

## Cantilever wall analysis

### Input data

#### Project

Date : 25.1.2017 r/

#### Settings

Standard - EN 1997 - DA2

#### Materials and standards

Concrete structures : EN 1992-1-1 (EC2)

Coefficients EN 1992-1-1 : standard

#### Wall analysis

Active earth pressure calculation : Coulomb

Passive earth pressure calculation : Caquot-Kerisel

Earthquake analysis : Mononobe-Okabe

Shape of earth wedge : Calculate as skew

Base key : The base key is considered as inclined footing bottom

Verification methodology : according to EN 1997

Design approach : 2 - reduction of actions and resistances

| Partial factors on actions (A) |              |              |            |
|--------------------------------|--------------|--------------|------------|
| Transient design situation     |              |              |            |
|                                |              | Unfavourable | Favourable |
| Permanent actions :            | $\gamma_G =$ | 1,35 [-]     | 1,00 [-]   |
| Variable actions :             | $\gamma_Q =$ | 1,50 [-]     | 0,00 [-]   |
| Water load :                   | $\gamma_w =$ | 1,35 [-]     |            |

| Partial factors for resistances (R)    |  |                 |          |
|----------------------------------------|--|-----------------|----------|
| Transient design situation             |  |                 |          |
| Partial factor on overturning :        |  | $\gamma_{Re} =$ | 1,40 [-] |
| Partial factor on sliding resistance : |  | $\gamma_{Rh} =$ | 1,10 [-] |
| Partial factor on bearing capacity :   |  | $\gamma_{Rv} =$ | 1,40 [-] |

#### Material of structure

Unit weight  $\gamma = 23,56 \text{ kN/m}^3$

Analysis of concrete structures carried out according to the standard EN 1992-1-1 (EC2).

Concrete : C 25/30

Cylinder compressive strength  $f_{ck} = 25,00 \text{ MPa}$

Tensile strength  $f_{ct} = 2,60 \text{ MPa}$

Longitudinal steel : B500

Yield strength  $f_{yk} = 500,00 \text{ MPa}$

#### Geometry of structure

| No. | Coordinate<br>X [m] | Depth<br>Z [m] |
|-----|---------------------|----------------|
| 1   | 0,00                | 0,00           |
| 2   | 0,00                | 2,30           |
| 3   | 1,40                | 2,30           |
| 4   | 1,40                | 2,70           |
| 5   | -0,25               | 2,70           |
| 6   | -0,25               | 2,30           |
| 7   | -0,25               | 0,00           |

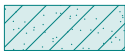
The origin [0,0] is located at the most upper right point of the wall.  
Wall section area = 1,23 m<sup>2</sup>.

#### Basic soil parameters

| No. | Name         | Pattern                                                                           | $\Phi_{ef}$<br>[°] | $C_{ef}$<br>[kPa] | $\gamma$<br>[kN/m <sup>3</sup> ] | $\gamma_{su}$<br>[kN/m <sup>3</sup> ] | $\delta$<br>[°] |
|-----|--------------|-----------------------------------------------------------------------------------|--------------------|-------------------|----------------------------------|---------------------------------------|-----------------|
| 1   | Трошен камък |  | 26,00              | 0,00              | 20,00                            | 12,00                                 | 10,00           |

All soils are considered as cohesionless for at rest pressure analysis.

#### Geological profile and assigned soils

| No. | Layer<br>[m] | Assigned soil | Pattern                                                                             |
|-----|--------------|---------------|-------------------------------------------------------------------------------------|
| 1   | -            | Трошен камък  |  |

#### Terrain profile

Terrain behind the structure is flat.

#### Water influence

GWT behind the structure lies at a depth of 1,80 m  
Uplift in foot. bottom due to different pressures is not considered.

#### Input surface surcharges

| No. | Surcharge<br>new | change | Action   | Mag.1<br>[kN/m <sup>2</sup> ] | Mag.2<br>[kN/m <sup>2</sup> ] | Ord.x<br>x [m] | Length<br>l [m] | Depth<br>z [m] |
|-----|------------------|--------|----------|-------------------------------|-------------------------------|----------------|-----------------|----------------|
| 1   | YES              |        | variable | 5,00                          |                               | 0,00           | 2,00            | on terrain     |
| 2   | YES              |        | variable | 10,00                         |                               | 2,00           | 5,00            | on terrain     |

| No. | Name       |
|-----|------------|
| 1   | Пешеходци  |
| 2   | Автомобили |

#### Resistance on front face of the structure

Resistance on front face of the structure: at rest  
Soil on front face of the structure - Трошен камък  
Soil thickness in front of structure  $h = 1,00$  m  
Terrain in front of structure is flat.

#### Settings of the stage of construction

Design situation : transient  
The wall is free to move. Active earth pressure is therefore assumed.

#### Verification No. 1

##### Pressure at rest on front face of the structure - partial results

| Layer<br>No. | Thickness<br>[m] | $\alpha$<br>[°] | $\Phi_d$<br>[°] | $C_d$<br>[kPa] | $\gamma$<br>[kN/m <sup>3</sup> ] | $K_r$ | Comment |
|--------------|------------------|-----------------|-----------------|----------------|----------------------------------|-------|---------|
| 1            | 0,60             | 0,00            | 26,00           | 0,00           | 20,00                            | 0,562 |         |
| 2            | 0,00             | 0,00            | 26,00           | 0,00           | 20,00                            | 0,562 |         |
| 3            | 0,40             | 0,00            | 26,00           | 0,00           | 20,00                            | 0,562 |         |

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#### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m]<br>End [m] | $\sigma_z$<br>[kPa] | $\sigma_w$<br>[kPa] | Pressure<br>[kPa] | Hor. comp.<br>[kPa] | Vert. comp.<br>[kPa] |
|-----------|----------------------|---------------------|---------------------|-------------------|---------------------|----------------------|
| 1         | 0,00                 | 0,00                | 0,00                | 0,00              | 0,00                | 0,00                 |
|           | 0,60                 | 12,00               | 0,00                | 6,74              | 6,74                | 0,00                 |
| 2         | 0,60                 | 12,00               | 0,00                | 6,74              | 6,74                | 0,00                 |
|           | 0,60                 | 12,03               | 0,00                | 6,75              | 6,75                | 0,00                 |
| 3         | 0,60                 | 12,03               | 0,00                | 6,75              | 6,75                | 0,00                 |
|           | 1,00                 | 20,00               | 0,00                | 11,23             | 11,23               | 0,00                 |

#### Active pressure behind the structure - partial results

| Layer No. | Thickness<br>[m] | $\alpha$<br>[°] | $\varphi_d$<br>[°] | $c_d$<br>[kPa] | $\gamma$<br>[kN/m <sup>3</sup> ] | $\delta_d$<br>[°] | $K_a$ | Comment |
|-----------|------------------|-----------------|--------------------|----------------|----------------------------------|-------------------|-------|---------|
| 1         | 0,06             | 0,00            | 26,00              | 0,00           | 20,00                            | 10,00             | 0,359 |         |
| 2         | 1,74             | 32,00           | 26,00              | 0,00           | 20,00                            | 26,00             | 0,737 |         |
| 3         | 0,50             | 32,00           | 26,00              | 0,00           | 12,00                            | 26,00             | 0,737 |         |
| 4         | 0,40             | 0,00            | 26,00              | 0,00           | 12,00                            | 10,00             | 0,359 |         |

#### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m]<br>End [m] | $\sigma_z$<br>[kPa] | $\sigma_w$<br>[kPa] | Pressure<br>[kPa] | Hor. comp.<br>[kPa] | Vert. comp.<br>[kPa] |
|-----------|----------------------|---------------------|---------------------|-------------------|---------------------|----------------------|
| 1         | 0,00                 | 0,00                | 0,00                | 0,00              | 0,00                | 0,00                 |
|           | 0,06                 | 1,19                | 0,00                | 0,43              | 0,42                | 0,07                 |
| 2         | 0,06                 | 1,19                | 0,00                | 0,88              | 0,47                | 0,74                 |
|           | 1,80                 | 36,00               | 0,00                | 26,52             | 14,06               | 22,49                |
| 3         | 1,80                 | 36,00               | 0,00                | 26,52             | 14,06               | 22,49                |
|           | 2,30                 | 42,00               | 5,00                | 30,95             | 16,40               | 26,24                |
| 4         | 2,30                 | 42,00               | 5,00                | 15,08             | 14,85               | 2,62                 |
|           | 2,70                 | 46,80               | 9,00                | 16,80             | 16,55               | 2,92                 |

#### Water pressure distribution

| Point No. | Depth<br>[m] | Hor. comp.<br>[kPa] | Vert. comp.<br>[kPa] |
|-----------|--------------|---------------------|----------------------|
| 1         | 0,00         | 0,00                | 0,00                 |
| 2         | 0,06         | 0,00                | 0,00                 |
| 3         | 1,80         | 0,00                | 0,00                 |
| 4         | 2,30         | 5,00                | 0,00                 |
| 5         | 2,70         | 9,00                | 0,00                 |

#### Pressure profile due to surcharge - Пешеходци

| Point No. | Depth<br>[m] | Hor. comp.<br>[kPa] | Vert. comp.<br>[kPa] |
|-----------|--------------|---------------------|----------------------|
| 1         | 0,00         | 0,00                | 0,00                 |
| 2         | 0,00         | 0,00                | 0,00                 |
| 3         | 0,02         | 0,00                | 0,00                 |
| 4         | 0,02         | 1,83                | 0,32                 |
| 5         | 0,06         | 1,83                | 0,32                 |
| 6         | 0,06         | 0,91                | 1,46                 |
| 7         | 1,80         | 0,89                | 1,42                 |
| 8         | 2,30         | 0,88                | 1,41                 |
| 9         | 2,30         | 1,76                | 0,31                 |

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| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|-----------|-----------|------------------|-------------------|
| 10        | 2,70      | 1,75             | 0,31              |

#### Forces acting on construction

| Name                 | F <sub>hor</sub> [kN/m] | App.Pt. z [m] | F <sub>vert</sub> [kN/m] | App.Pt. x [m] | Coeff. overturn. | Coeff. sliding | Coeff. stress |
|----------------------|-------------------------|---------------|--------------------------|---------------|------------------|----------------|---------------|
| Weight - wall        | 0,00                    | -0,83         | 29,10                    | 0,50          | 1,000            | 1,000          | 1,350         |
| FF resistance        | -5,62                   | -0,33         | 0,00                     | 0,00          | 1,000            | 1,000          | 1,000         |
| Weight - earth wedge | 0,00                    | -1,24         | 26,39                    | 0,69          | 1,000            | 1,000          | 1,350         |
| Active pressure      | 26,54                   | -0,95         | 33,52                    | 1,18          | 1,350            | 1,350          | 1,350         |
| Water pressure       | 4,05                    | -0,30         | 0,00                     | 0,25          | 1,350            | 1,350          | 1,350         |
| Uplift pressure      | 0,00                    | -2,70         | 0,00                     | 0,25          | 1,000            | 1,000          | 1,000         |
| Пешеходци            | 2,77                    | -1,22         | 3,35                     | 0,97          | 1,500            | 1,500          | 1,500         |
| Автомобили           | 3,61                    | -0,75         | 3,89                     | 1,26          | 1,500            | 1,500          | 1,500         |

#### Verification of complete wall

##### Check for overturning stability

Resisting moment  $M_{res} = 70,19 \text{ kNm/m}$

Overturning moment  $M_{ovr} = 42,79 \text{ kNm/m}$

**Wall for overturning is SATISFACTORY**

##### Check for slip

Resisting horizontal force  $H_{res} = 49,48 \text{ kN/m}$

Active horizontal force  $H_{act} = 45,26 \text{ kN/m}$

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 128,29 kPa

#### Bearing capacity of foundation soil

##### Forces acting at the centre of the footing bottom

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] | Eccentricity [m] | Stress [kPa] |
|-----|----------------|--------------------|--------------------|------------------|--------------|
| 1   | 41,19          | 131,02             | 45,26              | 0,31             | 128,29       |
| 2   | 36,59          | 111,60             | 45,26              | 0,33             | 112,24       |

##### Bearing capacity of foundation soil check

##### Eccentricity verification

Max. eccentricity of normal force  $e = 327,9 \text{ mm}$

Maximum allowable eccentricity  $e_{alw} = 544,5 \text{ mm}$

**Eccentricity of the normal force is SATISFACTORY**

##### Footing bottom bearing capacity verification

Design bearing capacity of foundation soil  $R = 250,00 \text{ kPa}$

Partial factor on earth resistance  $\gamma_{Rv} = 1,40$

Max. stress at footing bottom  $\sigma = 128,29 \text{ kPa}$

Bearing capacity of foundation soil  $R_d = 178,57 \text{ kPa}$

**Bearing capacity of foundation soil is SATISFACTORY**

**Overall verification - bearing capacity of found. soil is SATISFACTORY**

## Dimensioning No. 1

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m <sup>3</sup> ] | $K_r$ | Comment |
|-----------|---------------|--------------|-----------------|-------------|-------------------------------|-------|---------|
| 1         | 0,60          | 0,00         | 26,00           | 0,00        | 20,00                         | 0,562 |         |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m]<br>End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|-----------|----------------------|------------------|------------------|----------------|------------------|-------------------|
| 1         | 0,00                 | 0,00             | 0,00             | 0,00           | 0,00             | 0,00              |
|           | 0,60                 | 11,98            | 0,00             | 6,73           | 6,73             | 0,00              |

### Pressure at rest behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m <sup>3</sup> ] | $K_r$ | Comment |
|-----------|---------------|--------------|-----------------|-------------|-------------------------------|-------|---------|
| 1         | 1,80          | 0,00         | 26,00           | 0,00        | 20,00                         | 0,562 |         |
| 2         | 0,50          | 0,00         | 26,00           | 0,00        | 12,00                         | 0,562 |         |

### Pressure at rest distribution behind the structure (without surcharge)

| Layer No. | Start [m]<br>End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|-----------|----------------------|------------------|------------------|----------------|------------------|-------------------|
| 1         | 0,00                 | 0,00             | 0,00             | 0,00           | 0,00             | 0,00              |
|           | 1,80                 | 36,00            | 0,00             | 20,22          | 20,22            | 0,00              |
| 2         | 1,80                 | 36,00            | 0,00             | 20,22          | 20,22            | 0,00              |
|           | 2,30                 | 41,99            | 4,99             | 23,58          | 23,58            | 0,00              |

### Forces acting on construction

| Name             | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. moment | Coeff. norm.force | Coeff. shear for. |
|------------------|------------------|---------------|-------------------|---------------|---------------|-------------------|-------------------|
| Weight - wall    | 0,00             | -1,15         | 13,54             | 0,12          | 1,000         | 1,350             | 1,000             |
| FF resistance    | -2,01            | -0,20         | 0,00              | 0,00          | 1,000         | 1,000             | 1,000             |
| Pressure at rest | 29,12            | -0,78         | 0,00              | 0,25          | 1,350         | 1,000             | 1,350             |
| Water pressure   | 1,24             | -0,17         | 0,00              | 0,25          | 1,350         | 1,000             | 1,350             |
| Uplift pressure  | 0,00             | -2,30         | 0,00              | 0,25          | 1,000         | 1,000             | 1,000             |
| Пешеходци        | 2,83             | -1,48         | 0,00              | 0,25          | 1,500         | 0,000             | 1,500             |
| Автомобили       | 4,42             | -0,89         | 0,00              | 0,25          | 1,500         | 0,000             | 1,500             |

### Wall stem check

Reinforcement and dimensions of the cross-section

Bar diameter = 12,0 mm

Number of bars = 5

Reinforcement cover = 30,0 mm

Cross-section width = 1,00 m

Cross-section depth = 0,25 m

Reinforcement ratio  $\rho = 0,26 \% > 0,14 \% = \rho_{min}$

Position of neutral axis  $x = 0,02 \text{ m} < 0,13 \text{ m} = x_{max}$

Ultimate shear force  $V_{Rd} = 103,29 \text{ kN} > 49,84 \text{ kN} = V_{Ed}$

Ultimate moment  $M_{Rd} = 50,80 \text{ kNm} > 42,63 \text{ kNm} = M_{Ed}$

**Cross-section is SATISFACTORY.**