# Geotechnical design of foundation

This document shows the way in which actions will be combined according to EN 1990. And, the design situation and its calculation are based on Eurocode 7: Geothehnical Design Worked examples ANNEX A.2.

References:
- Eurocode 7: Geotechnical Design Worked examples
- EN 1997
- EN 1990

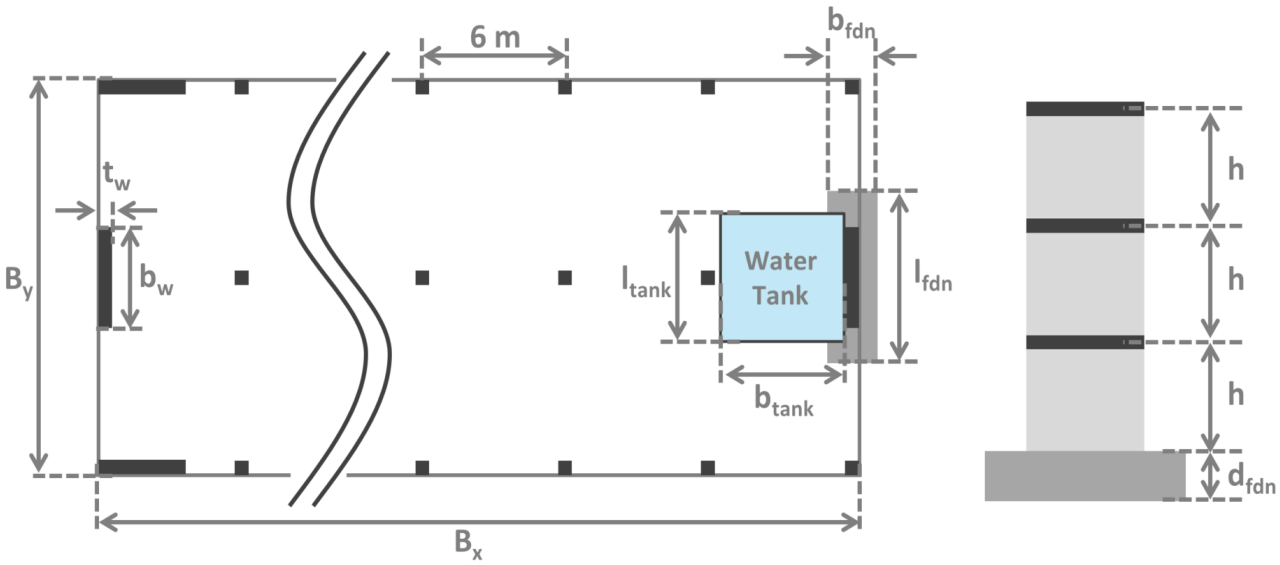


**Figure 1 : Design example : 3 storey building**

## 1. Design situation

## 1-1. Design parameters

### Basic geometries

| | |
|---|---|
| Number of storey | $n := 3$ |
| Length | $B_x := 48\ \mathrm{m}$ |
| Width | $B_y := 15\ \mathrm{m}$ |

Number of bays in long direction $N_x := 8$

Number of bays in short direction $N_y := 2$

Height of each storey $h := 3.2\ \mathbf{m}$

Thickness of floor $d_{floor} := 250\ \mathbf{mm}$

## Shear wall

Thickness $t_w := 300\ \mathbf{mm}$

Width $b_w := 4\ \mathbf{m}$

## Water tank

Depth $d_{tank} := 2\ \mathbf{m}$

Length $l_{tank} := 5\ \mathbf{m}$

Width $b_{tank} := 5\ \mathbf{m}$

## Strip fundation

Length $l_{fdn} := 6.5\ \mathbf{m}$

Breadth $b_{fdn} := 2\ \mathbf{m}$

Thickness $d_{fdn} := 1.5\ \mathbf{m}$

## Characteristic of imposed/wind actions

Roof loading $q_{rf\_k} := 0.6\ \mathbf{kPa}$

Office floor loading $q_{off\_k} := 2.5\ \mathbf{kPa}$

Partition loading $q_{par\_k} := 0.8\ \mathbf{kPa}$

Wind $q_{w\_k} := 1.15\ \mathbf{kPa}$

### Weight density

Reinforced concrete $\gamma_{c\_k} := 25\ \frac{kN}{m^3}$

Water $\gamma_{w\_k} := 10\ \frac{kN}{m^3}$

### Area

Total plan area of building $A_{tot} := B_x \cdot B_y = 720\ m^2$

Area above the stability wall $A := \frac{B_y + b_w}{2} \cdot \frac{1}{2} \cdot \frac{B_x}{N_x} = 28.500\ m^2$

## 1-2. Characteristic actions - permanent

### Self-weight of slabs

Floor $g_{fl\_Gk} := \gamma_{c\_k} \cdot d_{floor} = 6.25\ kPa$

Screed on roof $g_{scr\_Gk} := 1.5\ kPa$

Raised floor $g_{r\_fl\_Gk} := 0.5\ kPa$

### Self weight of others

Water tank on roof $W_{tank\_Gk} := \frac{1}{2} \cdot \gamma_{w\_k} \cdot d_{tank} \cdot l_{tank} \cdot b_{tank} = 250\ kN$

Core wall $W_{wall\_Gk} := \gamma_{c\_k} \cdot t_w \cdot b_w \cdot (n \cdot h) = 288.000\ kN$

Pad fundation $W_{fdn\_Gk} := \gamma_{c\_k} \cdot d_{fdn} \cdot b_{fdn} \cdot l_{fdn} = 487.500\ kN$

### Total self weight

Total self weight on removable members

$$N_{Gk1} := \left(n \cdot g_{fl\_Gk} \cdot A\right) + \left(g_{scr\_Gk} \cdot A\right) + W_{wall\_Gk} + W_{fdn\_Gk}$$

$N_{Gk1} = 1352.625\ kN$

Total self weight of removable members

$$N_{Gk2} := \left((n - 1) \cdot g_{r\_fl\_Gk} \cdot A\right) + W_{tank\_Gk}$$

$N_{Gk2} = 278.500\ kN$

## 1-3. Characteristic actions - variable

### Imposed actions (normal to ground)

on roof $N_{rf\_Qk} := q_{rf\_k} \cdot A = 17.100\ \mathbf{kN}$

on floors $N_{fl\_Qk} := (n - 1) \cdot \left(q_{off\_k} + q_{par\_k}\right) \cdot A = 188.100\ \mathbf{kN}$

### Wind actions (horizontal direction)

on roof $Q_{w\_rf\_Qk} := q_{w\_k} \cdot \frac{h}{2} \cdot \frac{B_x}{2} = 44.160\ \mathbf{kN}$

on each floor $Q_{w\_fl\_Qk} := q_{w\_k} \cdot h \cdot \frac{B_x}{2} = 88.320\ \mathbf{kN}$

### Tota wind action (normal to ground)

$N_{w\_Qk} := 0\ \mathbf{kN}$

### Moment effect of wind action

first floor $M_{w\_Qk1} := Q_{w\_fl\_Qk} \cdot \left((n - 2) \cdot h + d_{fdn}\right)$

$M_{w\_Qk1} = 415.104\ \mathbf{kN\ m}$

second floor $M_{w\_Qk2} := Q_{w\_fl\_Qk} \cdot \left((n - 1) \cdot h + d_{fdn}\right)$

$M_{w\_Qk2} = 697.728\ \mathbf{kN\ m}$

roof $M_{w\_Qk3} := Q_{w\_rf\_Qk} \cdot \left(n \cdot h + d_{fdn}\right)$

$M_{w\_Qk3} = 490.176\ \mathbf{kN\ m}$

total $M_{w\_Qk} := M_{w\_Qk1} + M_{w\_Qk2} + M_{w\_Qk3}$

$M_{w\_Qk} = 1603.008\ \mathbf{kN\ m}$

# 2. Combination of actions for persistent and transient design situations - ULS (Ultimate Limit State) verification

## 2-1. Combination 1

Wind as leading variable action / Vertical actions unfavaourable / Partial factors from Set B

### Partial factors

| | |
|---|---|
| on permanent actions | $\gamma_G := 1.35$ |
| on variable actions (wind) | $\gamma_{Q\_w} := 1.5$ |
| on variable actions (imposed loads) | $\gamma_{Q\_i} := 1.5$ |

### Combination factors

| | |
|---|---|
| for wind | $\psi_w := 1.0$ |
| for imposed load in office areas (Category B) | $\psi_{fl} := 0.7$ |
| for imposed load on roof (Category H) | $\psi_{rf} := 0$ |

### Design value of normal action effect

$$N_{Ed} := \gamma_G \cdot \left(N_{Gk1} + N_{Gk2}\right) + \gamma_{Q\_w} \cdot \psi_w \cdot N_{w\_Qk} + \gamma_{Q\_i} \cdot \left(\psi_{fl} \cdot N_{fl\_Qk} + \psi_{rf} \cdot N_{rf\_Qk}\right)$$

$N_{Ed} = 2399.524\ \mathbf{kN}$

### Design value of moment effect

$M_{Ed} := \gamma_{Q\_w} \cdot \psi_w \cdot M_{w\_Qk} = 2404.512\ \mathbf{kN\ m}$

### Maximum bearing pressure on underside of foundation

$$P_{max\_Ed} := \frac{N_{Ed}}{b_{fdn} \cdot l_{fdn}} + \frac{6 \cdot M_{Ed}}{b_{fdn} \cdot l_{fdn}^{2}} = 355.313\ \mathbf{kPa}$$

## 2-2. Combination 2

Wind as leading variable action / Vertical actions favaourable / Partial factors from Set B

### Partial factors

on permanent, favourable $\gamma_{G\_fav} := 1.0$

### Design value of normal action effect

$N_{Ed} := \gamma_{G\_fav} \cdot \left( N_{Gk1} + N_{Gk2} \right) = 1631.125\ \mathbf{kN}$

### Design value of moment effect

$M_{Ed} := \gamma_{Q\_w} \cdot \psi_w \cdot M_{w\_Qk} = 2404.512\ \mathbf{kN\ m}$

### Maximum bearing pressure on underside of foundation

$$P_{max\_Ed} := \frac{N_{Ed}}{b_{fdn} \cdot l_{fdn}} - \frac{6 \cdot M_{Ed}}{b_{fdn} \cdot l_{fdn}^{2}} = -45.263\ \mathbf{kPa}$$

### Line of action is outside the middle-third and eccentricity

$$ecc := \frac{M_{Ed}}{N_{Ed}} = 1.474\ \mathbf{m}$$

### Revised maximum bearing pressure on underside of foundation

$$P_{max\_Ed} := \frac{8}{3} \cdot \frac{N_{Ed}}{\left( l_{fdn} - 2 \cdot ecc \right)^{2}} = 344.810\ \mathbf{kPa}$$

# 2-3. Combination 3

Imposed loads as leading variable action / Vertical actions unfavaourable / Partial factors from Set B

## Combination factors

| | |
|---|---|
| for wind | $\psi_w := 0.6$ |
| for imposed load in office areas (Category B) | $\psi_{fl} := 1$ |
| for imposed load on roof (Category H) | $\psi_{rf} := 1$ |

## Design value of normal action effect

$$N_{Ed} := \gamma_G \cdot \left(N_{Gk1} + N_{Gk2}\right) + \gamma_{Q\_w} \cdot \psi_w \cdot N_{w\_Qk} + \gamma_{Q\_i} \cdot \left(\psi_{fl} \cdot N_{fl\_Qk} + \psi_{rf} \cdot N_{rf\_Qk}\right)$$

$N_{Ed} = 2509.819\ \mathbf{kN}$

## Design value of moment effect

$M_{Ed} := \gamma_{Q\_w} \cdot \psi_w \cdot M_{w\_Qk} = 1442.707\ \mathbf{kN\ m}$

## Maximum bearing pressure on underside of foundation

$$P_{max\_Ed} := \frac{N_{Ed}}{b_{fdn} \cdot l_{fdn}} + \frac{6 \cdot M_{Ed}}{b_{fdn} \cdot l_{fdn}^{2}} = 295.504\ \mathbf{kPa}$$

## 2-4. Combination 4

Wind as leading variable action / Vertical actions unfavaourable / Partial factors from Set C

### Partial factors

| | |
|---|---|
| on permanent actions | $\gamma_G := 1$ |
| on variable actions (wind) | $\gamma_{Q\_w} := 1.3$ |
| on variable actions (imposed loads) | $\gamma_{Q\_i} := 1.3$ |

### Combination factors

| | |
|---|---|
| for wind | $\psi_w := 1.0$ |
| for imposed load in office areas (Category B) | $\psi_{fl} := 0.7$ |
| for imposed load on roof (Category H) | $\psi_{rf} := 0$ |

### Design value of normal action effect

$$N_{Ed} := \gamma_G \cdot \left(N_{Gk1} + N_{Gk2}\right) + \gamma_{Q\_w} \cdot \psi_w \cdot N_{w\_Qk} + \gamma_{Q\_i} \cdot \left(\psi_{fl} \cdot N_{fl\_Qk} + \psi_{rf} \cdot N_{rf\_Qk}\right)$$

$N_{Ed} = 1802.296\ \mathbf{kN}$

### Design value of moment effect

$M_{Ed} := \gamma_{Q\_w} \cdot \psi_w \cdot M_{w\_Qk} = 2083.910\ \mathbf{kN\ m}$

## 2-5. Combination 5

Wind as leading variable action / Vertical actions favaourable / Partial factors from Set C

### Design value of normal action effect

$N_{Ed} := \gamma_{G\_fav} \cdot \left( N_{Gk1} + N_{Gk2} \right) = 1631.125\ \mathbf{kN}$

### Design value of moment effect

$M_{Ed} := \gamma_{Q\_w} \cdot \psi_{w} \cdot M_{w\_Qk} = 2083.910\ \mathbf{kN\ m}$

## 2-6. Combination 6

Imposed loads as leading variable action / Vertical actions unfavaourable / Partial factors from Set C

### Combination factors

| | |
|---|---|
| for wind | $\psi_{w} := 0.6$ |
| for imposed load in office areas (Category B) | $\psi_{fl} := 1$ |
| for imposed load on roof (Category H) | $\psi_{rf} := 1$ |

### Design value of normal action effect

$N_{Ed} := \gamma_{G} \cdot \left( N_{Gk1} + N_{Gk2} \right) + \gamma_{Q\_w} \cdot \psi_{w} \cdot N_{w\_Qk} + \gamma_{Q\_i} \cdot \left( \psi_{fl} \cdot N_{fl\_Qk} + \psi_{rf} \cdot N_{rf\_Qk} \right)$

$N_{Ed} = 1897.885\ \mathbf{kN}$

### Design value of moment effect

$M_{Ed} := \gamma_{Q\_w} \cdot \psi_{w} \cdot M_{w\_Qk} = 1250.346\ \mathbf{kN\ m}$

# 3. Combination of actions for Quasi-persistent design situations - SLS (Serviceability limit states) verification

## 3-1. Combination 7

Wind as leading variable action / Vertical actions unfavaourable / Partial factors from SLS

### Partial factors

| | |
|---|---|
| on permanent actions | $\gamma_G := 1$ |
| on variable actions (wind) | $\gamma_{Q\_w} := 1$ |
| on variable actions (imposed loads) | $\gamma_{Q\_i} := 1$ |

### Combination factors

| | |
|---|---|
| for wind | $\psi_w := 0$ |
| for imposed load in office areas (Category B) | $\psi_{fl} := 0.3$ |
| for imposed load on roof (Category H) | $\psi_{rf} := 0$ |

### Design value of normal action effect

$$N_{Ed} := \gamma_G \cdot \left(N_{Gk1} + N_{Gk2}\right) + \gamma_{Q\_w} \cdot \psi_w \cdot N_{w\_Qk} + \gamma_{Q\_i} \cdot \left(\psi_{fl} \cdot N_{fl\_Qk} + \psi_{rf} \cdot N_{rf\_Qk}\right)$$

$N_{Ed} = 1687.555$ **kN**

### Design value of moment effect

$M_{Ed} := \gamma_{Q\_w} \cdot \psi_w \cdot M_{w\_Qk} = 0.$

## 3-2. Combination 8

Wind as leading variable action / Vertical actions favaourable / Partial factors from SLS

### Design value of normal action effect

$N_{Ed} := \gamma_{G\_fav} \cdot \left( N_{Gk1} + N_{Gk2} \right) = 1631.125\ \mathbf{kN}$

### Design value of moment effect

$M_{Ed} := \gamma_{Q\_w} \cdot \psi_w \cdot M_{w\_Qk} = 0.$

## 3-3. Combination 9

Imposed loads as leading variable action / Vertical actions unfavaourable
/ Partial factors from SLS

### Combination factors

| | |
|---|---|
| for wind | $\psi_w := 0$ |
| for imposed load in office areas (Category B) | $\psi_{fl} := 0.3$ |
| for imposed load on roof (Category H) | $\psi_{rf} := 0$ |

### Design value of normal action effect

$N_{Ed} := \gamma_G \cdot \left( N_{Gk1} + N_{Gk2} \right) + \gamma_{Q\_w} \cdot \psi_w \cdot N_{w\_Qk} + \gamma_{Q\_i} \cdot \left( \psi_{fl} \cdot N_{fl\_Qk} + \psi_{rf} \cdot N_{rf\_Qk} \right)$

$N_{Ed} = 1687.555\ \mathbf{kN}$

### Design value of moment effect

$M_{Ed} := \gamma_{Q\_w} \cdot \psi_w \cdot M_{w\_Qk} = 0.$