Universitatea Politehnica Timişoara
Facultatea de Construcţii
Departamentul de Căi de Comunicație Terestre, Fundații și Cadastru

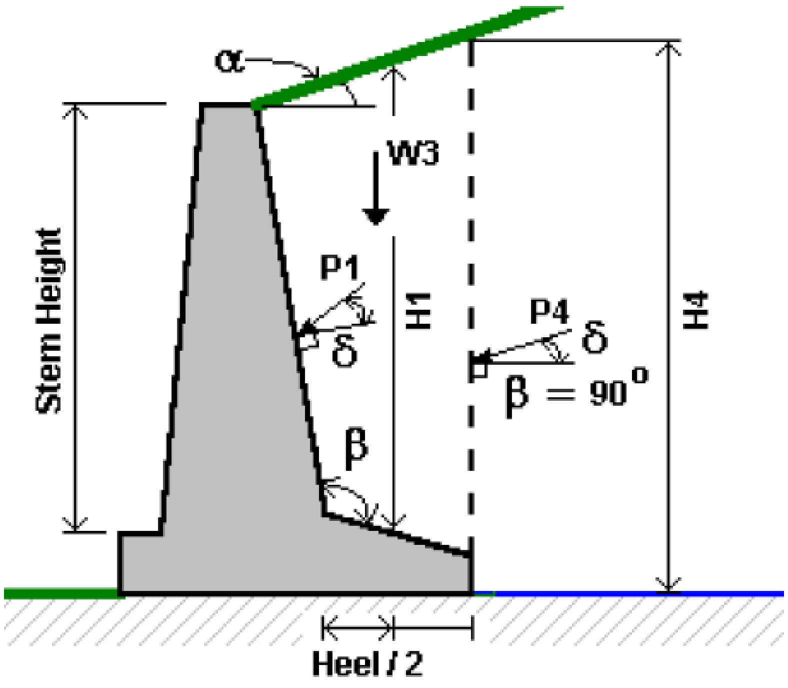
FOUNDATIONS

- CURS 6 -

Lateral Earth Pressure and Retaining Walls

Prof.dr.ing Adrian CIUTINA

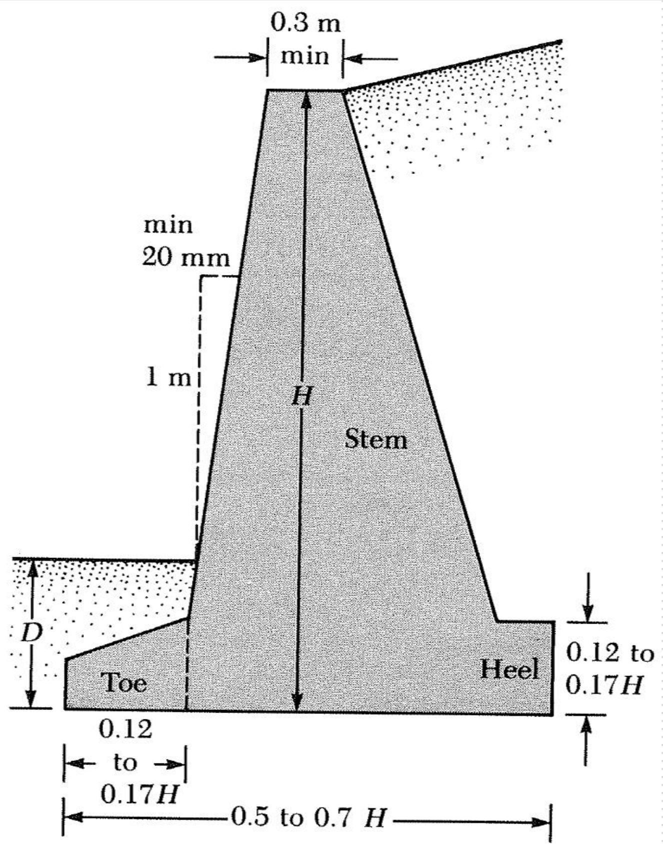
- A **retaining wall** is a wall that provides lateral support for a vertical or near vertical slope of soil.



§ 5.3 Proportioning of retaining walls

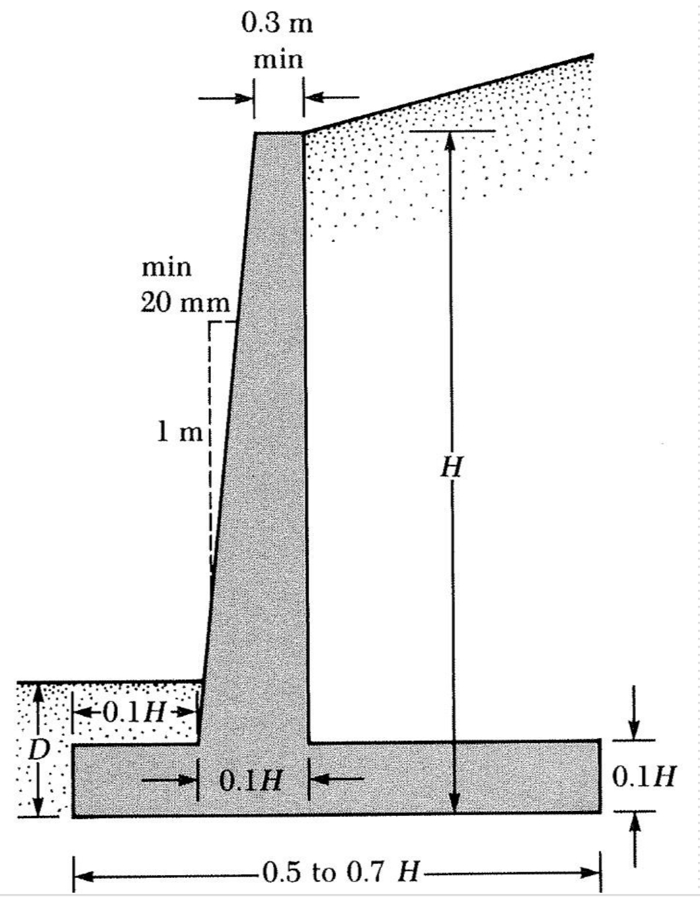
- When designing retaining walls, one must assume some of its dimensions (*proportioning*).
- Proportioning allows the engineer to check trial sections for stability in an iterative process.

- For gravity RW:
  - Top: min 0.3m
  - Sole length: 0.5-0.7H
  - Heel height: 0.12-0.17 H
  - Toe length: 0.12-0.17 H
  - Frost depth (D): in accordance with the local frost conditions (not less than 0.6m)



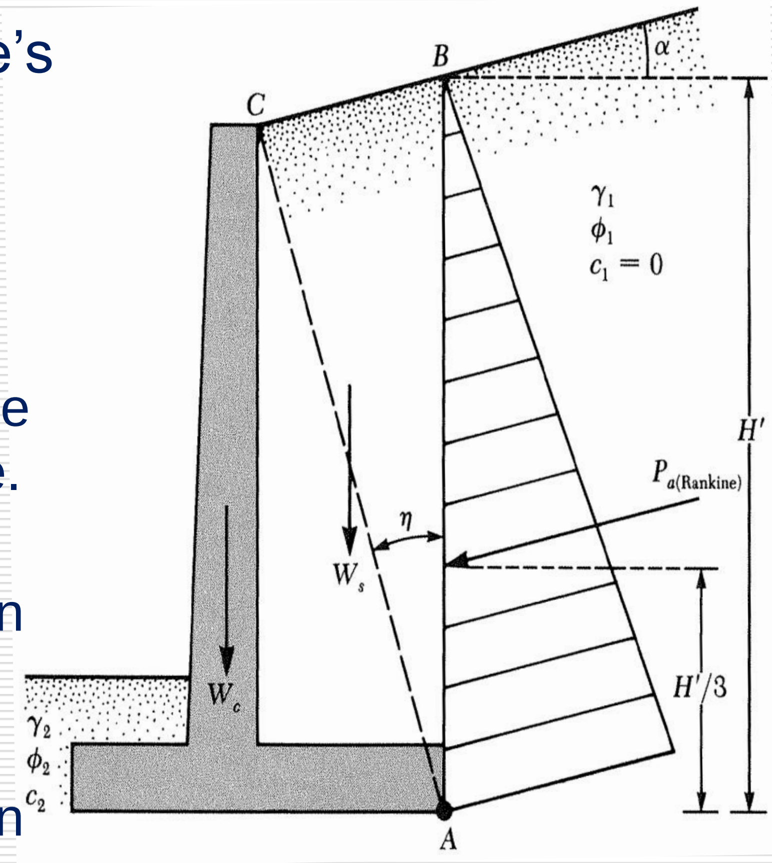
§ 5.3 Proportioning of retaining walls

- For counterfort and cantilever RW:
  - Top: min 0.3m
  - Sole: 0.5-0.7H
  - Heel height: approx. 0.1H
  - Toe length: approx. 0.1H
  - Frost depth (D): in accordance with the local frost conditions (not less than 0.6m)
  - counterfort slabs: aprox. 0.3m, spaced center to center 0.3-0.7H.



§ 5.4 Design of retaining walls
Application of Lateral Earth Pressure to Design

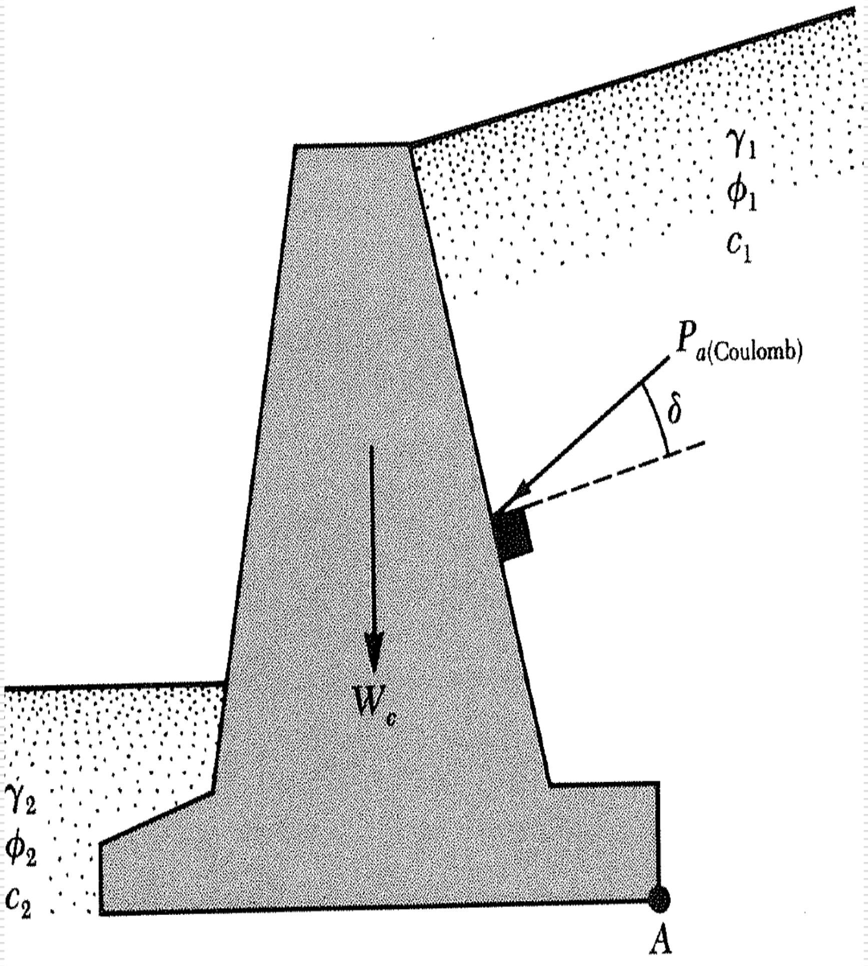
- For the design of RW, the general theories of application of lateral earth pressure on RW should be made on the basis of some assumptions:
- In case of cantilever RW, if the Rankine's earth pressure is to be used, then:
  - The active pressure is considered as acting on the vertical line starting from the edge of the heel.
  - The Rankine active pressure acts on the line AB, constructed from the heel edge.
  - The weight of the wall slabs and the weight of the soil above the heel acts on their centroids.
  - The weight of the wall slabs and the weight of the soil above the heel acts on their mid-widths.



§ 5.4 Design of retaining walls
Stability checks for retaining walls

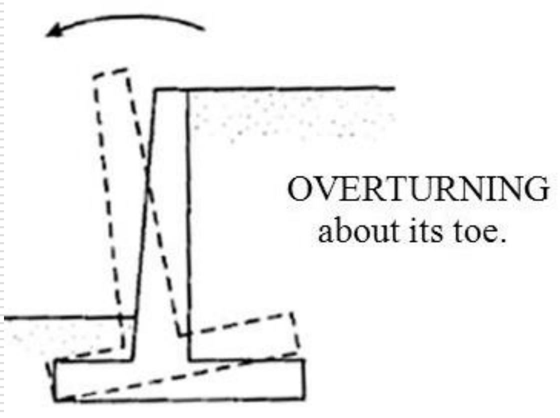
- Assumptions to check the stability of retaining walls in case of applying the Coulomb's theory:
  - The forces to be considered are the active force P_a and the RW weight W_c
  - The active pressure is considered as acting on the internal face of the wall.
  - The angle δ made with the normal on the wall edge represents the friction angle between the soil and the retaining surface:

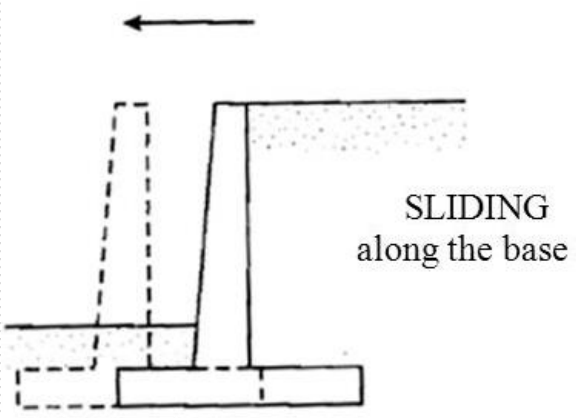
$$\delta = (1/2.....1/3)\Phi$$

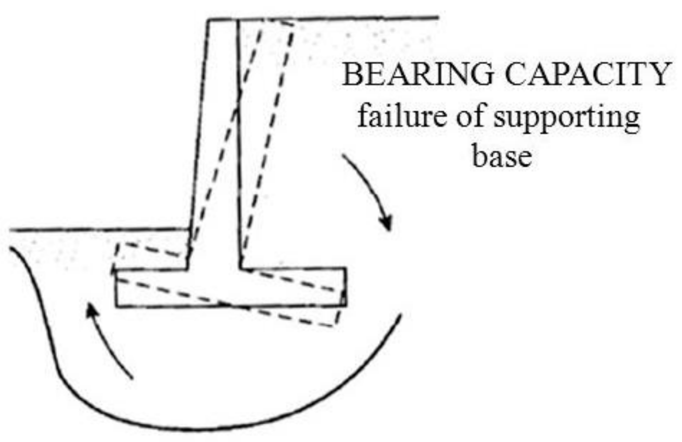


§ 5.4 Design of retaining walls
Stability checks for retaining walls

- To check the stability of retaining walls, the following checks are necessary:
  - Check for overturning about toe
  - Check for sliding along its base
  - Check for bearing capacity failure at the base
  - Check for settlement
  - Check for overall stability



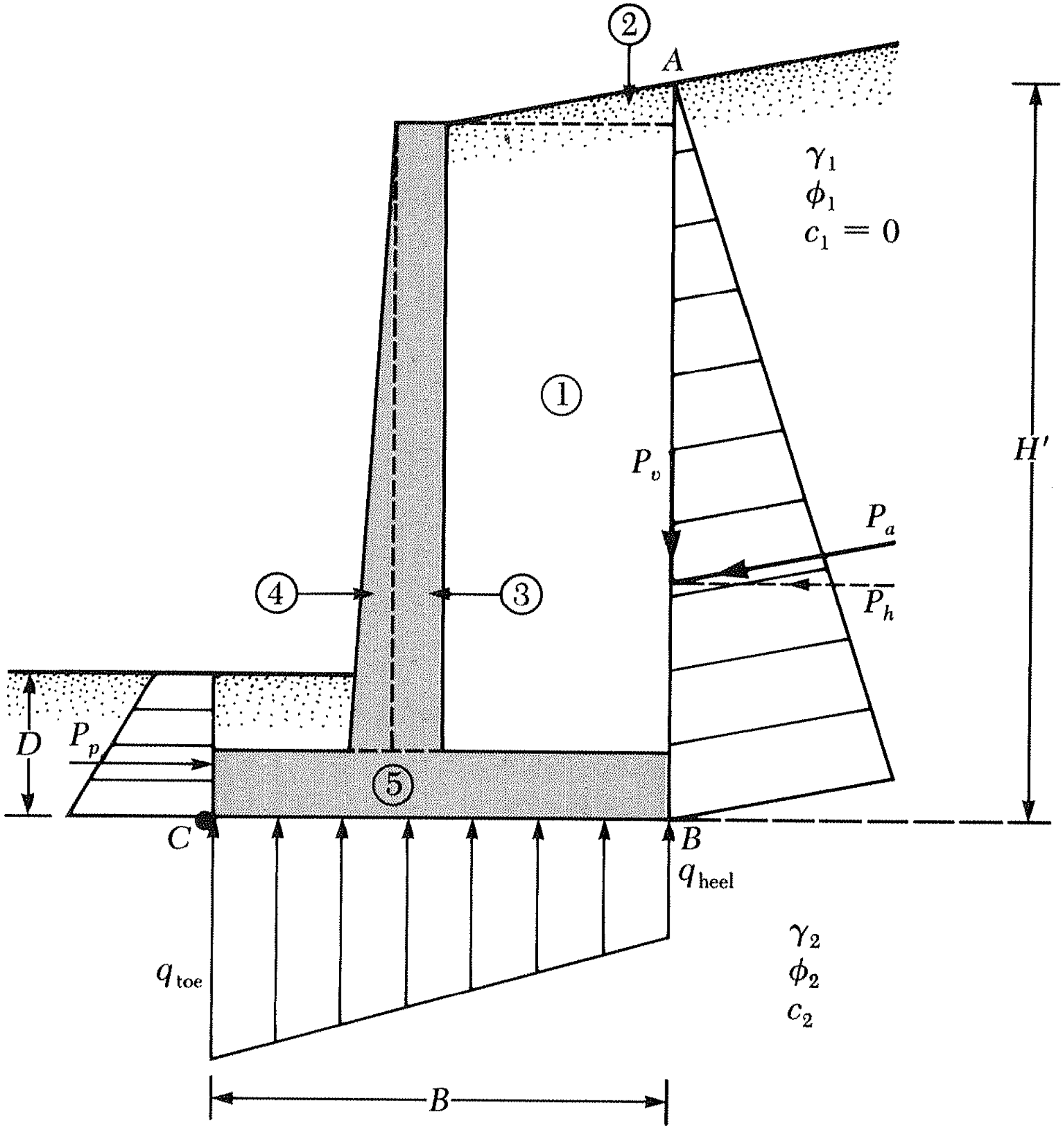




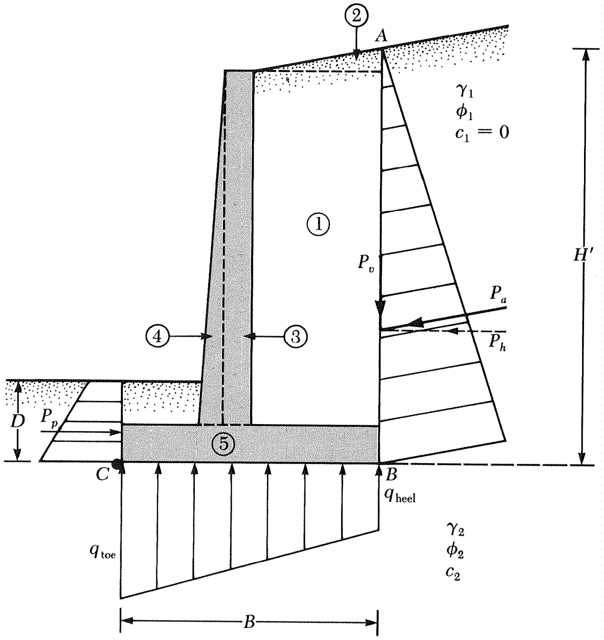
§ 5.4 Design of retaining walls
Stability checks for retaining walls – check for overturning

- The figure shows the forces acting on a cantilever (gravity) retaining wall.
- The Rankine Active Pressure P_a acts on the vertical plane AB drawn from the heel.
- On the same principles, the Rankine Passive Pressure P_p acts on the vertical plane C drawn from the toe.

$$P_p = \frac{1}{2} \cdot K_p \gamma_2 \cdot D^2 + 2c \cdot H \cdot \sqrt{K_p}$$



§ 5.4 Design of retaining walls
Stability checks for retaining walls – check for overturning



- The factor of safety against overturning about point C is given as:

$$FS = \frac{\Sigma M_R}{\Sigma M_O}$$

where:

ΣM_R - sum of moments of forces tending to resist overturning about point C

ΣM_O - sum of moments of forces tending to overturn about point C

$$P_h = P_a \cdot \cos \alpha \qquad \Sigma M_O = P_h \cdot H/3$$

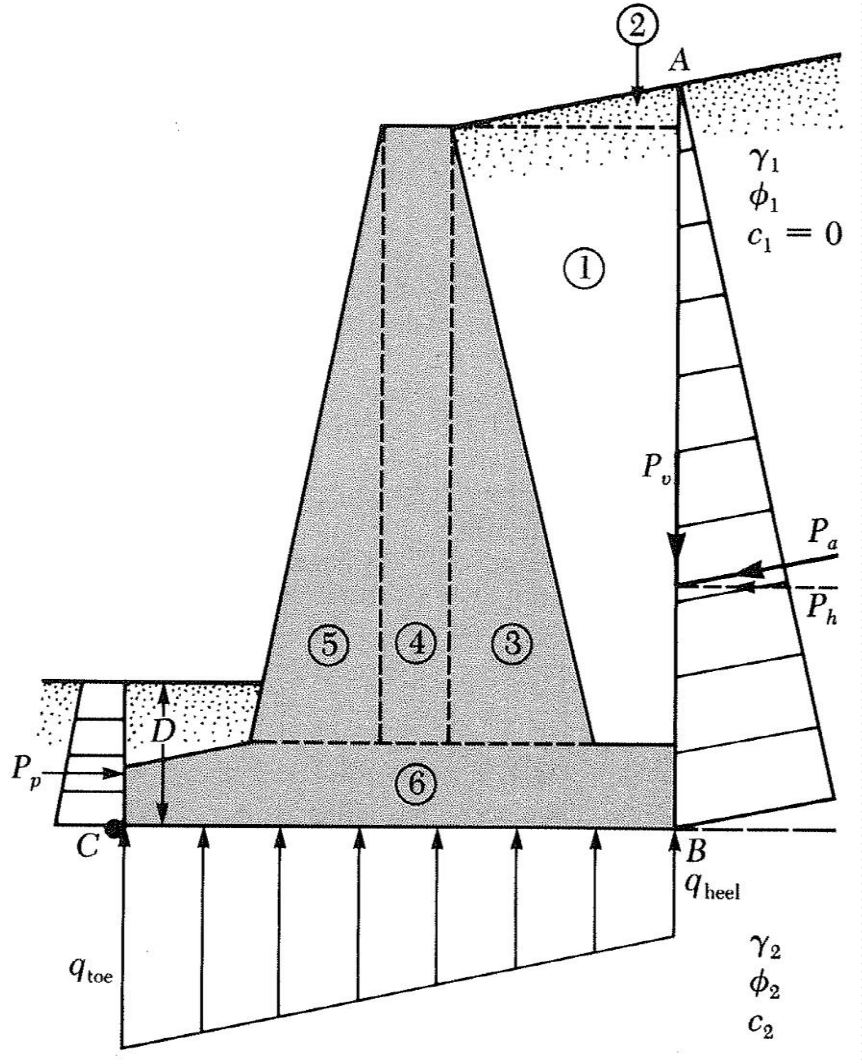
$$P_v = P_a \cdot \sin \alpha \qquad \Sigma M_R = \Sigma W \cdot d + P_v \cdot B + P_p \cdot d_p$$

- The design should be repeated for each action combination (see C1)

Obs: The usual minimum desirable values for the factor of safety with respect to overturning is 1.5…2.

§ 5.4 Design of retaining walls
Stability checks for retaining walls – check for overturning

- Check of overturning of gravity RW



Stability checks for retaining walls – check for overturning

Failure of RW by overturning:

§ 5.4 Design of retaining walls
Stability checks for retaining walls – check for sliding

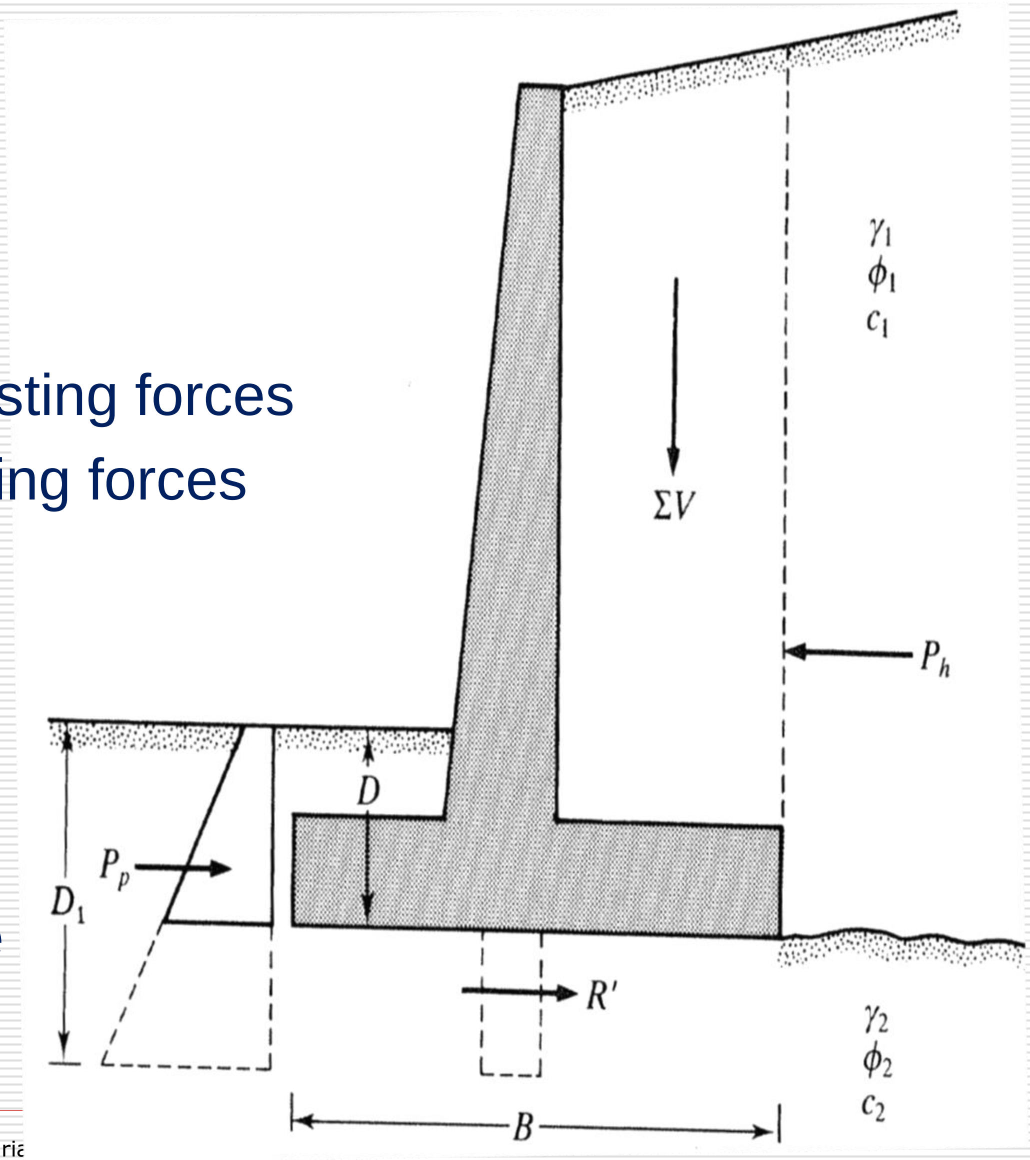
- The factor of safety for sliding may be expressed as:

$$FS_{(sliding)} = \frac{\Sigma F_R}{\Sigma F_d}$$

where:

ΣF_R - sum of the horizontal resisting forces

ΣF_d - sum of the horizontal driving forces



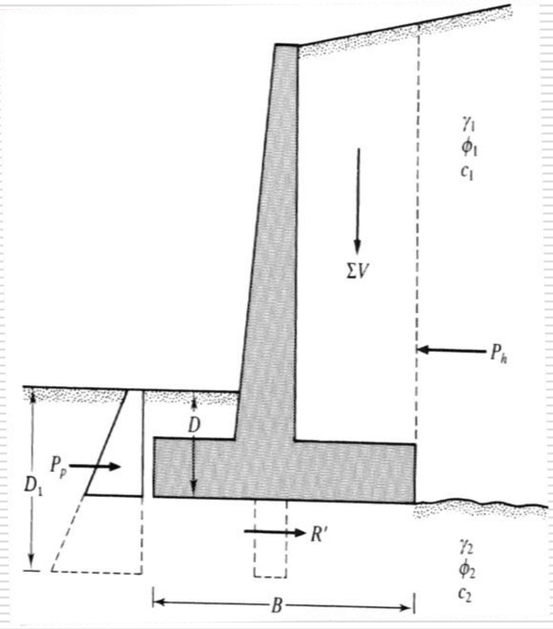
$$\Sigma F_d = P_h = P_a \cdot \cos\alpha$$

$$\Sigma F_R = R' + P_p$$

where:

R′ is the maximum resisting force developed at the interface between the base slab and the bottom soil

§ 5.4 Design of retaining walls
Stability checks for retaining walls – check for sliding



$$R' = \tau \cdot B = B \cdot (\sigma \cdot \tan\Phi_2 + c_2) = B \cdot \sigma \cdot \tan\Phi_2 + B \cdot c_2$$

but:

$B \cdot \sigma = \Sigma V$ - sum of the vertical forces

It results:

$$\Sigma F_R = (\Sigma V) \cdot \tan\Phi_2 + B \cdot c_2 + P_p$$

- In consequence, the factor of safety for sliding may be expressed as:

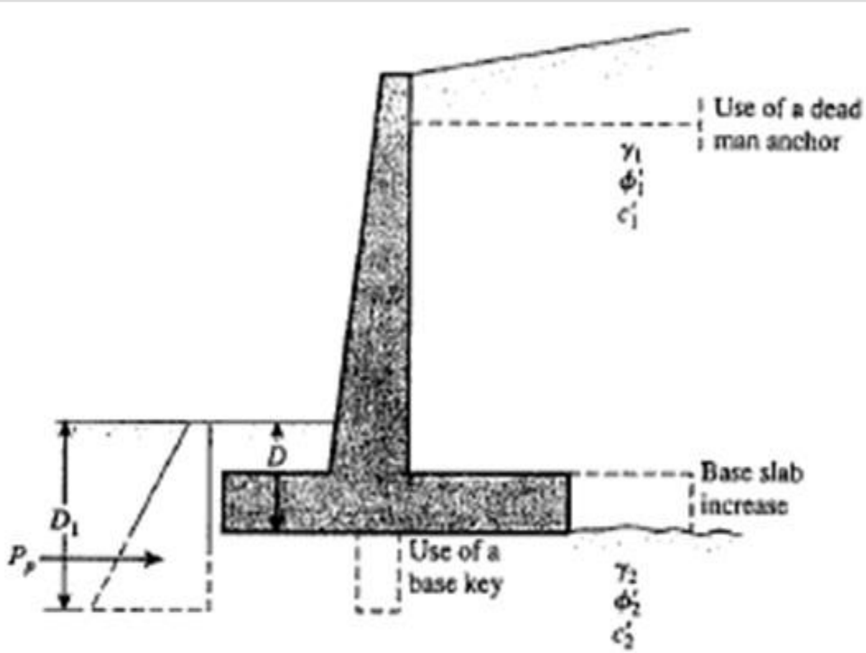
$$FS_{(sliding)} = \frac{(\Sigma V) \cdot \tan\Phi_2 + B \cdot c_2 + Pp}{P_a \cdot \cos\alpha}$$

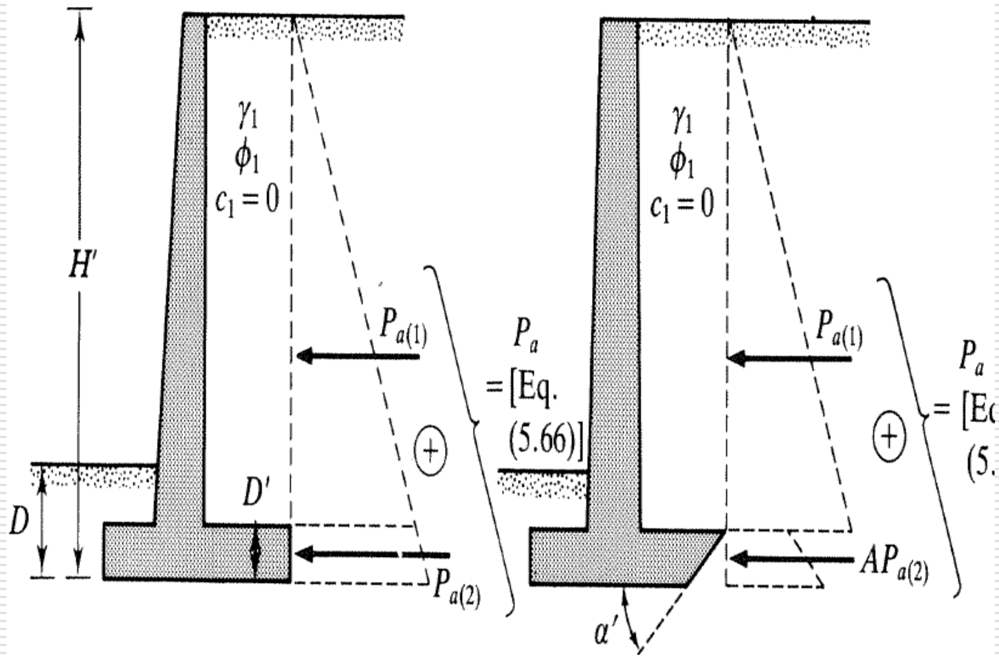
Obs: The usual minimum desirable values for the factor of safety with respect to overturning is 1.0 in accordance to EN 1997-1, as the partial safety factors were included in the design combination of actions.

Obs 2: In many cases, the passive force P_p is ignored in calculation.

§ 5.4 Design of retaining walls
Stability checks for retaining walls – check for sliding

- In many cases, the checking for sliding is not fulfilled. In order to improve the stability to sliding, we can adopt one of the following:





- Use of a base key: this will generate an additional passive pressure (resisting force) on the key height;
- Modification of the shape of the supporting surface (reducing the active pressure on the base slab);

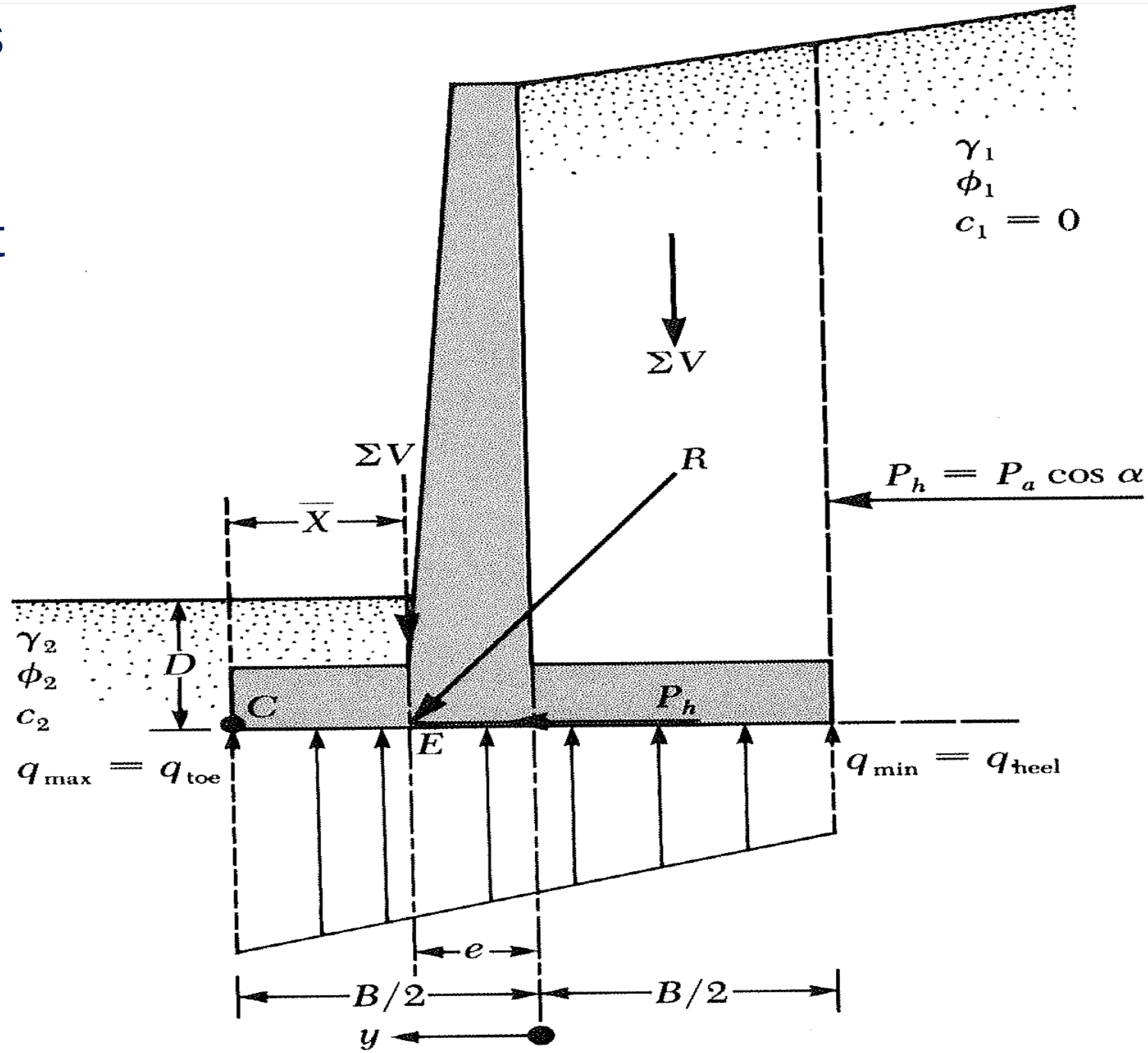
§ 5.4 Design of retaining walls
Stability checks for retaining walls – check for sliding

Failure of RW by sliding:

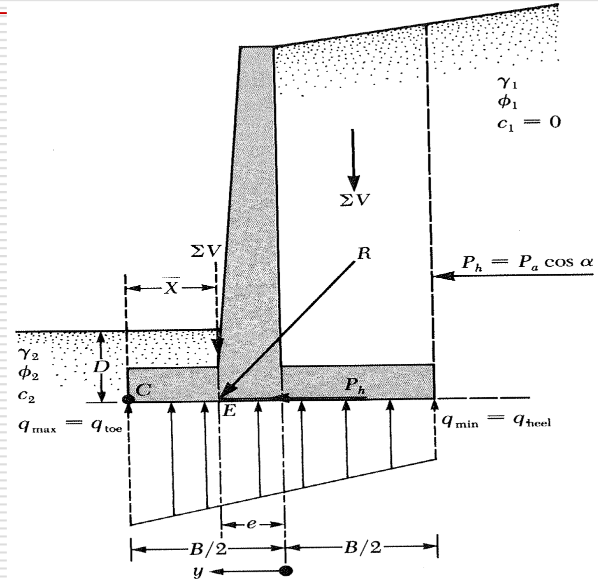
§ 5.4 Design of retaining walls
Stability checks for RW – check for bearing capacity failure

- The vertical pressure as transmitted to the soil by the base slab of the RW should be checked against the ultimate bearing capacity of the soil.

- q_{toe} and q_{heel} represents the maximum and the minimum pressures occurring at the limits of the toe and heel sections.



§ 5.4 Design of retaining walls
Stability checks for RW – check for bearing capacity failure



- The values of q_{toe} and q_{heel} can be determined in the following manner:
  - All the loads are reduced in a point on the basis of the foundation (e.g. center);
  - There could be computed the sum of vertical forces: $V = \Sigma W_i + Pav$
  - The net moment of the foundation is: $M_{net} = \Sigma M_R - \Sigma M_0$
- The values of q (σ) results from: $q_{max/min} = \frac{V}{A} \pm \frac{M_{net}}{W} = \frac{V}{B \cdot 1} \pm \frac{M_{net}}{B^2 \cdot 1/6}$
- Checking of the bearing capacity failure implies:

$$q_{max} \leq q_{conv}$$

Obs: Usually the entire base slab should be in compression.

Stability checks for RW – check for bearing capacity failure

Failure of RW by overpassing the bearing capacity: