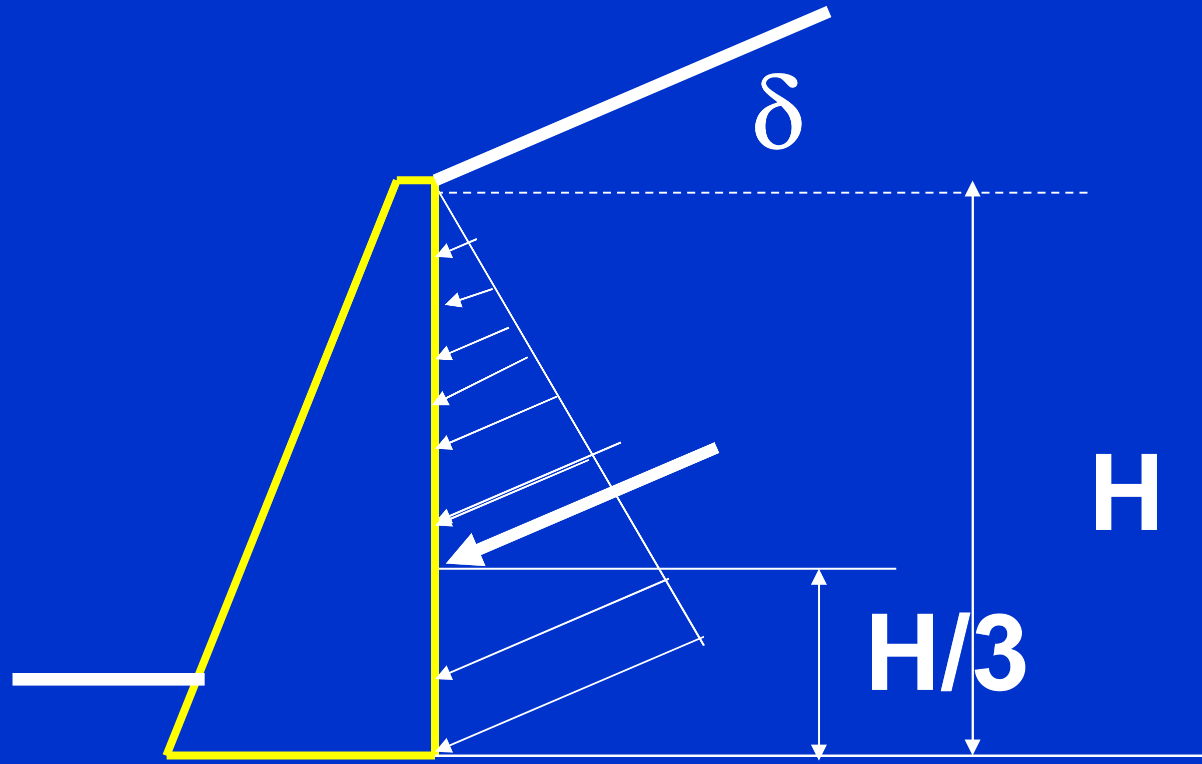
If a retaining wall is allowed to **move away** from the soil accompanied by a lateral soil expansion, the earth pressure **decreases** with the increasing expansion.

# ACTIVE EARTH PRESSURE

A **shear failure** of the soil is resulted with any **further expansion** and a sliding wedge tends to **move forward** and **downward**. The earth pressure associated with this state of failure is the **minimum pressure** and is known as active earth pressure.

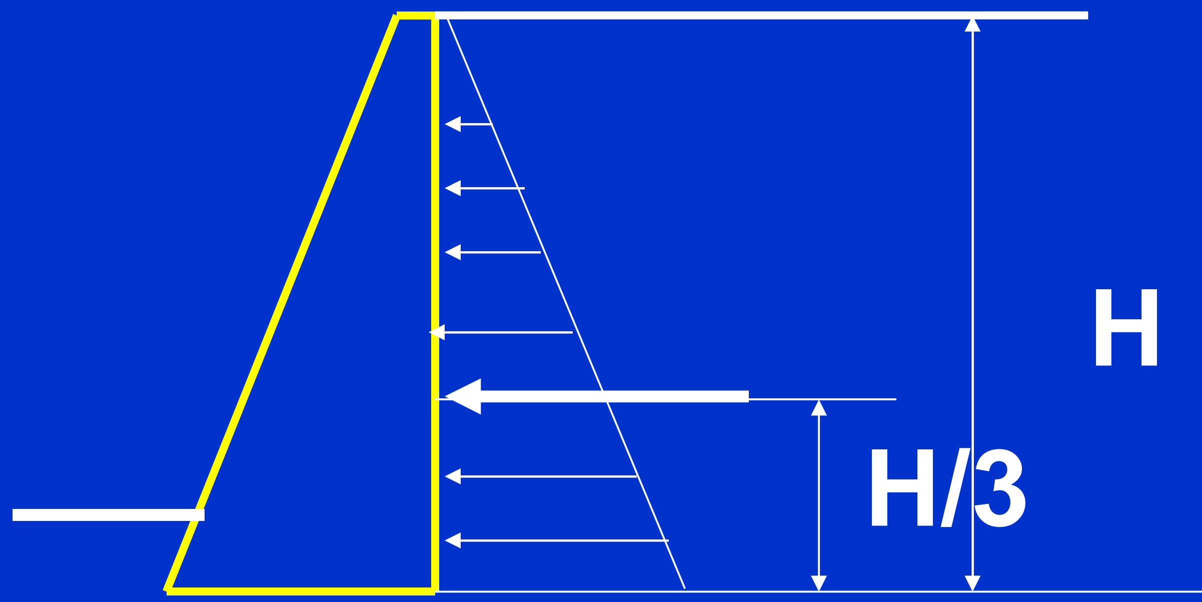
# EARTH PRESSURES






$$C_a = \cos\delta \frac{\cos\delta - \sqrt{\cos^2\delta - \cos^2\phi}}{\cos\delta + \sqrt{\cos^2\delta - \cos^2\phi}}$$

$\delta = 0$

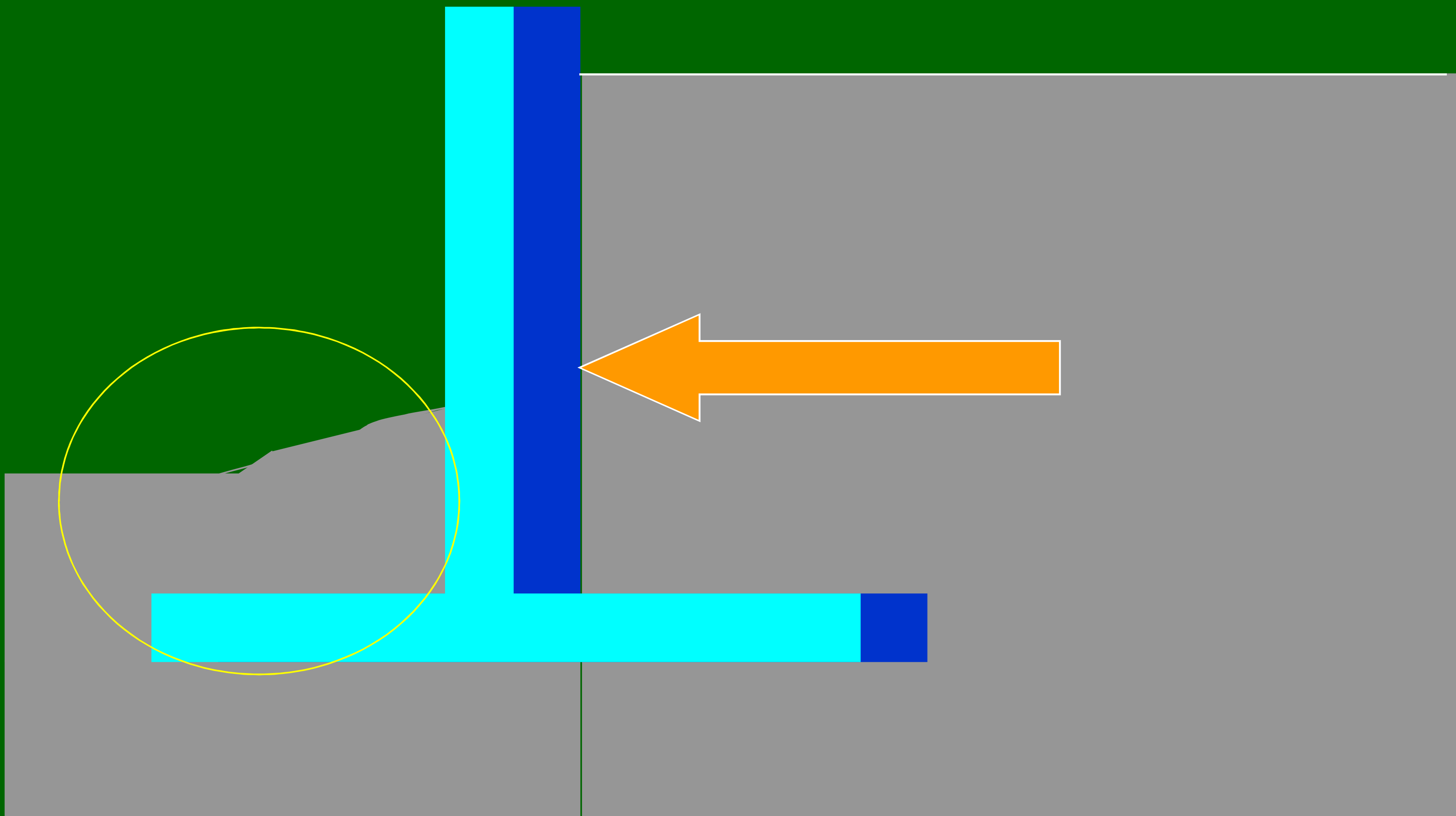



$$C_{ah} = \frac{1 - \sin\phi}{1 + \sin\phi}$$

# PASSIVE EARTH PRESSURE

If a retaining wall is allowed to move towards the soil accompanied by a lateral soil compression, the earth pressure increases with the increasing compression in the soil.

# PASSIVE EARTH PRESSURE



$$C_P = \cos\delta \frac{\cos\delta + \sqrt{\cos^2\delta - \cos^2\phi}}{\cos\delta - \sqrt{\cos^2\delta - \cos^2\phi}}$$

**δ = 0**

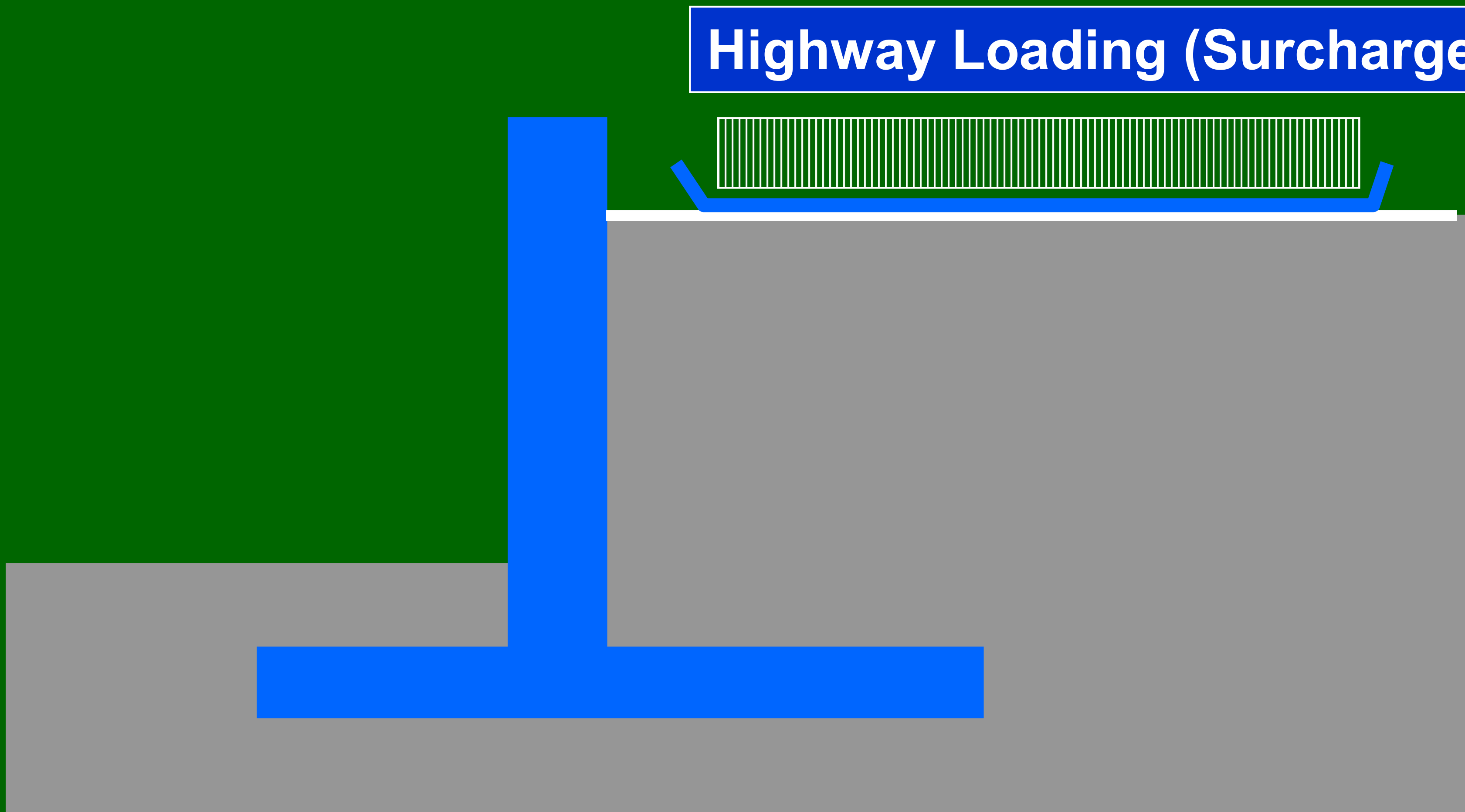
$$C_{ph} = \frac{1 + \sin\phi}{1 - \sin\phi}$$

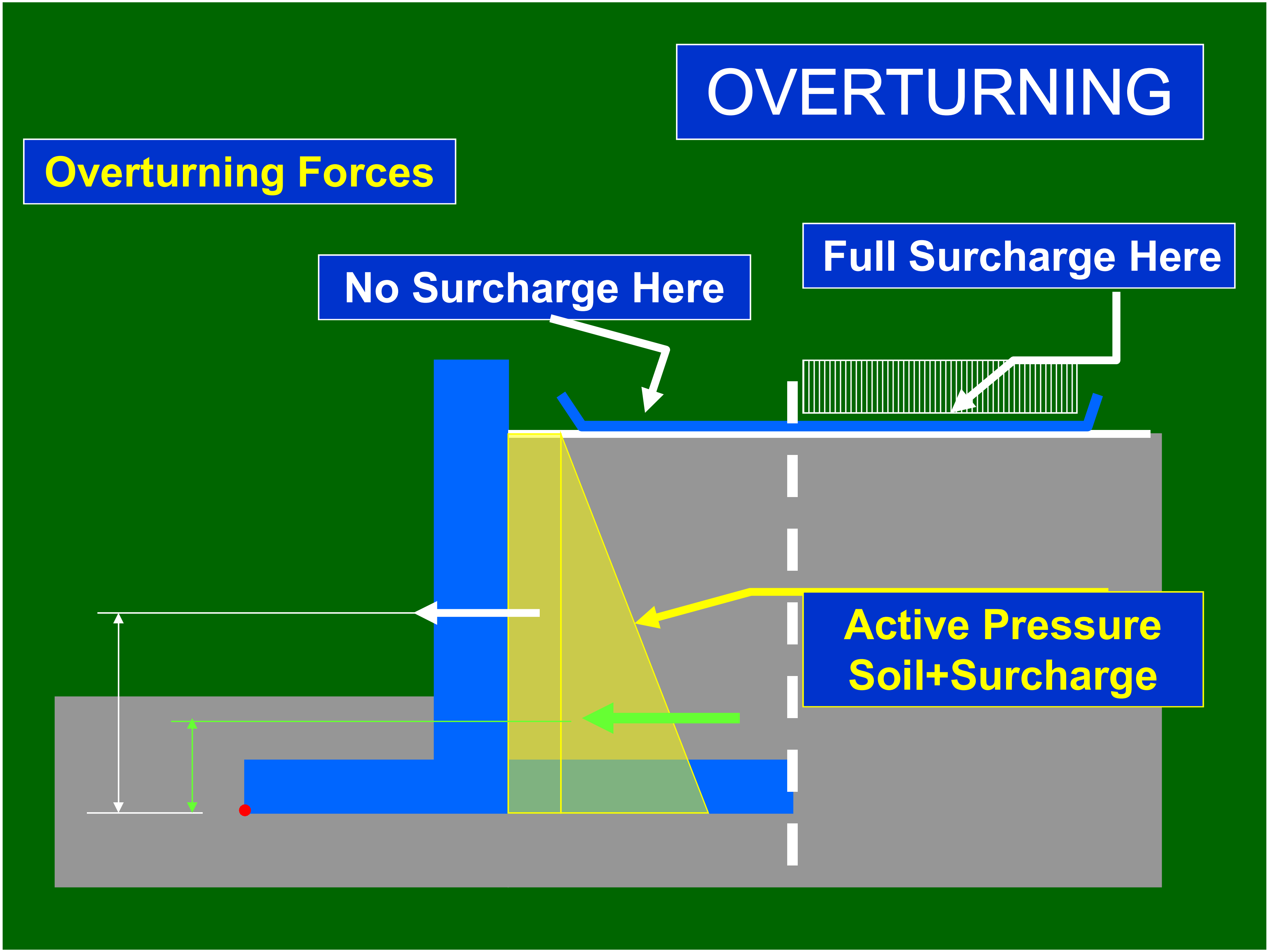
**= 1/$C_{ah}$**

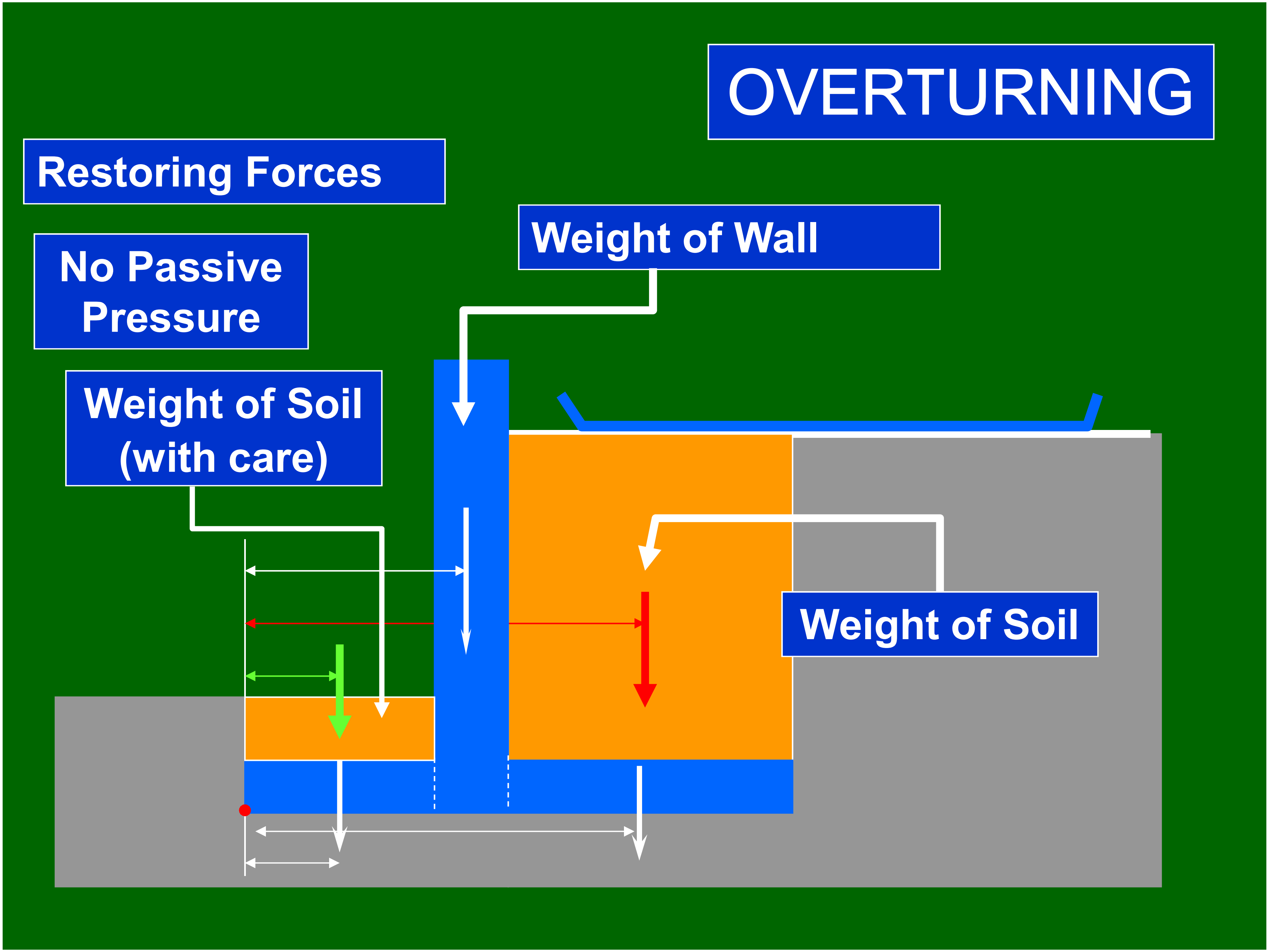
# STABILITY

- OVERTURNING
- SLIDING
- BEARING

# OVERTURNING



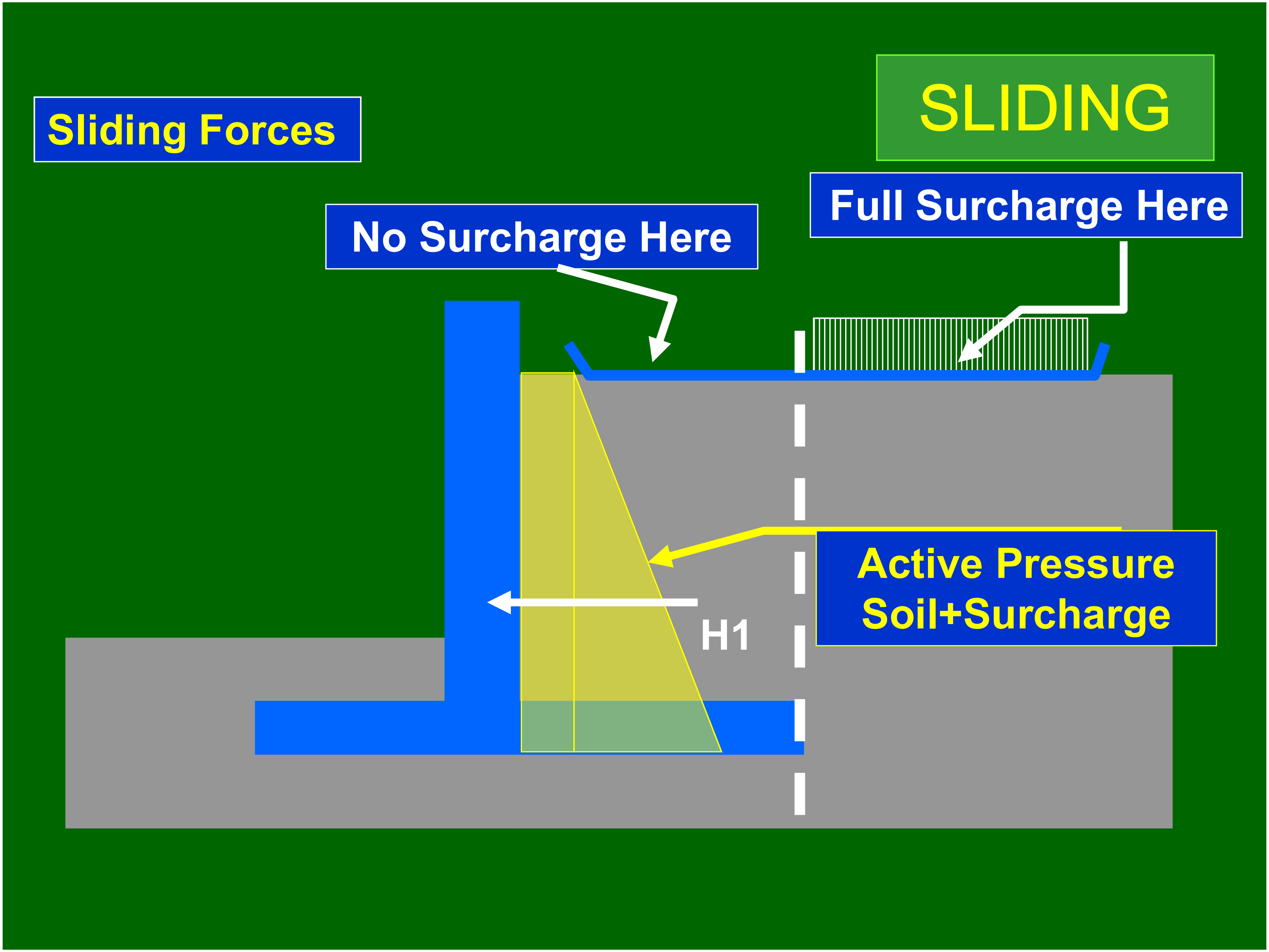

OVERTURNING
Overturning Forces
No Surcharge Here
Full Surcharge Here
Active Pressure
Soil+Surcharge


OVERTURNING
Restoring Forces
No Passive Pressure
Weight of Wall
Weight of Soil (with care)
Weight of Soil

# OVERTURNING

$$\text{FOS vs OT} = \frac{\text{Restoring Moment}}{\text{Overturning Moment}}$$

A FOS = 2 is considered sufficient


Sliding Forces
SLIDING
Full Surcharge Here
No Surcharge Here
Active Pressure
Soil+Surcharge
H1

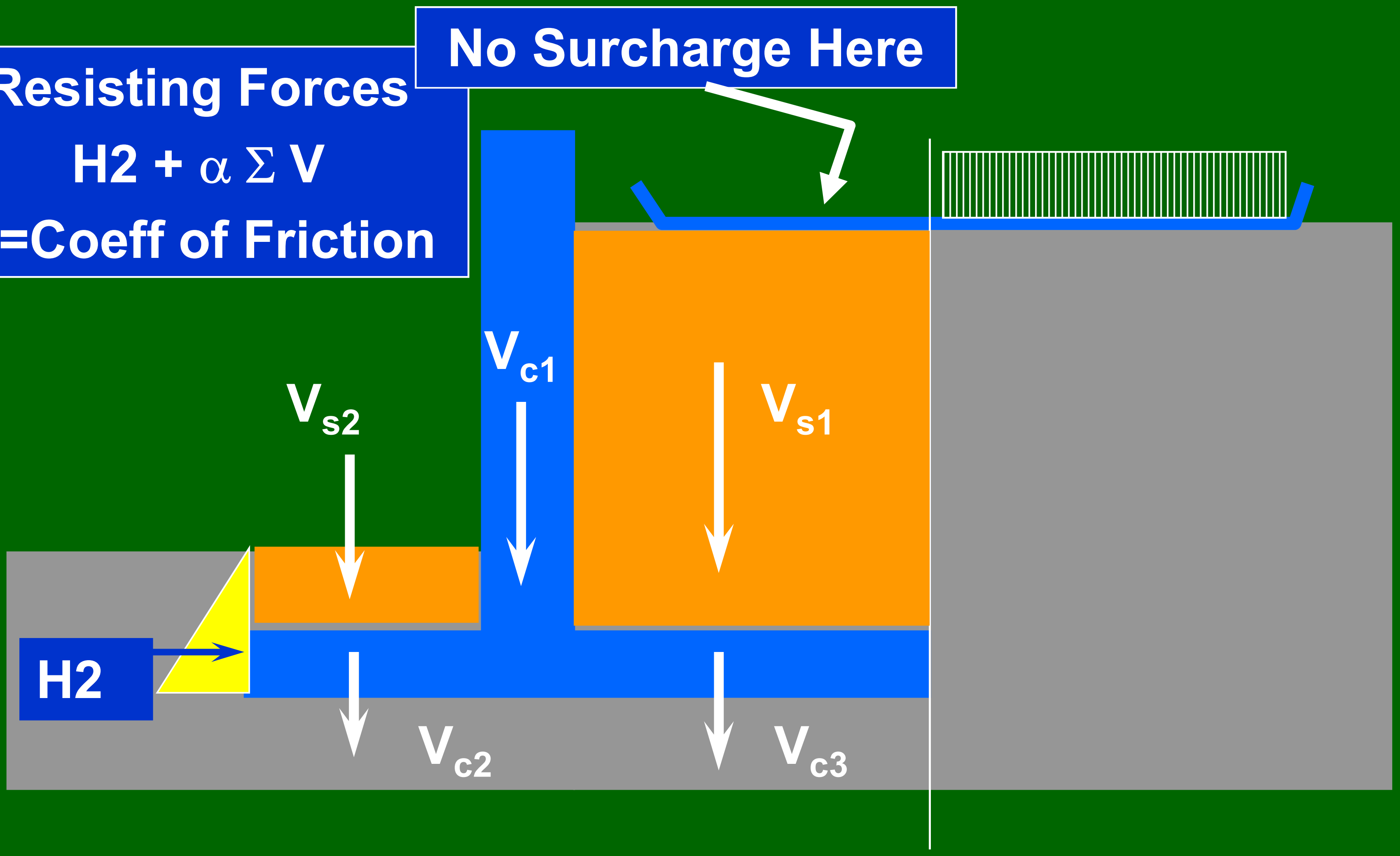
## SLIDING

**Resisting Forces**

**Resisting Forces**

**H2 + $\alpha \Sigma V$**

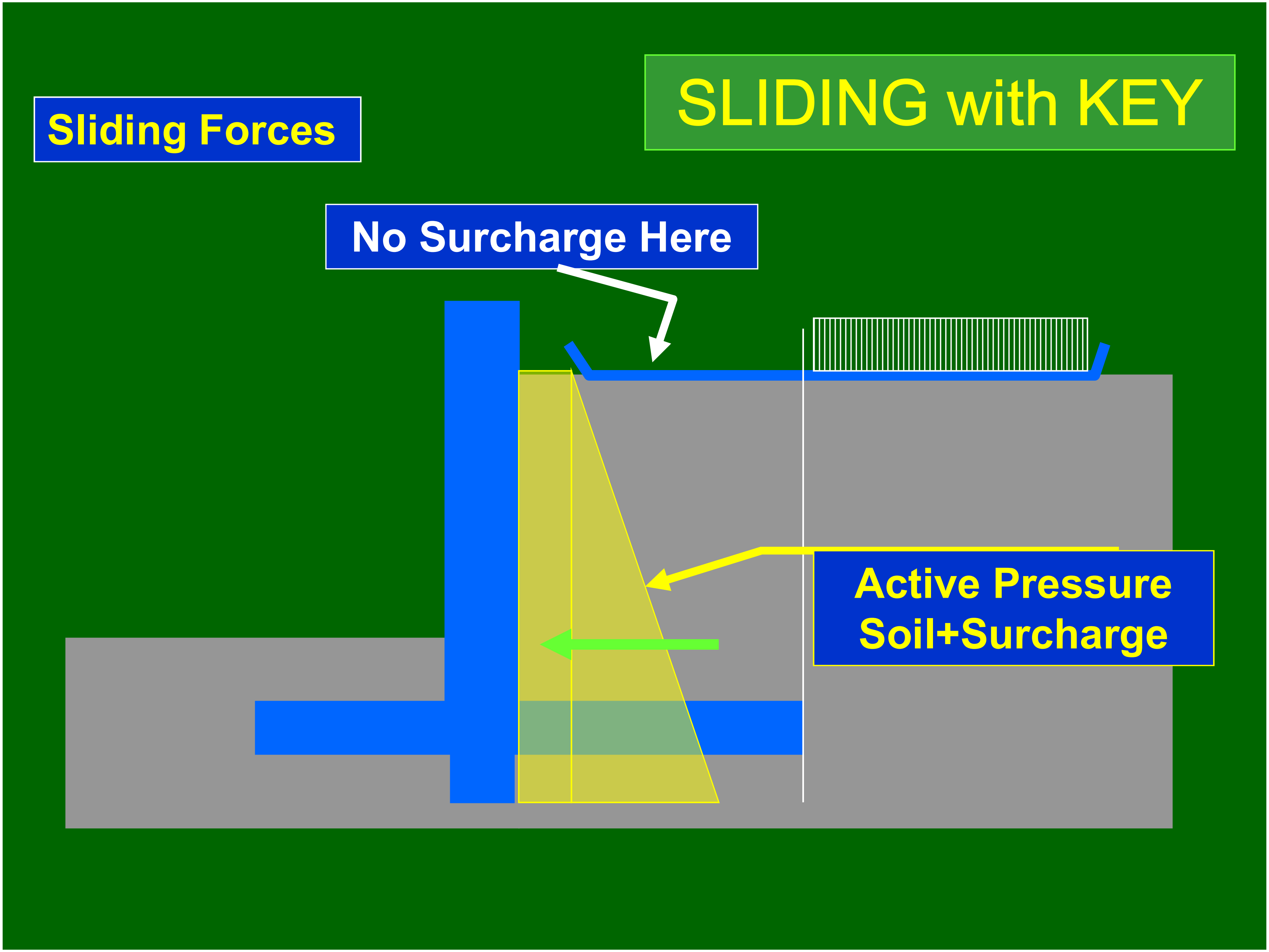
**$\alpha$=Coeff of Friction**



# SLIDING without KEY

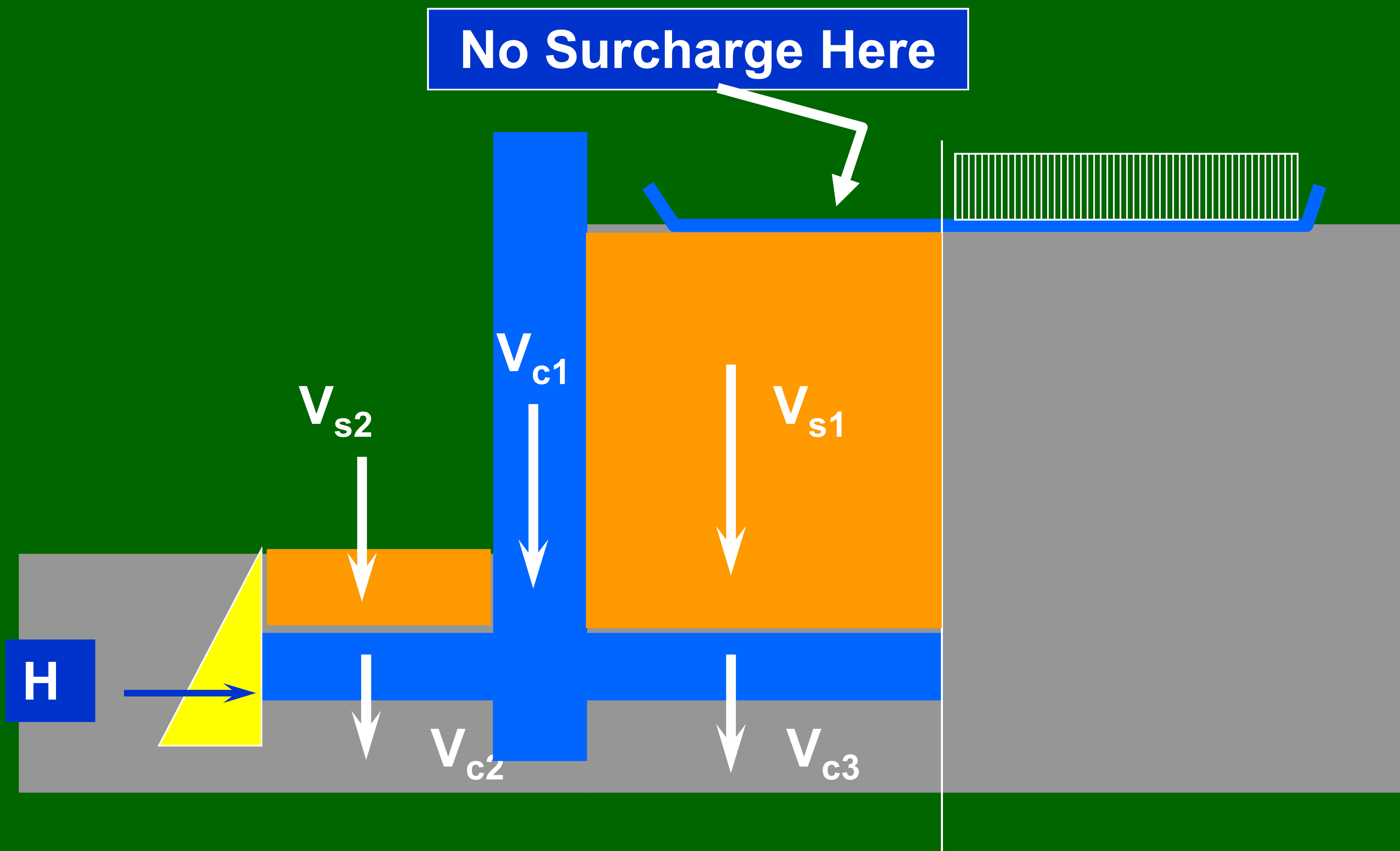
$$\text{FOS vs Sliding} = \frac{\text{Passive Earth Pressure Force} + \alpha \Sigma V}{\text{Active Earth Pressure Force}}$$

**A FOS = 1.5 is considered sufficient**


SLIDING with KEY
Sliding Forces
No Surcharge Here
Active Pressure
Soil+Surcharge

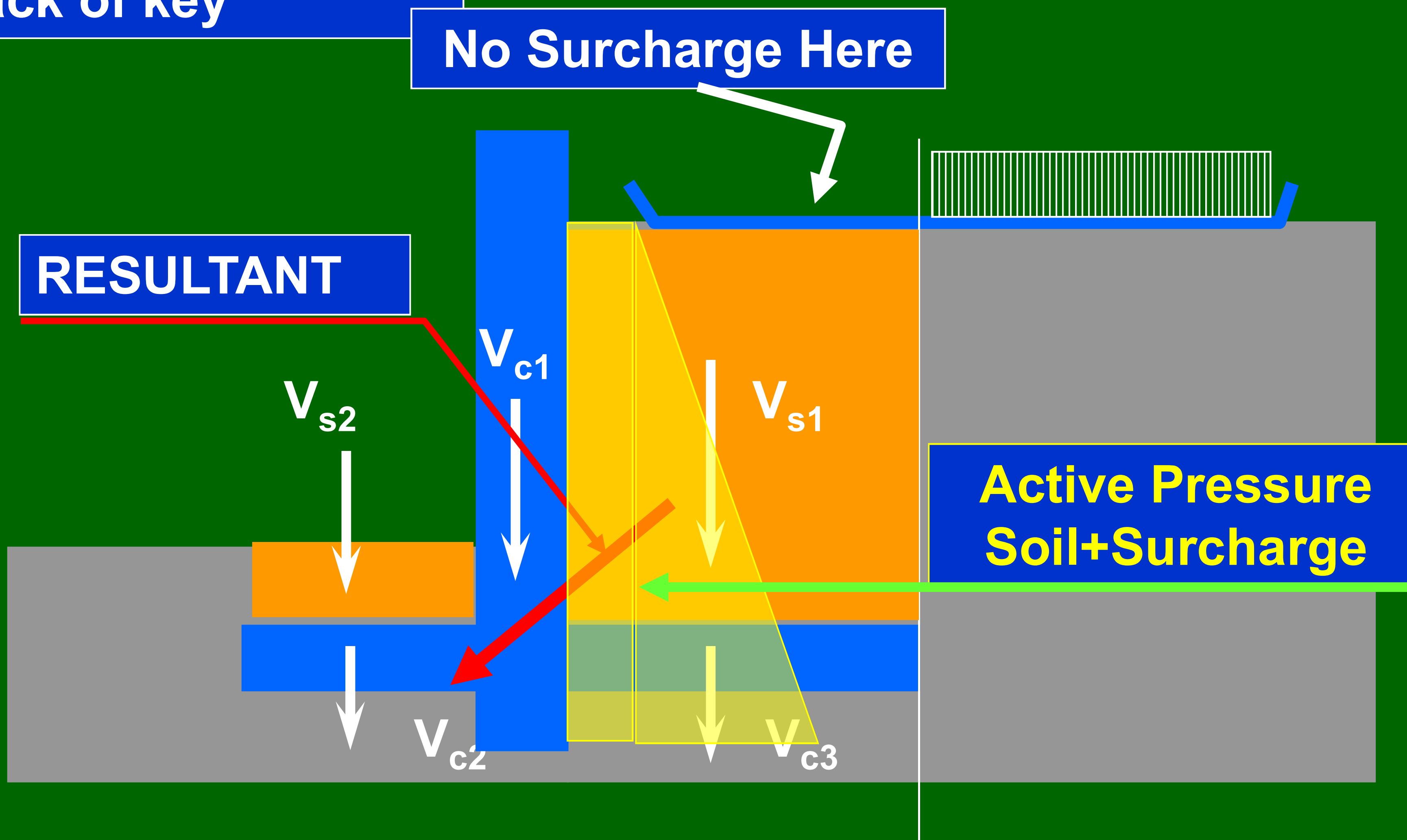
## SLIDING with KEY

**Resisting Forces**



# SLIDING with KEY

Find Vertical forces acting in front and back of key

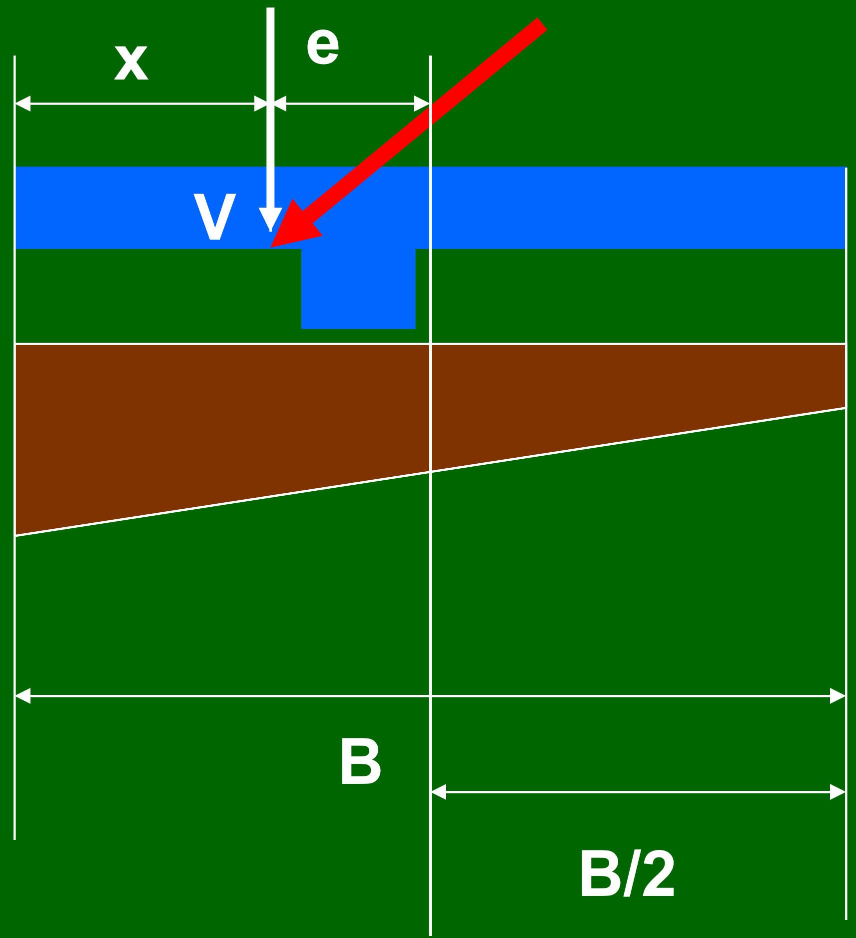


# SLIDING with KEY

**Determine Pressure Distribution Under Base**

**A=B**

**S=$B^2/6$**

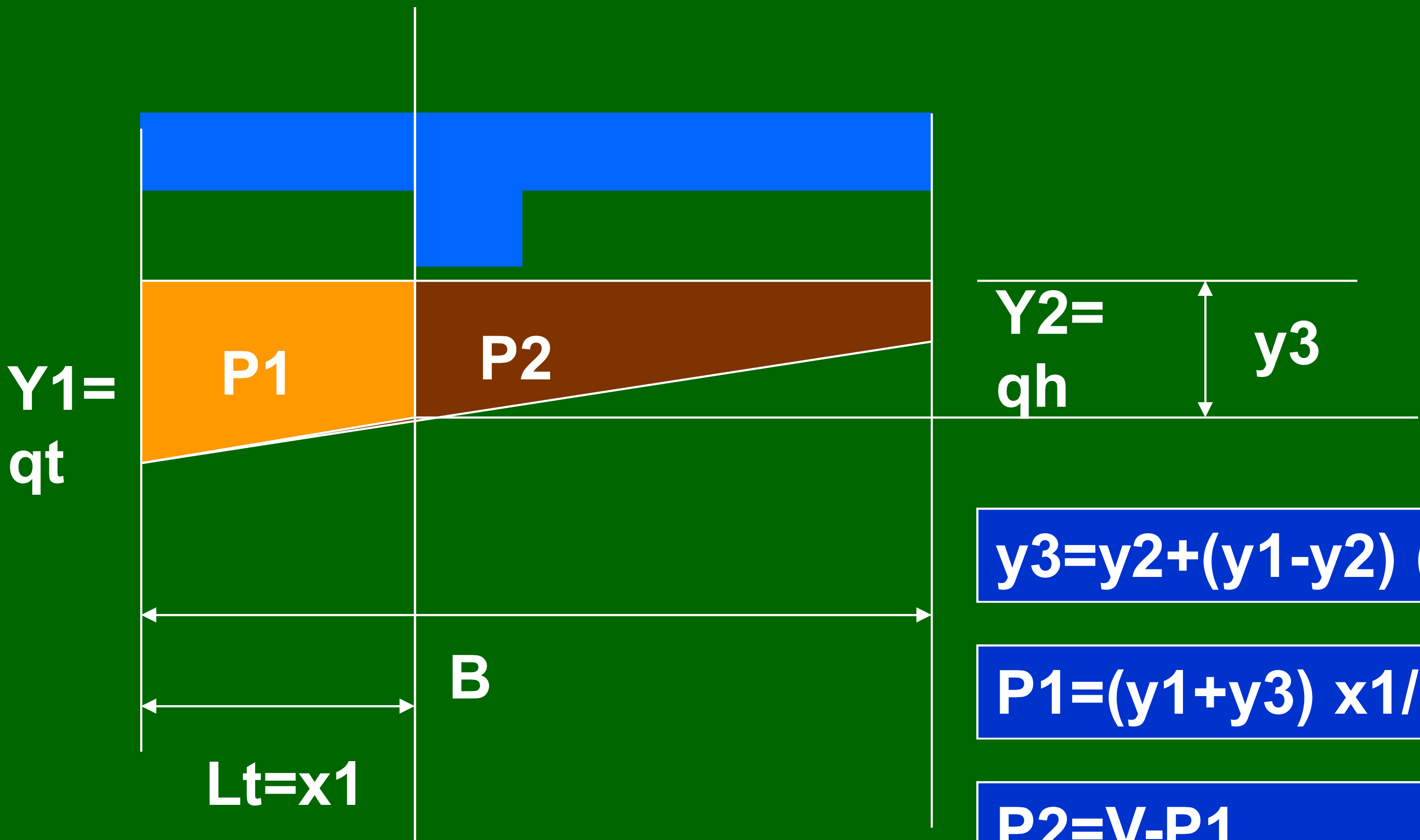



$$\frac{V}{B}+\frac{6Ve}{B^2}$$

$$\frac{V}{B}-\frac{6Ve}{B^2}$$

# SLIDING with KEY

## Determine Force in Front of KEY



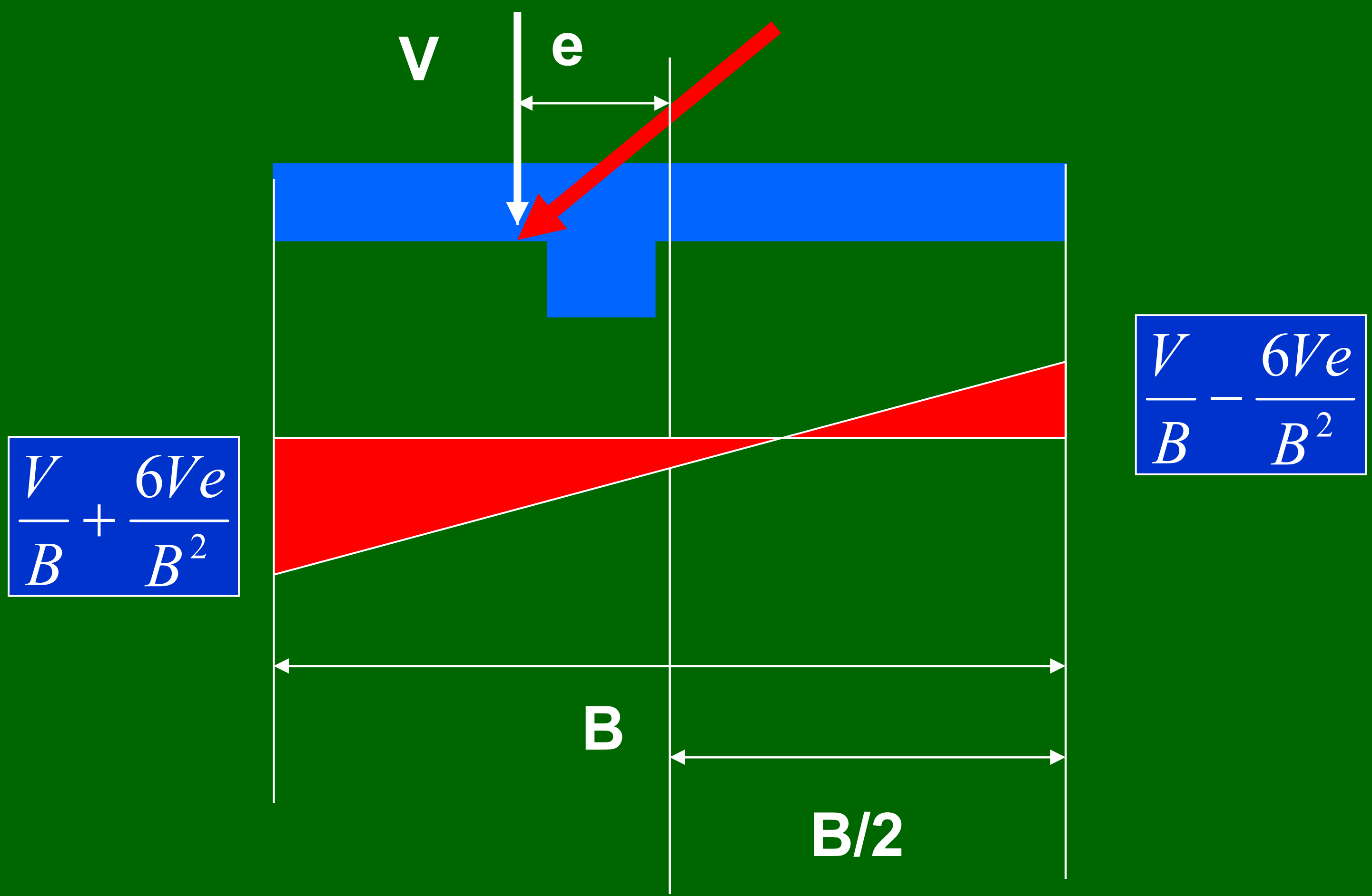

y3=y2+(y1-y2) (B-x1)/B

P1=(y1+y3) x1/2

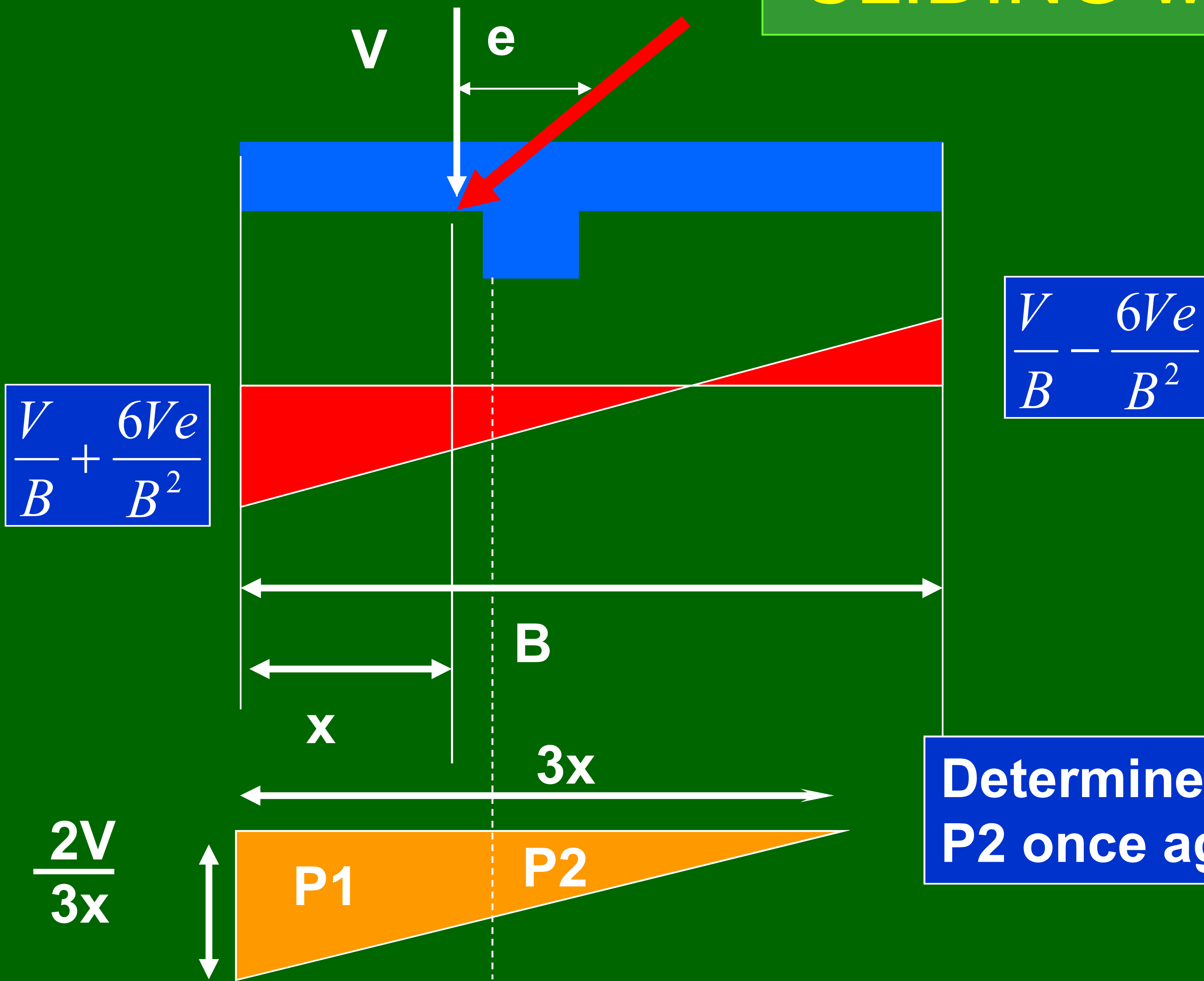
P2=V-P1

# SLIDING with KEY

**When Pressure Distribution Under Base is Partially Negative**



# SLIDING with KEY




**Determine P1 and P2 once again**

# SLIDING with KEY

Active Earth Pressure Force

Total Sliding Force = H1

Total Resisting Force = P1 tan $\phi$ + $\alpha$ P2 + H2

Force in Front of Key

Internal Friction of Soil

Friction b/w Soil, Concrete

Passive Earth Pressure Force

Force on and Back of Key

# BEARING

There are two possible critical conditions

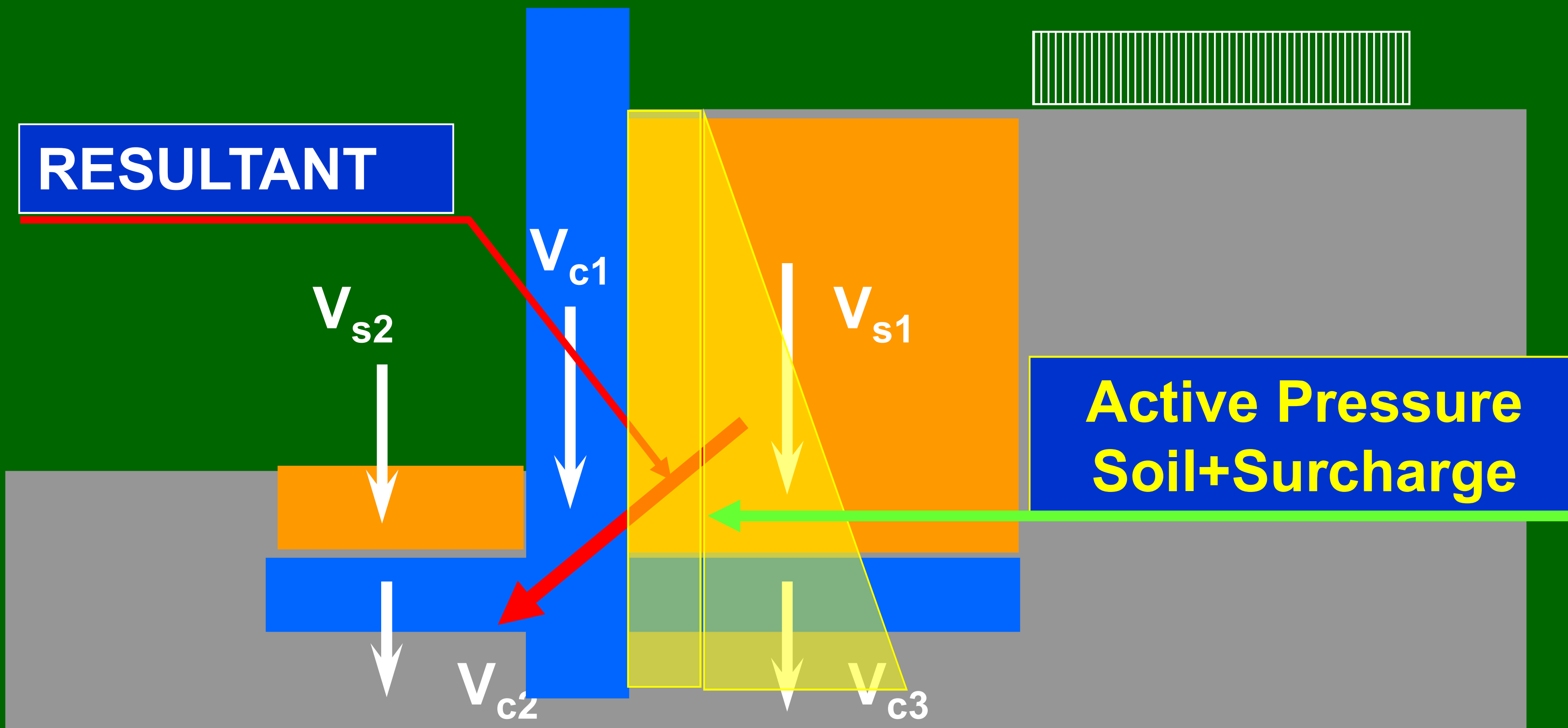
1. No surcharge on heel

2. Surcharge on heel

# BEARING

No Surcharge on Heel

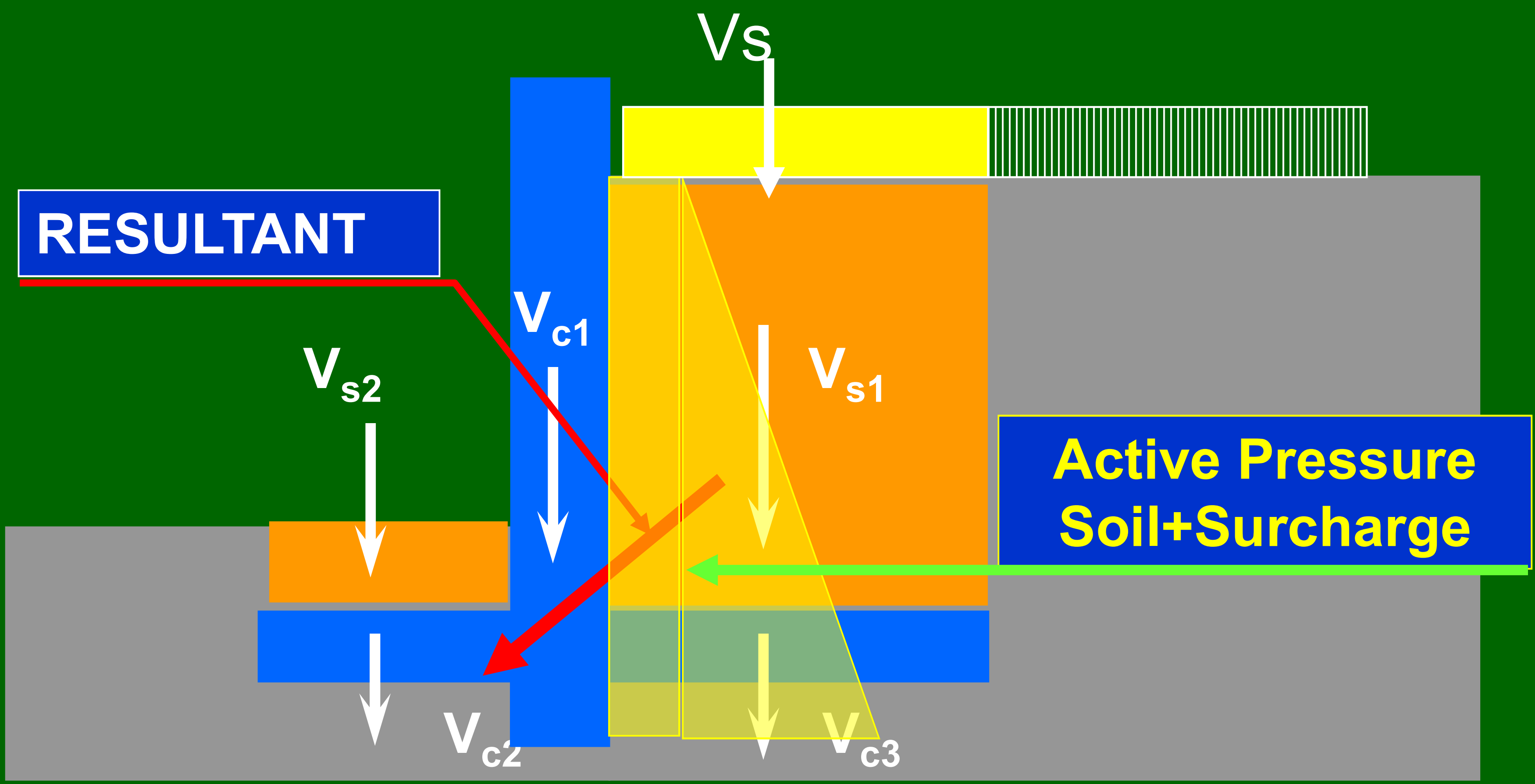
This case has been dealt already



DETERMINE THE PRESSURE DISTRIBUTION UNDER BASE SLAB

# BEARING

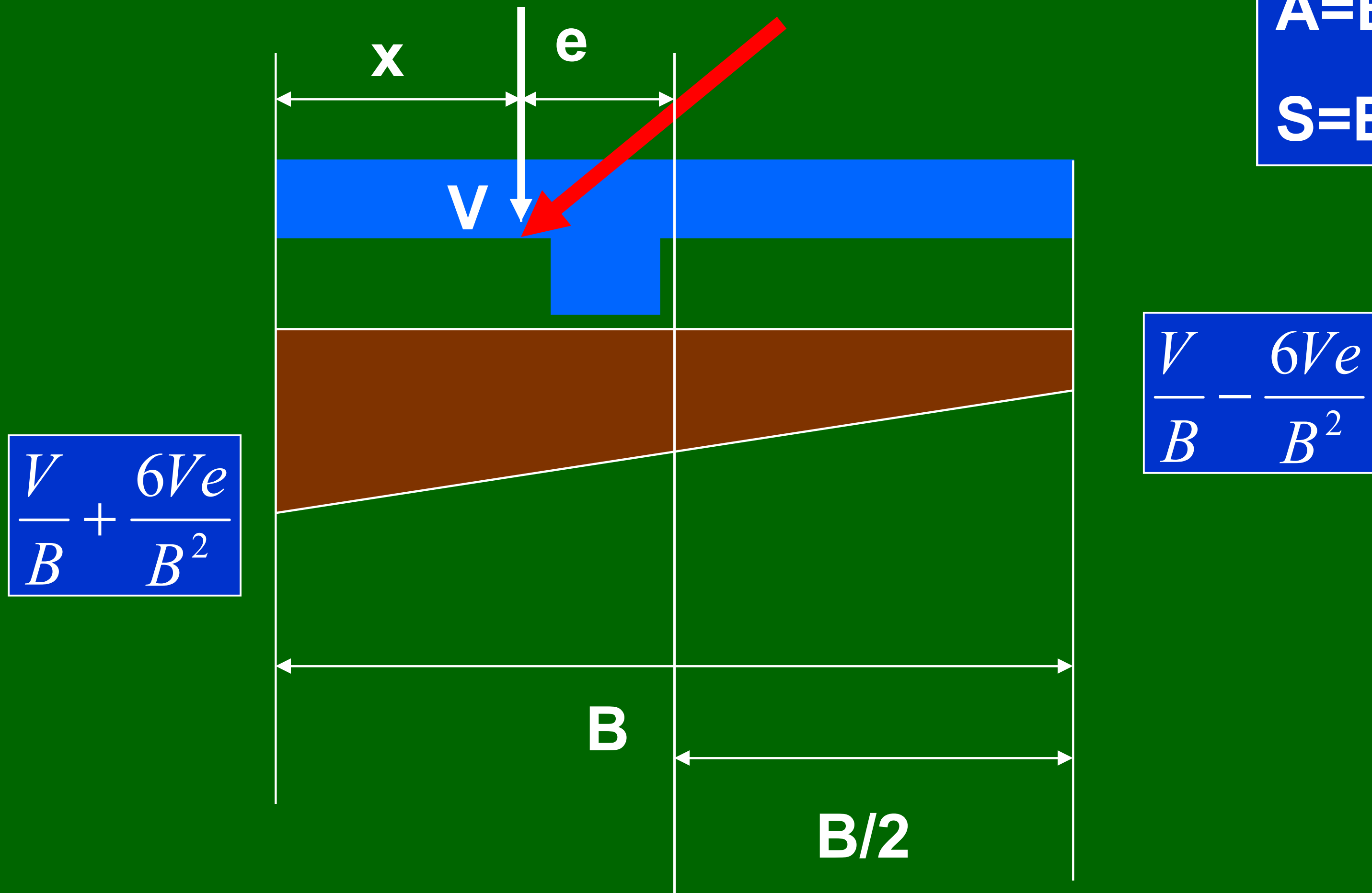
## Surcharge on Heel



# Determine Pressure Distribution Under Base

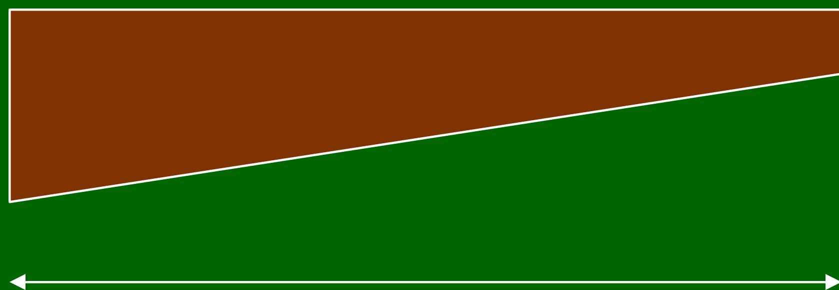
A=B

$S=B^2/6$



## Compare Pressure with Bearing Capacity

$$\frac{V}{B} + \frac{6Ve}{B^2}$$



$$\frac{V}{B} - \frac{6Ve}{B^2}$$

**B**

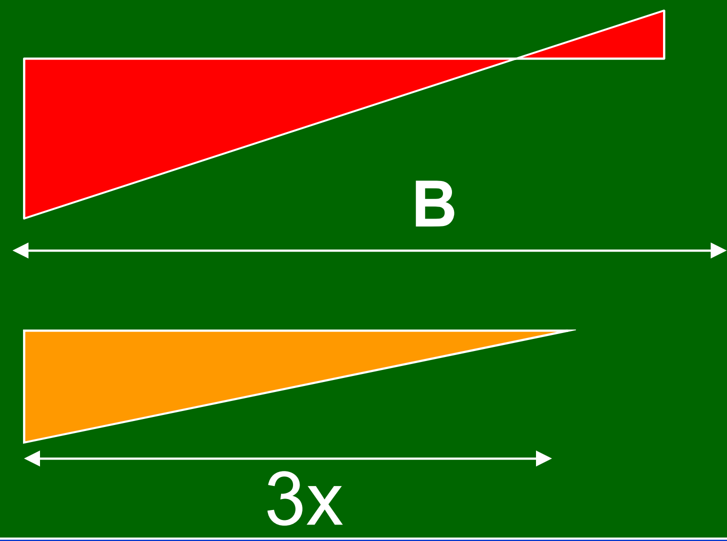
$$\text{FOS vs Bearing} = \frac{\text{Allowable Bearing}}{\text{Max Bearing Pressure}}$$

$$\frac{V}{B} + \frac{6Ve}{B^2}$$

## ALTERNATELY

$$\frac{V}{B} + \frac{6Ve}{B^2}$$

$$\frac{V}{B} - \frac{6Ve}{B^2}$$



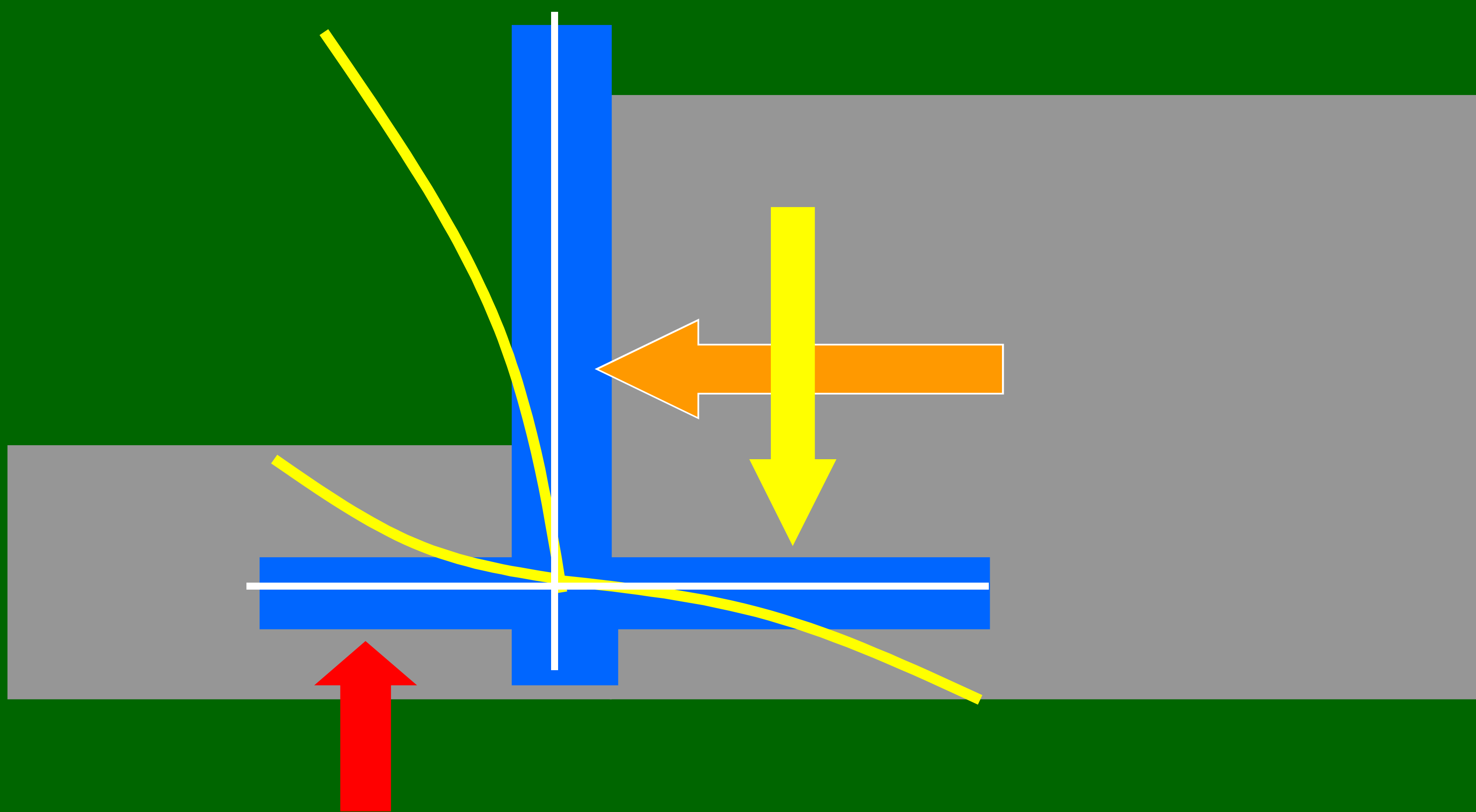

2V/3x

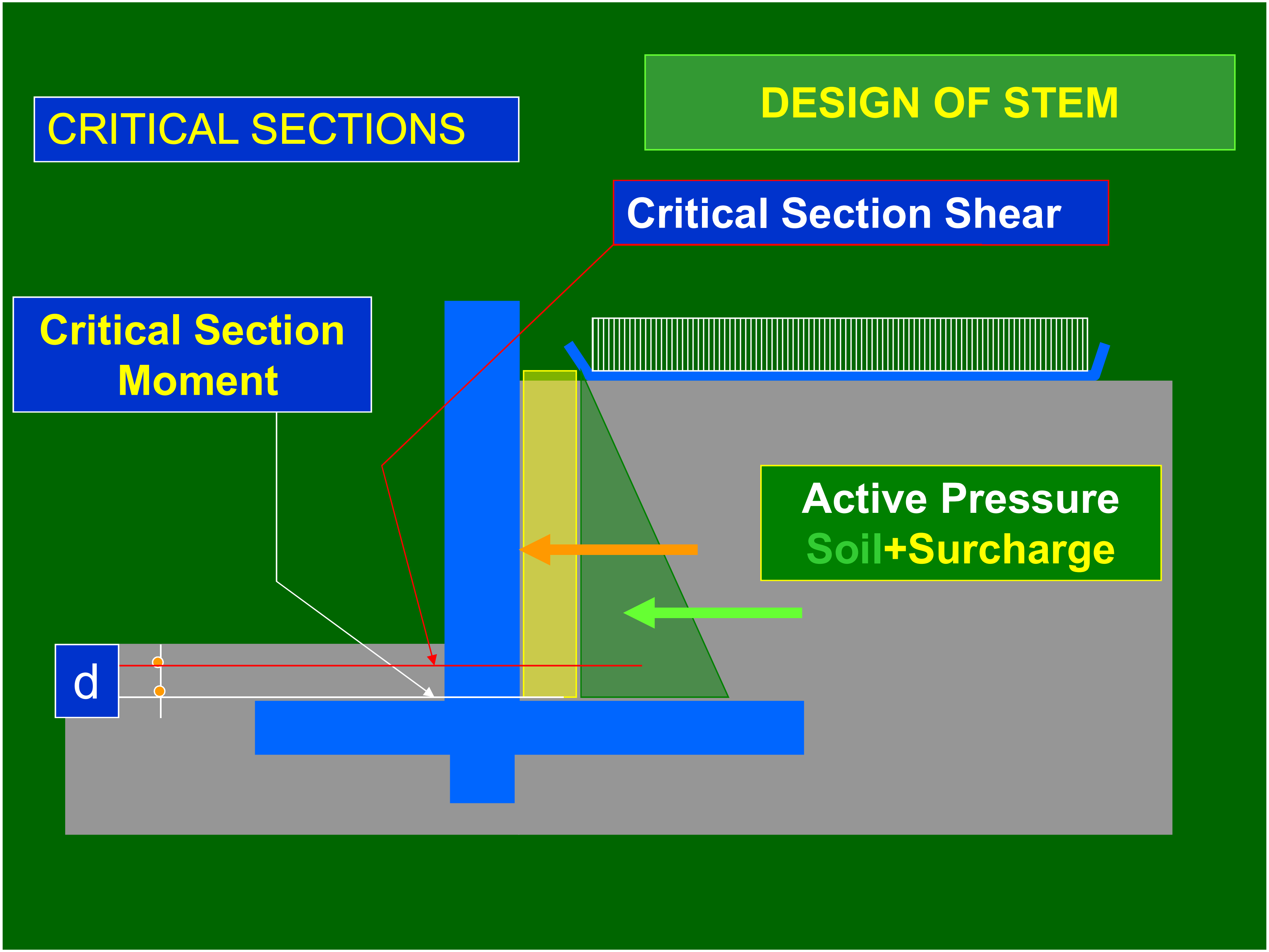
$$\text{FOS vs Bearing} = \frac{\text{Allowable Bearing}}{\text{Max Bearing Pressure}}$$

2V/3x

END OF PART I

# BENDING OF WALL



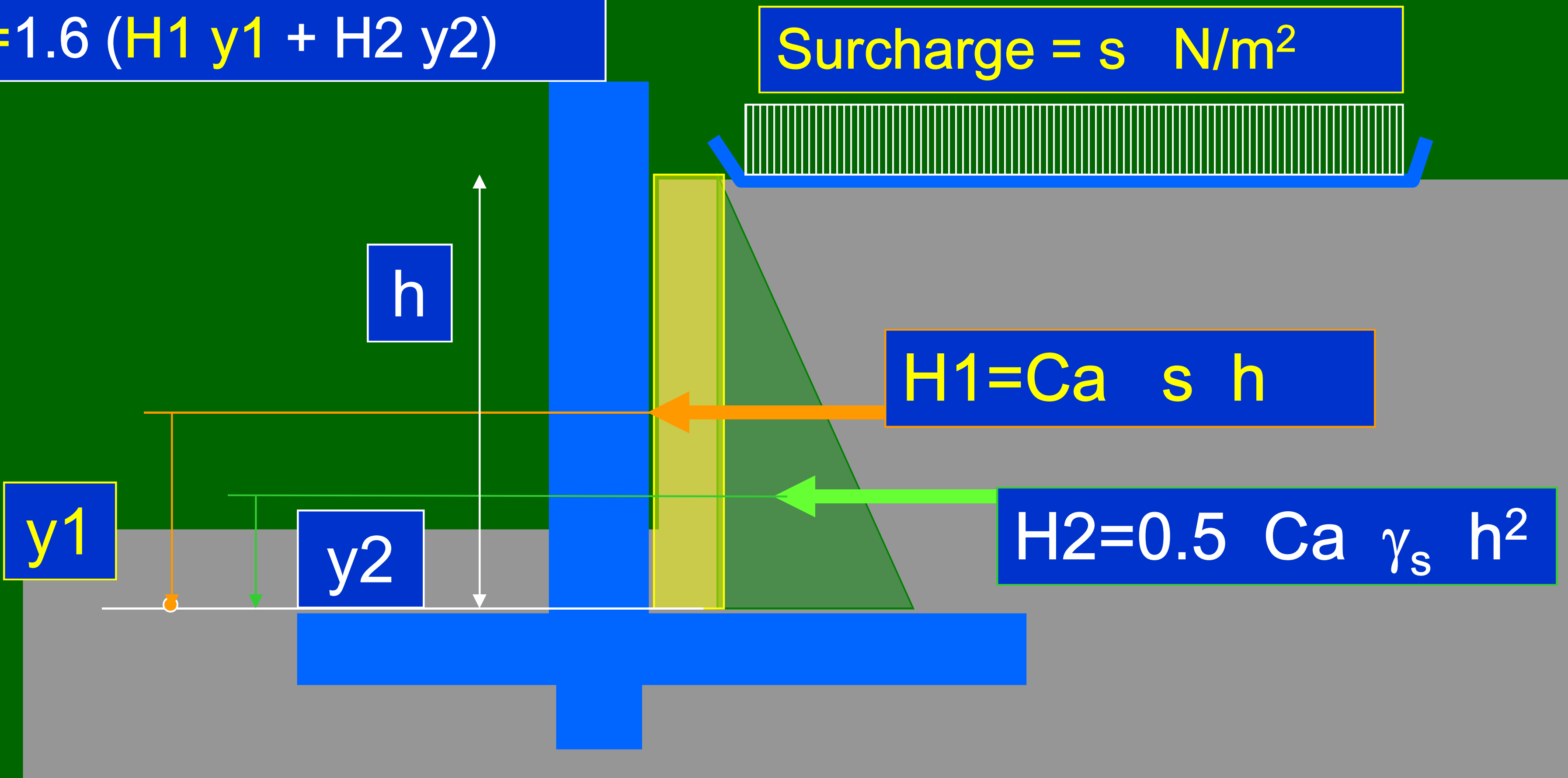


DESIGN OF STEM
CRITICAL SECTIONS
Critical Section Shear
Critical Section Moment
Active Pressure
Soil+Surcharge
d

# DESIGN OF STEM

Design Moment

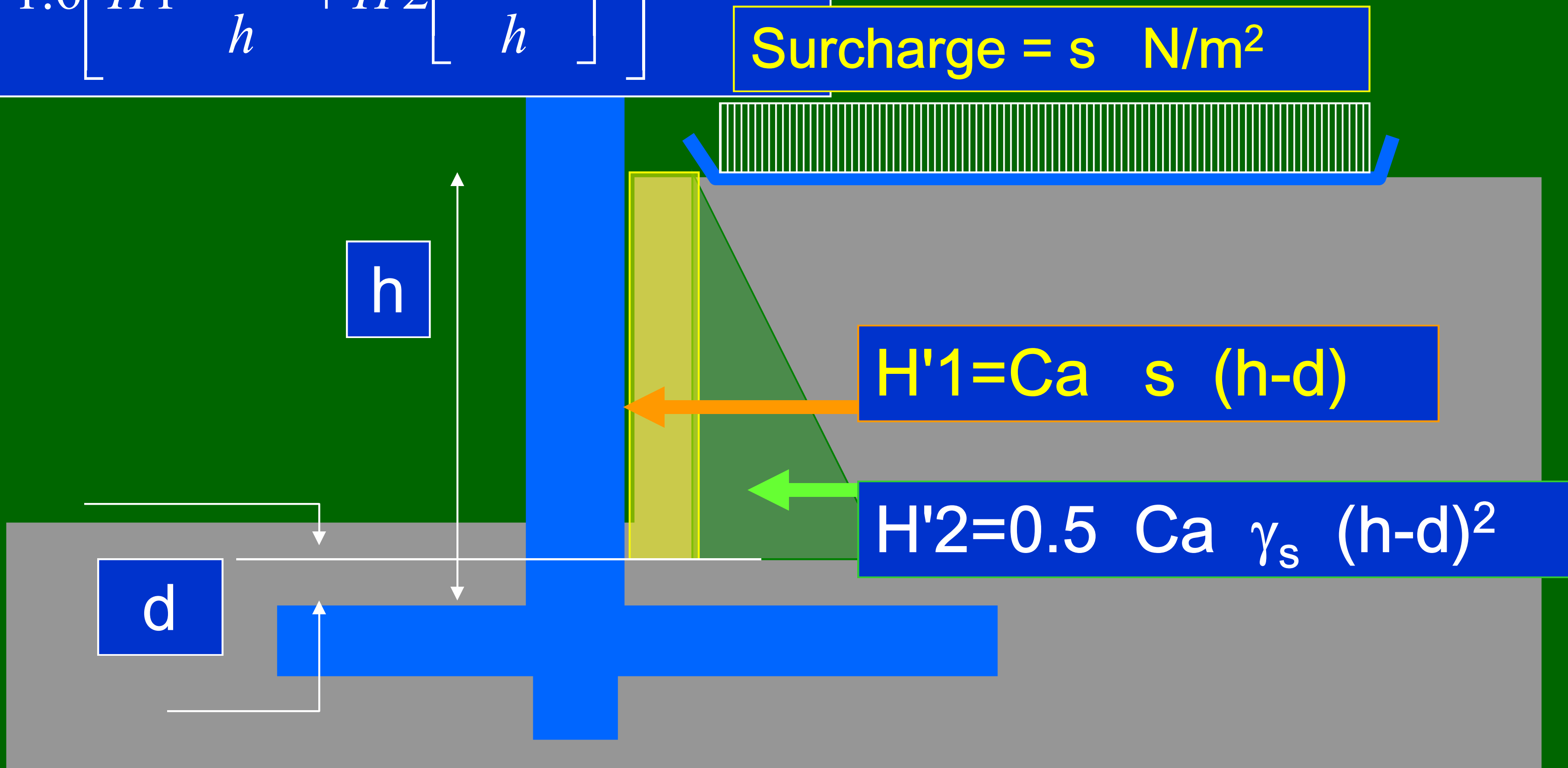
$=1.6\ (H1\ y1 + H2\ y2)$



# DESIGN OF STEM

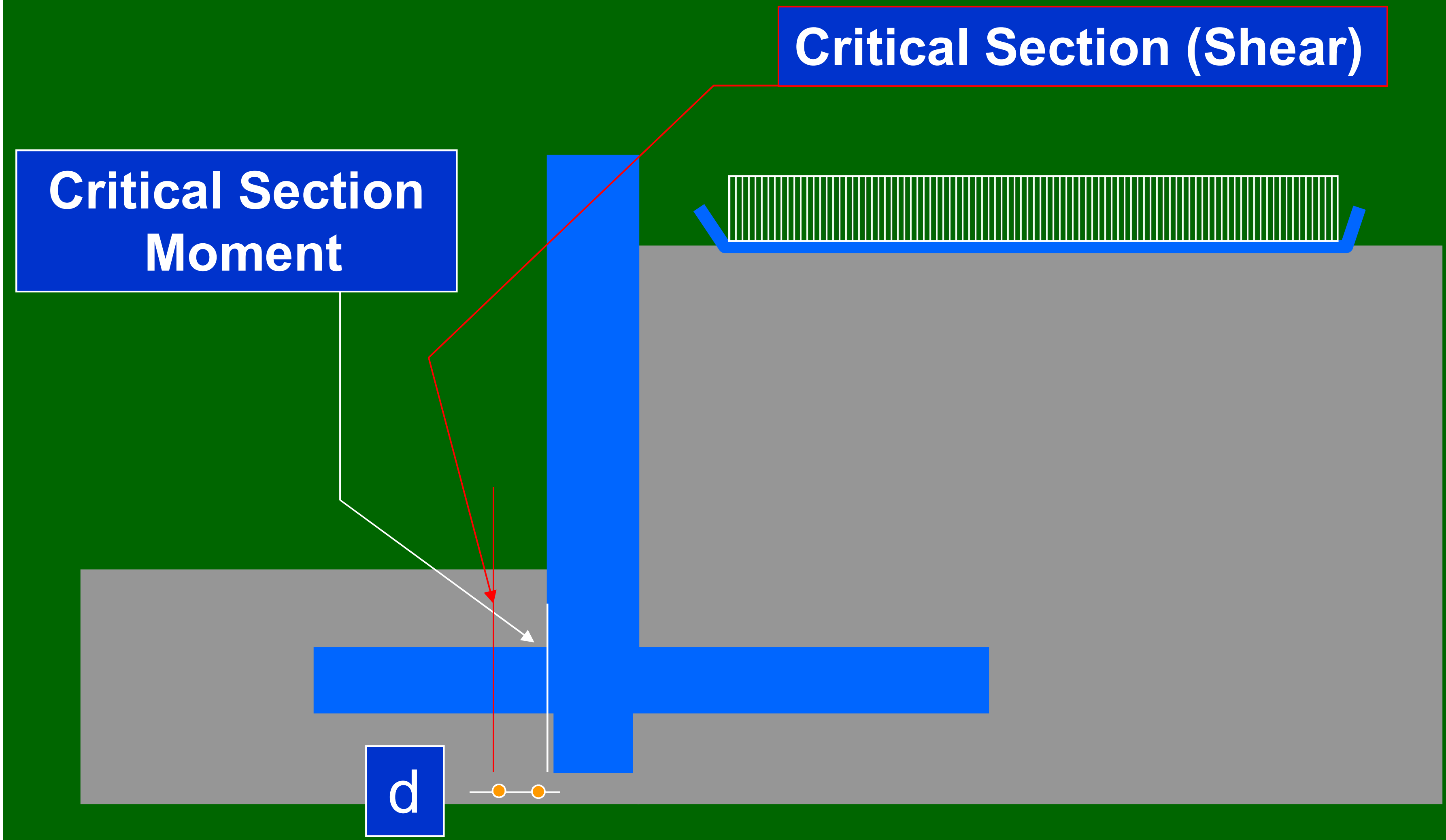
Design Shear=1.6(H '1+H '2)

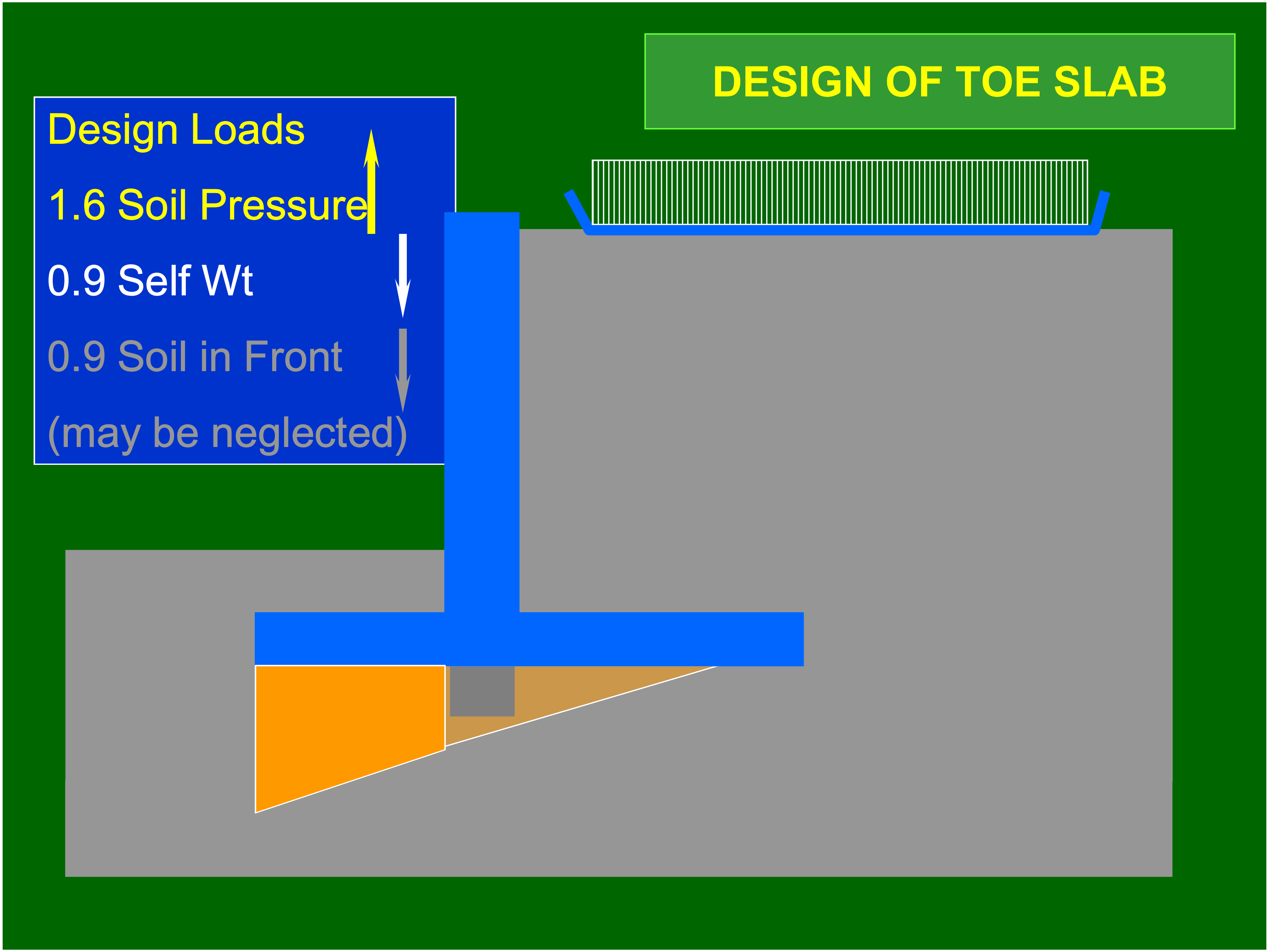
$$1.6\left[H1\frac{h-d}{h}+H2\left[\frac{h-d}{h}\right]^{2}\right]$$



## DESIGN OF TOE SLAB

### CRITICAL SECTIONS




DESIGN OF TOE SLAB
Design Loads
1.6 Soil Pressure
0.9 Self Wt
0.9 Soil in Front
(may be neglected)

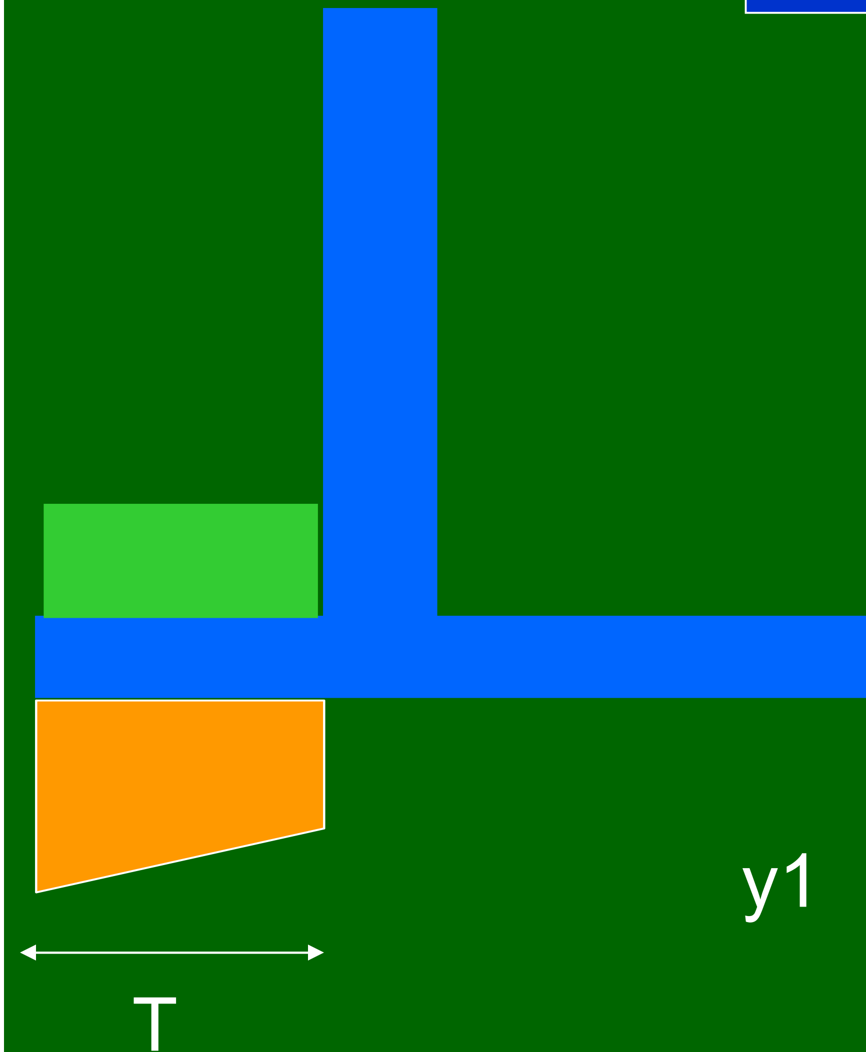
# TOE : DESIGN MOMENT

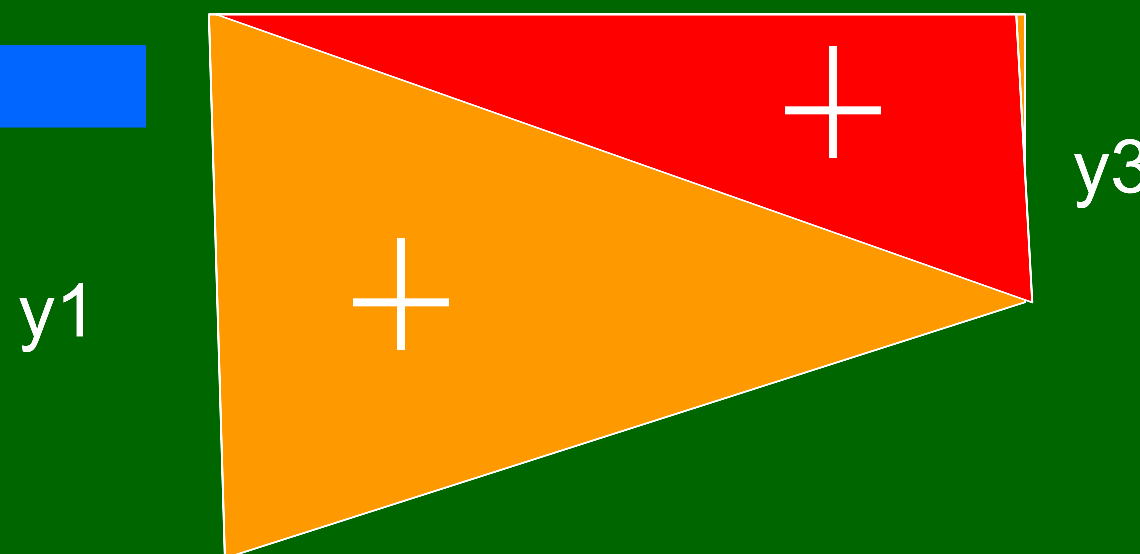
$1.6(0.5\ T\ y3)\ T/3$

$+1.6(0.5\ T\ y1)\ 2T/3$

$-0.9\ w_c\ T^2/2$

$-0.9\ w_s\ T^2/2$



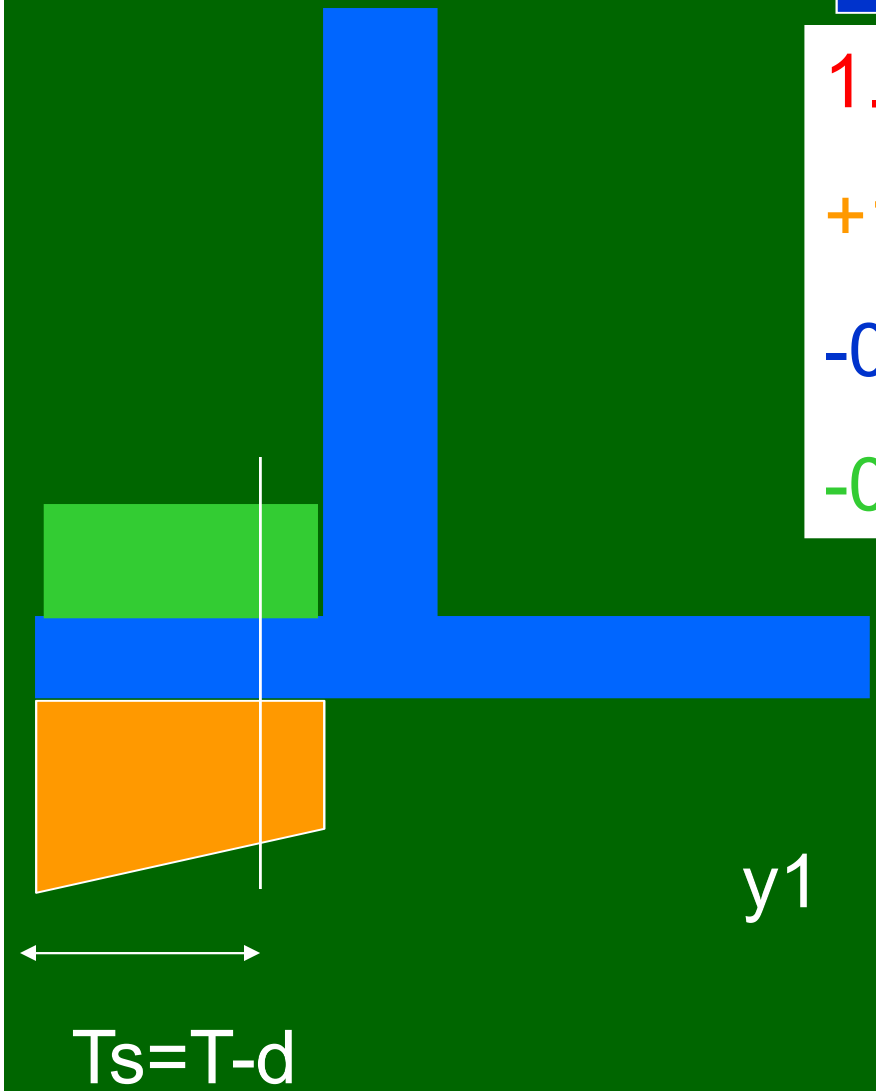
# TOE : DESIGN SHEAR

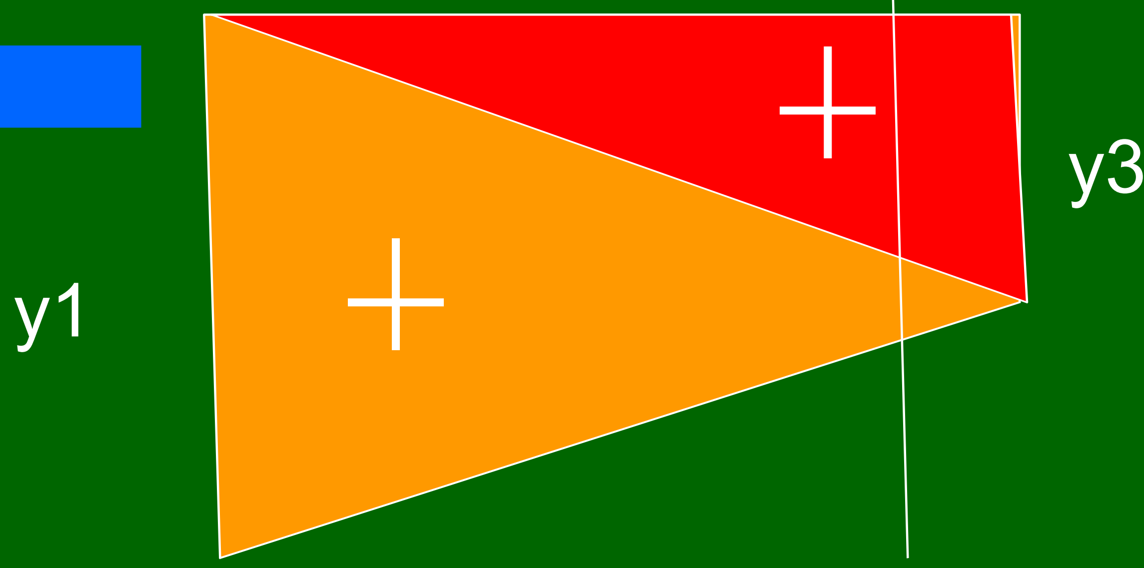
$1.6(0.5\ T_s)\ y3\ T_s/T$

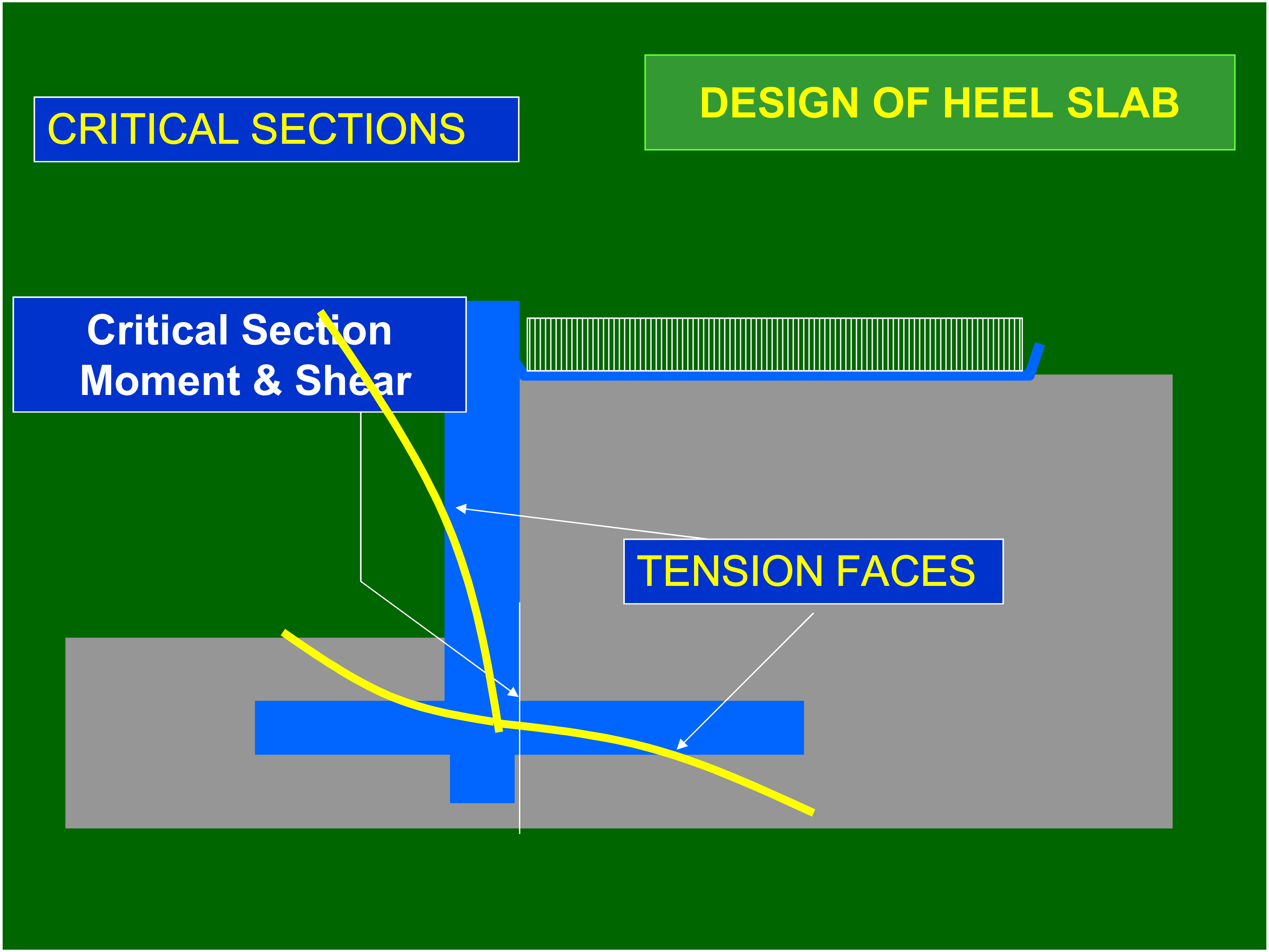
$+1.6(0.5\ T\ y1 - 0.5\ d\ [y1/T]\ d)$

$-0.9\ w_c\ T_s$

$-0.9\ w_s\ T_s$



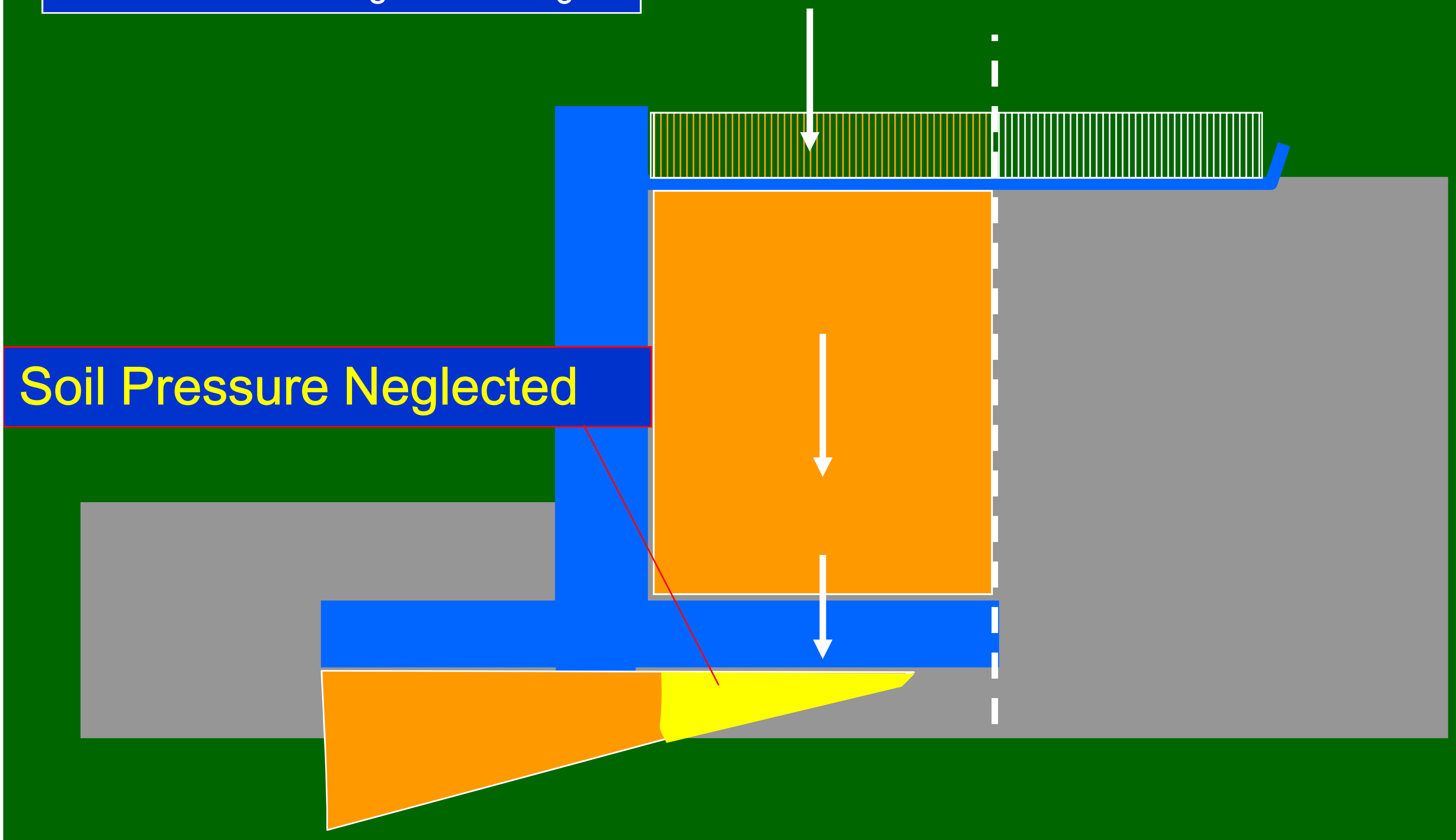




DESIGN OF HEEL SLAB
CRITICAL SECTIONS
Critical Section
Moment & Shear
TENSION FACES

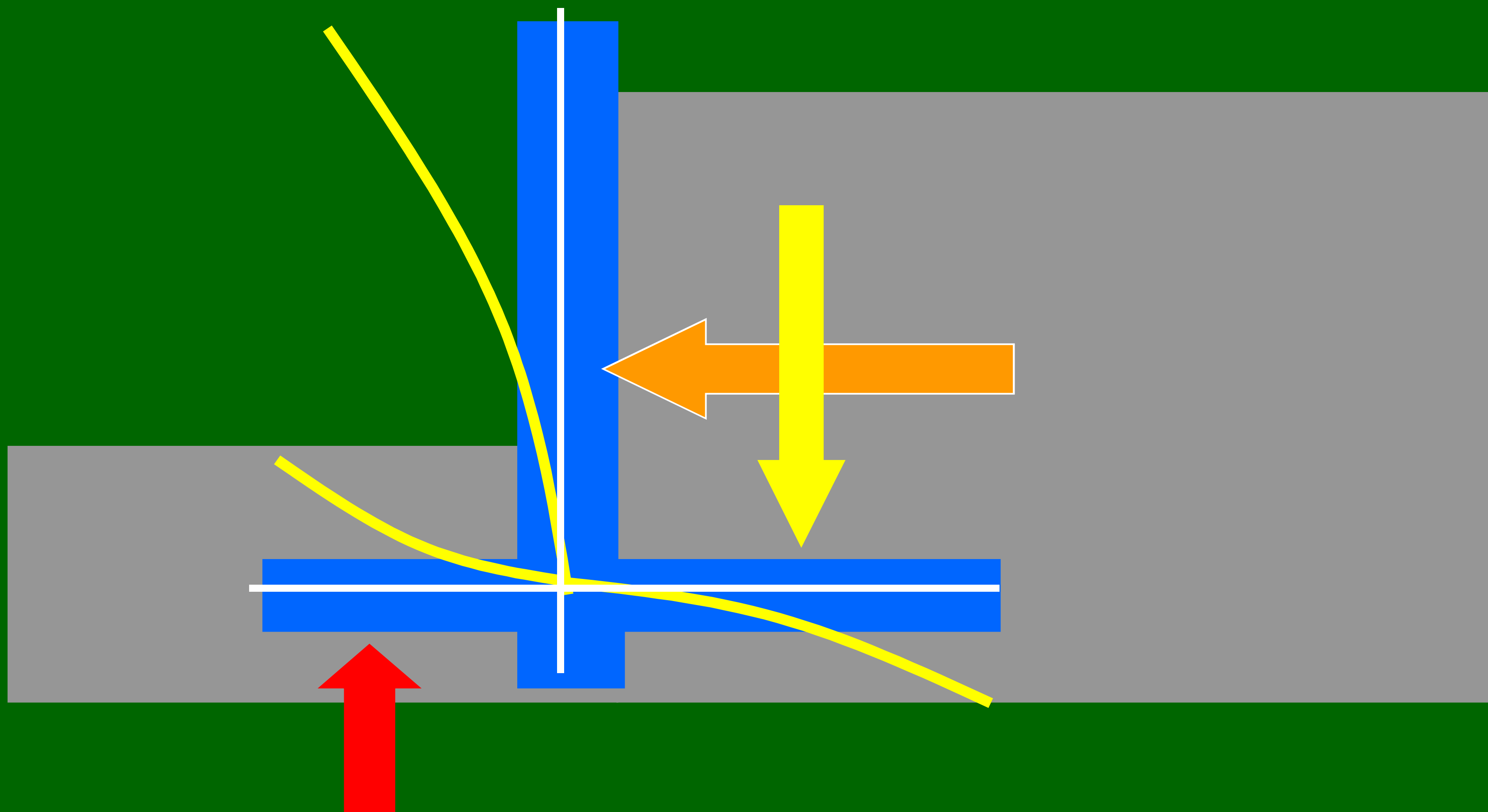
## DESIGN OF HEEL SLAB

**DESIGN LOADS**

$1.6\ s + 1.2\ w_s + 1.2\ w_c$

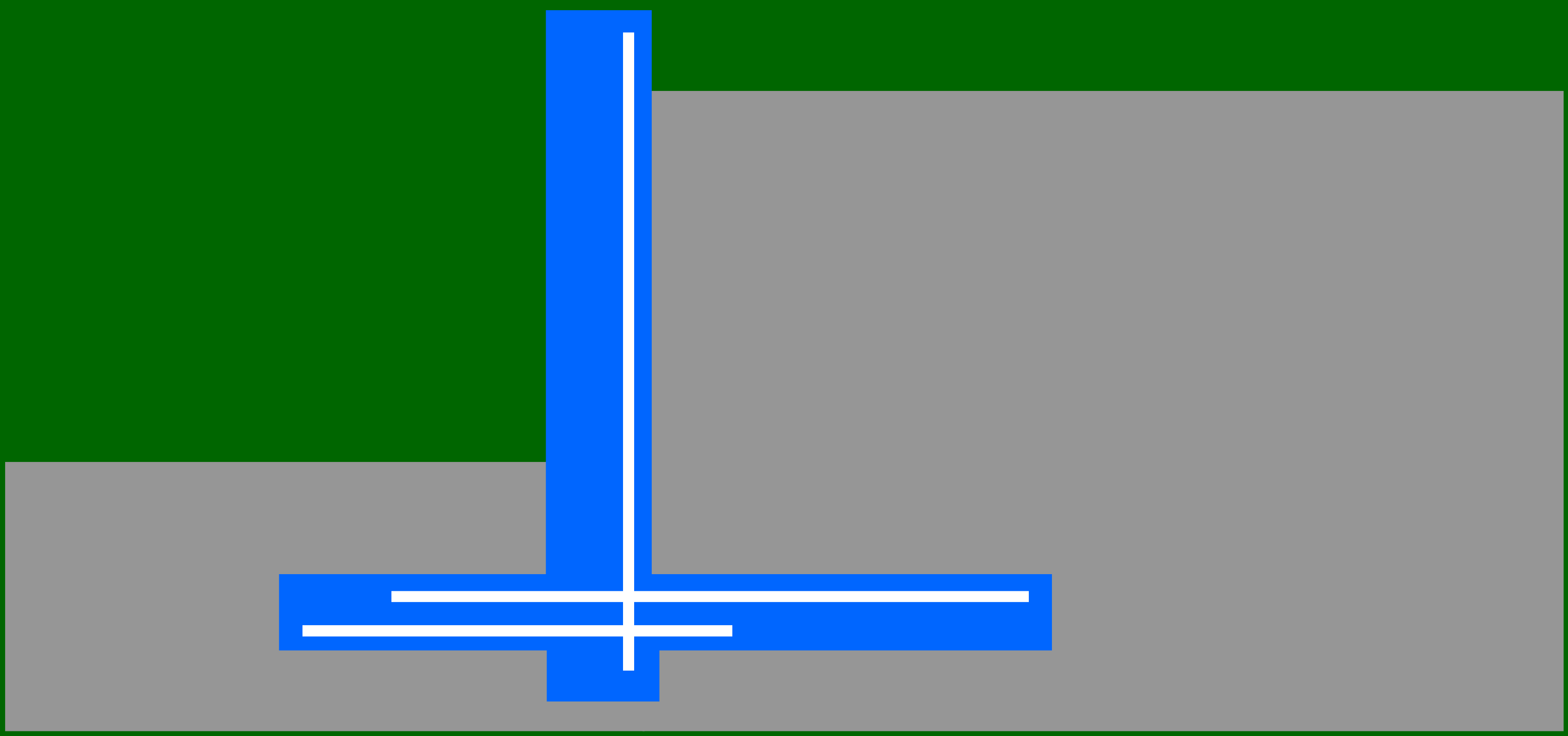


# BENDING OF WALL

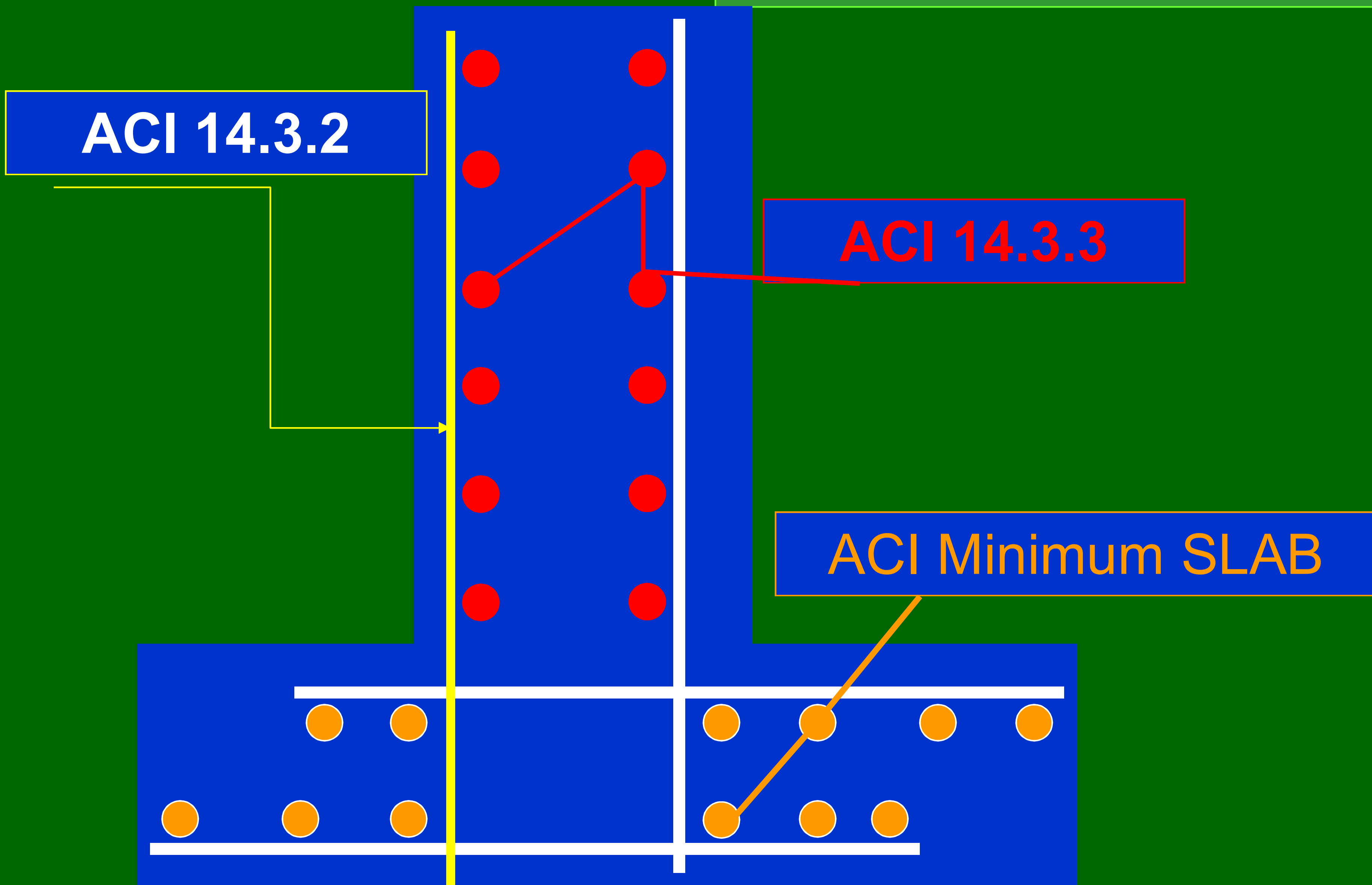


## MAIN REINFORCEMENT

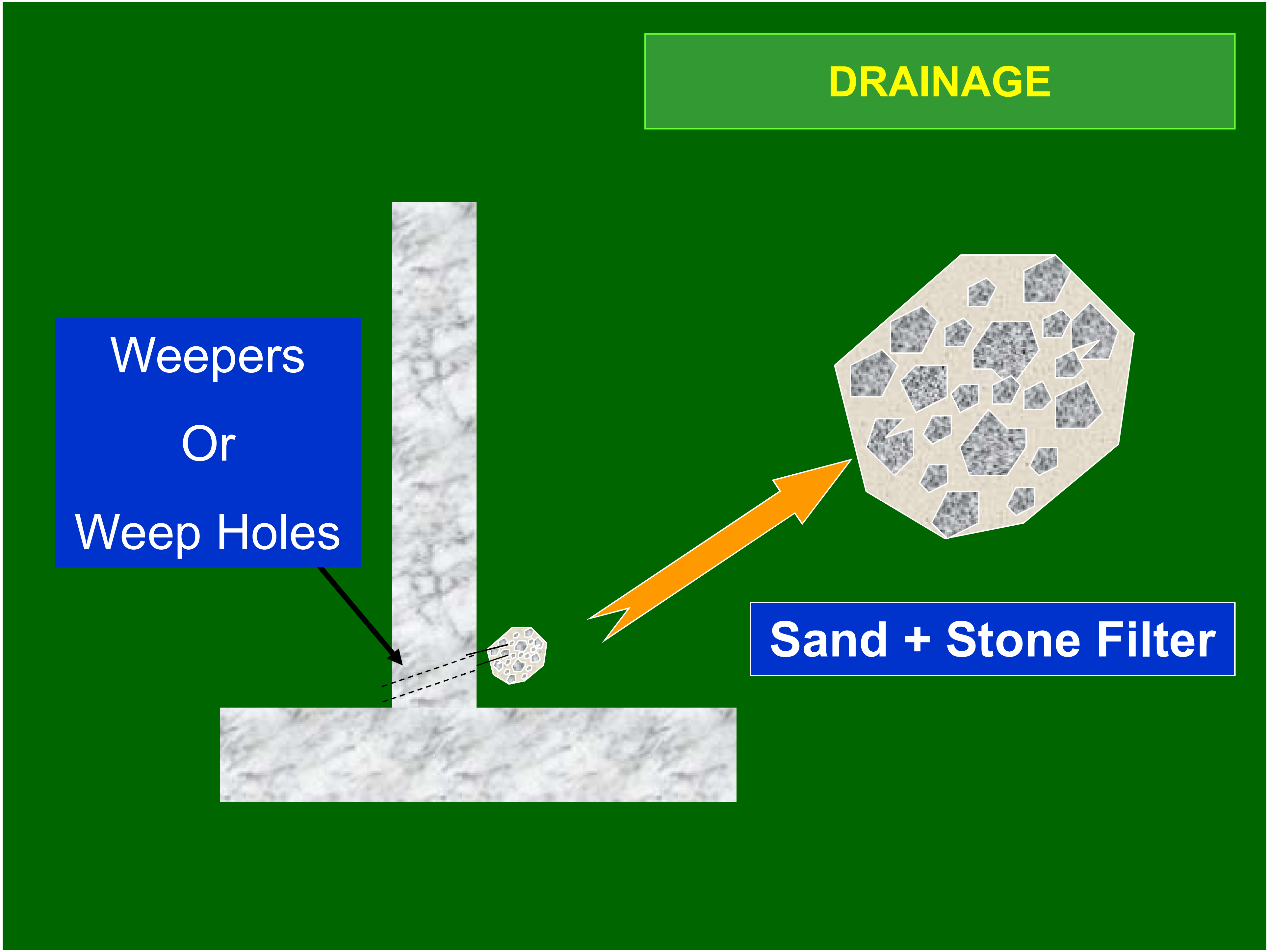
Minimum 75 mm Clear Cover



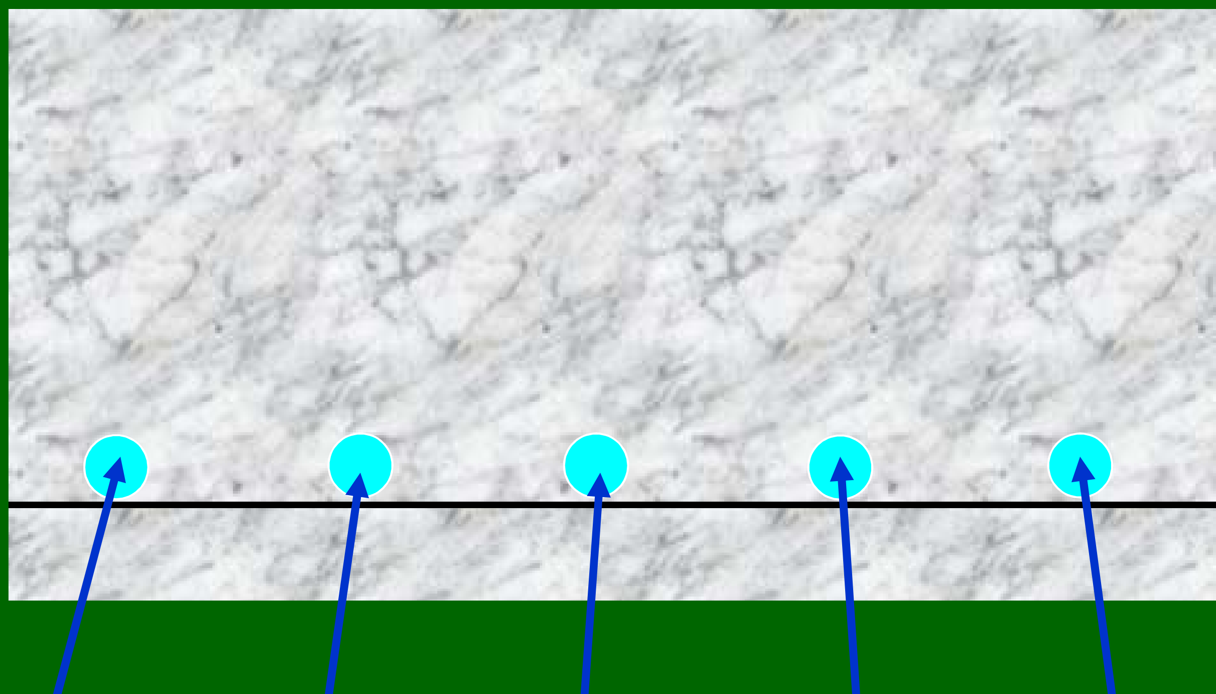
# ACI CODE
# SECONDARY STEELS



END OF PART II

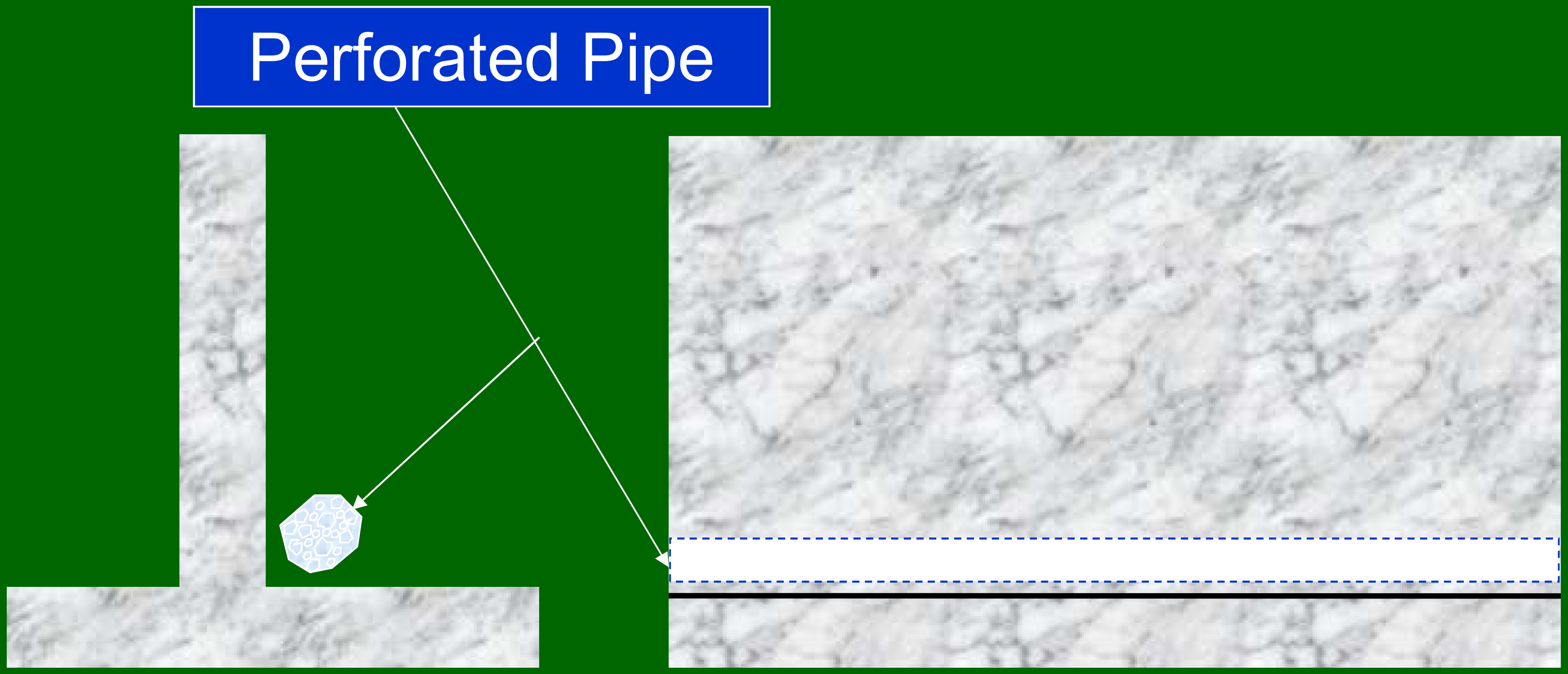

DRAINAGE
Weepers
Or
Weep Holes
Sand + Stone Filter

# DRAINAGE



Drainage Pipes f 100-200 mm @ 2.5 to 4 m

## DRAINAGE (Alternate)




Suited for short walls

END OF PART III