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 $d_{floor} = 250\text{mm}$ 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, $d_{tank} = 2\text{m}$ deep by $l_{tank} = 5\text{m}$ long by $b_{tank} = 5\text{m}$ wide sits in the middle of the roof. The shear walls are supported by strip foundations of length $l_{fdn} = 6.5\text{m}$, breadth $b_{fdn} = 2\text{m}$, and thickness $d_{fdn} = 1.5\text{m}$.

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

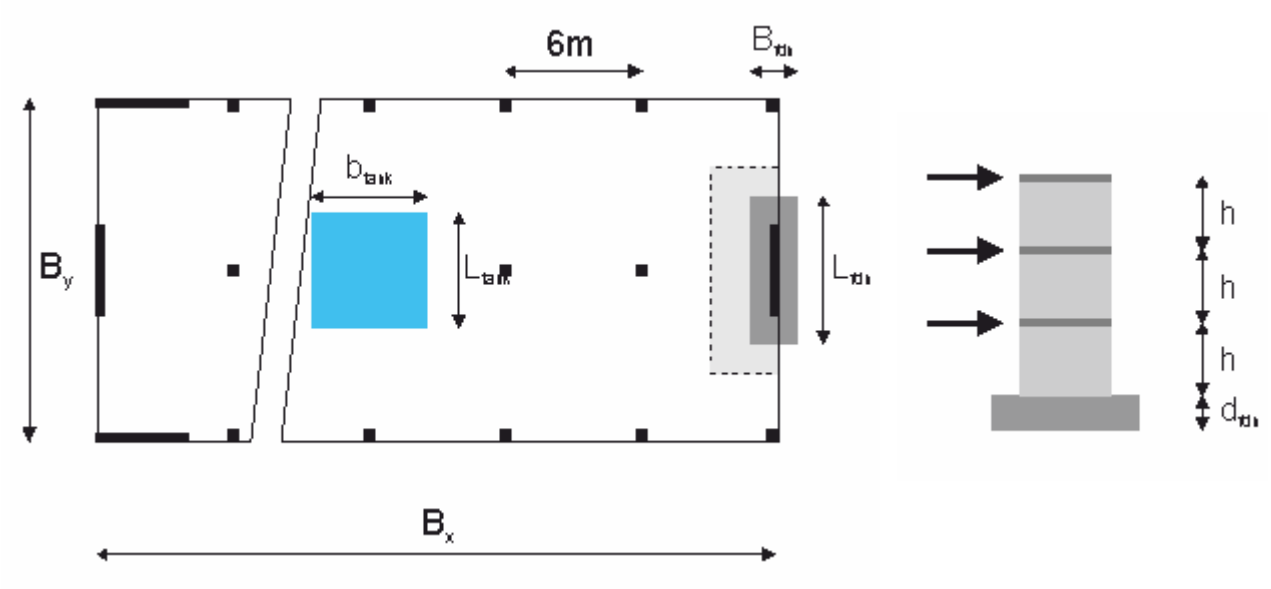
roof loading $q_{rf,k} = 0.6\text{kPa}$

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

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

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:

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

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:

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

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

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

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

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

Self-weight of core wall:

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

Self-weight of pad foundation:

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

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

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

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

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

Characteristic actions - variable

Imposed actions (normal to ground):

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

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

Wind actions (horizontal direction):

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

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):

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

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

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

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

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

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

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

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

Combination factors:

for wind $\psi_w = 1.0$

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

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

Design value of normal action effect:

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

Design value of moment effect:

$$M_{Ed} = \gamma_{Q,w}\psi_w M_{w,Qk} = 2405\,kN\,m$$

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

Design value of normal action effect:

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

Design value of moment effect:

$$M_{Ed} = \gamma_{Q,w}\psi_w M_{w,Qk} = 2405\,kN\,m$$

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

Combination factors:

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

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:

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

Design value of moment effect:

$$M_{Ed} = \gamma_{Q,w}\psi_w M_{w,Qk} = 1443\,kN\,m$$

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

Partial factors:

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

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

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

Combination factors:

for wind $\psi_w = 1.0$

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

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

Design value of normal action effect:

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

Design value of moment effect:

$$M_{Ed} = \gamma_{Q,w}\psi_w M_{w,Qk} = 2084\,kN\,m$$

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

Design value of normal action effect:

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

Design value of moment effect:

$$M_{Ed} = \gamma_{Q,w}\psi_w M_{w,Qk} = 2084\,kN\,m$$

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

Combination factors:

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

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:

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

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:

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

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:

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

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:

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

Design value of moment effect:

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