

Example JRC-01
3-storey domestic building subject to wind
Combinations of actions

Design situation

Consider an $n = 3$ storey building, $B_x = 48\text{m}$ by $B_y = 15\text{m}$ on plan, which is divided into $N_x = 8$ bays in the building's long direction and $N_y = 2$ bays in its short direction. The height of each storey is $h = 3.2\text{m}$. The floors of the building, which are $d_{\text{floor}} = 250\text{mm}$ thick.

Shear walls, intended to resist overturning, are located at both ends of the building and are $t_w = 300\text{mm}$ thick by $b_w = 4\text{m}$ wide on plan. A water tank, $d_{\text{tank}} = 2\text{m}$ deep by $l_{\text{tank}} = 5\text{m}$ long by $b_{\text{tank}} = 5\text{m}$ wide sits in the middle of the roof. The shear walls are supported by strip foundations of length $l_{\text{fdn}} = 6.5\text{m}$, breadth $b_{\text{fdn}} = 2\text{m}$, and thickness $d_{\text{fdn}} = 1.5\text{m}$.

The following characteristic imposed/wind actions act on the building:

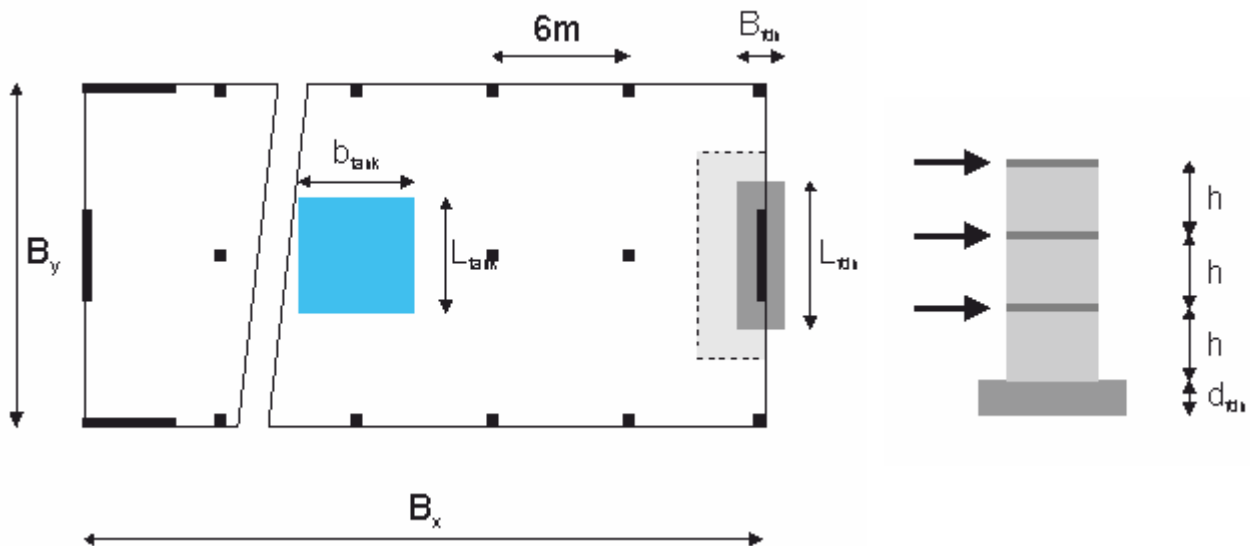
roof loading $q_{\text{rf},k} = 0.6\text{kPa}$

office floor loading $q_{\text{off},k} = 2.5\text{kPa}$

partition loading $q_{\text{par},k} = 0.8\text{kPa}$

wind (horizontal) $q_{w,k} = 1.15\text{kPa}$

The characteristic weight density of reinforced concrete is $\gamma_{c,k} = 25 \frac{\text{kN}}{\text{m}^3}$ and of water $\gamma_{w,k} = 10 \frac{\text{kN}}{\text{m}^3}$.



Geometry

Total plan area of building is:

$$A_{\text{tot}} = B_x \times B_y = 720 \text{m}^2$$

The tributary area above the stability wall has area:

$$A = \left(\frac{B_y + b_w}{2} \right) \times \frac{1}{2} \left(\frac{B_x}{N_x} \right) = 28.5 \text{m}^2$$

Characteristic actions - permanent

Self-weight of slabs:

$$\text{Floor: } g_{\text{fl},Gk} = \gamma_{c,k} \times d_{\text{floor}} = 6.25 \text{kPa}$$

Screed on roof: $g_{scr,Gk} = 1.5 \text{ kPa}$

Raised floor: $g_{r-fl,Gk} = 0.5 \text{ kPa}$ (removable)

Self-weight of water tank on roof - only half total weight is carried by the core wall

$$W_{\text{tank},Gk} = \frac{1}{2} \times \gamma_{w,k} \times d_{\text{tank}} \times l_{\text{tank}} \times b_{\text{tank}} = 250 \text{ kN (removable)}$$

Self-weight of core wall:

$$W_{\text{wall},Gk} = \gamma_{c,k} \times t_w \times b_w \times (n \times h) = 288 \text{ kN}$$

Self-weight of pad foundation:

$$W_{\text{fdn},Gk} = \gamma_{c,k} \times d_{\text{fdn}} \times b_{\text{fdn}} \times l_{\text{fdn}} = 488 \text{ kN}$$

Total self-weight of non-removable members (normal to ground):

$$N_{Gk_1} = (n \times g_{fl,Gk} \times A) + (g_{scr,Gk} \times A) + W_{\text{wall},Gk} + W_{\text{fdn},Gk} = 1353 \text{ kN}$$

Total self-weight of removable members (normal to ground):

$$N_{Gk_2} = [(n-1) \times g_{r-fl,Gk} \times A] + W_{\text{tank},Gk} = 279 \text{ kN}$$

Characteristic actions - variable

Imposed actions (normal to ground):

$$\text{on roof: } N_{rf,Qk} = q_{rf,k} \times A = 17.1 \text{ kN}$$

$$\text{on floors: } N_{fl,Qk} = (n-1) \times (q_{off,k} + q_{par,k}) \times A = 188.1 \text{ kN}$$

Wind actions (horizontal direction):

$$\text{on roof: } Q_{w,rf,Qk} = q_{w,k} \times \frac{h}{2} \times \frac{B_x}{2} = 44.2 \text{ kN}$$

$$\text{on each floor: } Q_{w,fl,Qk} = q_{w,k} \times h \times \frac{B_x}{2} = 88.3 \text{ kN}$$

Total wind action (normal to ground):

$$N_{w,Qk} = 0 \text{ kN}$$

Moment effect of wind action (on ground):

$$\text{first floor: } M_{w,Qk_1} = Q_{w,fl,Qk} \times [(n-2) \times h + d_{\text{fdn}}] = 415 \text{ kNm}$$

$$\text{second floor: } M_{w,Qk_2} = Q_{w,fl,Qk} \times [(n-1) \times h + d_{\text{fdn}}] = 698 \text{ kNm}$$

$$\text{roof: } M_{w,Qk_3} = Q_{w,rf,Qk} \times (n \times h + d_{\text{fdn}}) = 490 \text{ kNm}$$

$$\text{total: } M_{w,Qk} = \sum M_{w,Qk} = 1603 \text{ kNm}$$

Combinations of actions for persistent and transient design situations - ULS verifications

Combination 1 - wind as leading variable action, vertical actions unfavourable, partial factors from Set B

Partial factors

$$\text{on permanent actions: } \gamma_G = \gamma_{G,B} = 1.35$$

$$\text{on variable actions (wind): } \gamma_{Q,w} = \gamma_{Q,B} = 1.5$$

$$\text{on variable actions (imposed loads): } \gamma_{Q,i} = \gamma_{Q,B} = 1.5$$

Combination factors:

$$\text{for wind } \psi_w = 1.0$$

$$\text{for imposed load in office areas (Category B): } \psi_{fl} = \psi_{0,i,B} = 0.7$$

$$\text{for imposed load on roof (Category H): } \psi_{rf} = \psi_{0,i,H} = 0$$

Design value of normal action effect:

$$N_{Ed} = \gamma_G(N_{Gk_1} + N_{Gk_2}) + \gamma_{Q,w}\psi_w N_{w,Qk} + \gamma_{Q,i}(\psi_{fl} N_{fl,Qk} + \psi_{rf} N_{rf,Qk}) = 2400 \text{ kN}$$

Design value of moment effect:

$$M_{Ed} = \gamma_{Q,w}\psi_w M_{w,Qk} = 2405 \text{ kNm}$$

Combination 2 - wind as leading variable action, vertical actions favourable, partial factors from Set B

Design value of normal action effect:

$$N_{Ed} = \gamma_{G,fav}(N_{Gk_1} + N_{Gk_2}) = 1631 \text{ kN}$$

Design value of moment effect:

$$M_{Ed} = \gamma_{Q,w}\psi_w M_{w,Qk} = 2405 \text{ kNm}$$

Combination 3 - imposed loads as leading variable action, vertical actions unfavourable, partial factors from Set B

Combination factors:

$$\text{for wind } \psi_w = \psi_{0,w} = 0.6$$

$$\text{for imposed load in office areas (Category B): } \psi_{fl} = 1$$

$$\text{for imposed load on roof (Category H): } \psi_{rf} = 1$$

Design value of normal action effect:

$$N_{Ed} = \gamma_G(N_{Gk_1} + N_{Gk_2}) + \gamma_{Q,w}\psi_w N_{w,Qk} + \gamma_{Q,i}(\psi_{fl} N_{fl,Qk} + \psi_{rf} N_{rf,Qk}) = 2510 \text{ kN}$$

Design value of moment effect:

$$M_{Ed} = \gamma_{Q,w}\psi_w M_{w,Qk} = 1443 \text{ kNm}$$

Combination 4 - wind as leading variable action, vertical actions unfavourable, partial factors from Set C

Partial factors:

$$\text{on permanent actions: } \gamma_G = \gamma_{G,C} = 1$$

$$\text{on variable actions (wind): } \gamma_{Q,w} = \gamma_{Q,C} = 1.3$$

$$\text{on variable actions (imposed loads): } \gamma_{Q,i} = \gamma_{Q,C} = 1.3$$

Combination factors:

$$\text{for wind } \psi_w = 1.0$$

$$\text{for imposed load in office areas (Category B): } \psi_{fl} = \psi_{0,i,B} = 0.7$$

$$\text{for imposed load on roof (Category H): } \psi_{rf} = \psi_{0,i,H} = 0$$

Design value of normal action effect:

$$N_{Ed} = \gamma_G(N_{Gk_1} + N_{Gk_2}) + \gamma_{Q,w}\psi_w N_{w,Qk} + \gamma_{Q,i}(\psi_{fl} N_{fl,Qk} + \psi_{rf} N_{rf,Qk}) = 1802 \text{ kN}$$

Design value of moment effect:

$$M_{Ed} = \gamma_{Q,w}\psi_w M_{w,Qk} = 2084 \text{ kNm}$$

Combination 5 - wind as leading variable action, vertical actions favourable, partial factors from Set C

Design value of normal action effect:

$$N_{Ed} = \gamma_{G,fav}(N_{Gk_1} + N_{Gk_2}) = 1631 \text{ kN}$$

Design value of moment effect:

$$M_{Ed} = \gamma_{Q,w}\psi_w M_{w,Qk} = 2084 \text{ kNm}$$

Combination 6 - imposed loads as leading variable action, vertical actions unfavourable, partial factors from Set C

Combination factors:

$$\text{for wind } \psi_w = \psi_{0,w} = 0.6$$

$$\text{for imposed load in office areas (Category B): } \psi_{fl} = 1$$

for imposed load on roof (Category H): $\psi_{rf} = 1$

Design value of normal action effect:

$$N_{Ed} = \gamma_G(N_{Gk_1} + N_{Gk_2}) + \gamma_{Q,w}\psi_w N_{w,Qk} + \gamma_{Q,i}(\psi_{fl} N_{fl,Qk} + \psi_{rf} N_{rf,Qk}) = 1898 \text{ kN}$$

Design value of moment effect:

$$M_{Ed} = \gamma_{Q,w}\psi_w M_{w,Qk} = 1250 \text{ kNm}$$

Combinations of actions for quasi-permanent design situations - SLS verifications

Combination 7 - wind as leading variable action, vertical actions unfavourable, partial factors for SLS

Partial factors

on permanent actions: $\gamma_G = \gamma_{G,SLS} = 1$

on variable actions (wind): $\gamma_{Q,w} = \gamma_{Q,SLS} = 1$

on variable actions (imposed loads): $\gamma_{Q,i} = \gamma_{Q,SLS} = 1$

Combination factors:

for wind $\psi_w = \psi_{2,w} = 0$

for imposed load in office areas (Category B): $\psi_{fl} = \psi_{2,i,B} = 0.3$

for imposed load on roof (Category H): $\psi_{rf} = \psi_{2,i,H} = 0$

Design value of normal action effect:

$$N_{Ed} = \gamma_G(N_{Gk_1} + N_{Gk_2}) + \gamma_{Q,w}\psi_w N_{w,Qk} + \gamma_{Q,i}(\psi_{fl} N_{fl,Qk} + \psi_{rf} N_{rf,Qk}) = 1688 \text{ kN}$$

Design value of moment effect:

$$M_{Ed} = \gamma_{Q,w}\psi_w M_{w,Qk} = 0 \text{ kNm}$$

Combination 8 - wind as leading variable action, vertical actions favourable, partial factors for SLS

Design value of normal action effect:

$$N_{Ed} = \gamma_{G,fav}(N_{Gk_1} + N_{Gk_2}) = 1631 \text{ kN}$$

Design value of moment effect:

$$M_{Ed} = \gamma_{Q,w}\psi_w M_{w,Qk} = 0 \text{ kNm}$$

Combination 3 - imposed loads as leading variable action, vertical actions unfavourable, partial factors for SLS

Combination factors:

for wind $\psi_w = \psi_{2,w} = 0$

for imposed load in office areas (Category B): $\psi_{fl} = \psi_{2,i,B} = 0.3$

for imposed load on roof (Category H): $\psi_{rf} = \psi_{2,i,H} = 0$

Design value of normal action effect:

$$N_{Ed} = \gamma_G(N_{Gk_1} + N_{Gk_2}) + \gamma_{Q,w}\psi_w N_{w,Qk} + \gamma_{Q,i}(\psi_{fl} N_{fl,Qk} + \psi_{rf} N_{rf,Qk}) = 1688 \text{ kN}$$

Design value of moment effect:

$$M_{Ed} = \gamma_{Q,w}\psi_w M_{w,Qk} = 0 \text{ kNm}$$