## *2 Wapeningsberekening*

$h$ = 180 mm $d_t$ = 66 mm $d_b$ = 66 mm $d_v$ = 114 mm

$n_{xx}$ = 0,00 kN/m $n_{yy}$ = 0,00 kN/m $n_{xy}$ = 0,00 kN/m

$m_{xx}$ = 3,165 kNm/m $m_{yy}$ = 18,33 kNm/m $m_{xy}$ = 0,00 kNm/m

$v_x$ = 0,09 kN/m $v_y$ = 0,00 kN/m $\theta = 22^0$

$$v_0 = \sqrt{v_x^2 + v_y^2} = \sqrt{0{,}09^2 + 0{,}00^2} = 0{,}09 \text{ kN/m}$$

$$\tan\varphi_0 = \frac{v_y}{v_x} = \frac{0{,}00}{0{,}09} = 0{,}000 \qquad \varphi_0 = 0{,}0$$

$\sin\varphi_0 = 0{,}000$ $\cos\varphi_0 = 1{,}000$

Shear capacity

$\rho_{lx} = A_{slx} / (b_w\ d)$ = 80 /(1000 x 147)= 0,000543

$\rho_{ly} = A_{sly} / (b_w\ d)$ = 370 /(1000 x 147)= 0,002515

$\rho_l = \rho_{lx} \cos^2\varphi_0 + \rho_{ly} \sin^2\varphi_0 = 0{,}000543 \leq 0{,}02$

$n_{nn} = n_{xx} \cos^2\varphi_0 + n_{yy} \sin^2\varphi_0 + n_{xy} \sin 2\varphi_0 = 0{,}00$ kN/m

$$k = 1 + \sqrt{\frac{200}{d}} = 1 + \sqrt{\frac{200}{147}} = 2{,}166 > 2{,}0 \rightarrow k = 2{,}0$$

$V_{Rd,c} = [C_{Rd,c}\ k\ (100\ \rho_l\ f_{ck})^{1/3} + k_1\ \sigma_{cp}]\ b_w\ d =$ ...(6.2.a)

$= [0{,}12 \times 2 \times (100 \times 0{,}000543 \times 20)^{1/3} + 0{,}15 \times 0] \times 1000 \times 147 \times 10^{-3} = 36{,}26$ kN

$v_{min} = 0{,}035\ k^{3/2}\ f_{ck}^{1/2} = 0{,}035 \times 2^{3/2} \times 20^{1/2} = 0{,}443$ MPa ...(6.3N)

$V_{Rd,c} = (v_{min} + k_1\ \sigma_{cp})\ b_w\ d = (0{,}443 + 0{,}15 \times 0) \times 1000 \times 147 \times 10^{-3} = 65{,}08$ kN ...(6.2.b)

$V_{Rd,c} = \max(V_{Rd,c\,(6.2.a)}\ ;\ V_{Rd,c\,(6.2.b)}) = \max(36{,}26; 65{,}08) = 65{,}08$ kN

$v_o < V_{Rdc}$ → No shear force reinforcement is required.

Top shell

$$n_{xxt} = \frac{-m_{xx}}{d_v} + (1-\gamma)n_{xx} = \frac{-3{,}16}{0{,}114} + (1 - 0{,}50) \times 0{,}00 = -27{,}76 \text{ kN/m}$$

$$n_{yyt} = \frac{-m_{yy}}{d_v} + (1-\gamma)n_{yy} = \frac{-18{,}33}{0{,}114} + (1 - 0{,}50) \times 0{,}00 = -160{,}75 \text{ kN/m}$$

$$n_{xyt} = \frac{-m_{xy}}{d_v} + (1-\gamma)n_{xy} = \frac{0{,}00}{0{,}114} + (1 - 0{,}50) \times 0{,}00 = 0{,}00 \text{ kN/m}$$

$n_{0t} = | n_{xyt} | = 0{,}00$ kN/m

| | | |
|---|---|---|
| 1: $n_{xxt} > -n_{0t}$ | $n_{yyt} > -n_{0t}$ | no |
| 2: $n_{xxt}\ n_{yyt} < n_{0t}^2$ | $n_{yyt} < -n_{0t}$ | no |
| 3: $n_{xxt}\ n_{yyt} < n_{0t}^2$ | $n_{xxt} < -n_{0t}$ | no |

4: $n_{xxt}\ n_{yyt} > n_{0t}^2$ $n_{xxt} < 0 \quad n_{yyt} < 0$ yes → Case 4 no reinforcement

Testing concrete pressure force

$$n_{ct} = \left| 1/2\,(n_{xxt} + n_{yyt}) - \sqrt{1/4\,(n_{xxt} - n_{yyt})^2 + n_{xyt}^2} \right| =$$

$$= \left| 1/2\,(-27{,}76 + -160{,}75) - \sqrt{1/4\,(-27{,}76 - -160{,}75)^2 + 0{,}00^2} \right| = 160{,}75 \text{ kN/m}$$

$n_{ct} < 1{,}0\ f_{cd}\ b_w\ d_t = 1{,}0 \times 13{,}33 \times 1000 \times 66 \times 10^{-3} = 880{,}00$ kN/m

<u>bottom shell</u>

$$n_{xxb} = \frac{m_{xx}}{d_v} + \gamma\ n_{xx} = \frac{3{,}16}{0{,}114} + 0{,}50 \times 0{,}00 = 27{,}76 \text{ kN/m}$$

$$n_{yyb} = \frac{m_{yy}}{d_v} + \gamma\ n_{yy} = \frac{18{,}33}{0{,}114} + 0{,}50 \times 0{,}00 = 160{,}75 \text{ kN/m}$$

$$n_{xyb} = \frac{m_{xy}}{d_v} + \gamma\ n_{xy} = \frac{0{,}00}{0{,}114} + 0{,}50 \times 0{,}00 = 0{,}00 \text{ kN/m}$$

$n_{0b} = \left| n_{xyb} \right| = 0{,}00$ kN/m

1: $n_{xxb} > -n_{0b}$ $n_{yyb} > -n_{0b}$ yes → Case 1 reinforcement in x and y dir.

2: $n_{xxb}\ n_{yyb} < n_{0b}^2$ $n_{yyb} < -n_{0b}$ no

3: $n_{xxb}\ n_{yyb} < n_{0b}^2$ $n_{xxb} < -n_{0b}$ no

4: $n_{xxb}\ n_{yyb} > n_{0b}^2$ $n_{xxb} < 0 \quad n_{yyb} < 0$ no

Testing concrete pressure force

$n_{cb} = 2\ n_{0b} = 2 \times 0{,}00 = 0{,}00$ kN/m

$n_{cb} < 1{,}0\ f_{cd}\ b_w\ d_b = 1{,}0 \times 13{,}33 \times 1000 \times 66 \times 10^{-3} = 880{,}00$ kN/m

Calculation of reinforcement

$n_{sxb} = n_{xxb} + n_{0b} = 27{,}76 + 0{,}00 = 27{,}76$ kN/m

$n_{syb} = n_{yyb} + n_{0b} = 160{,}75 + 0{,}00 = 160{,}75$ kN/m

$$A_{sxb,ULS} = \frac{n_{sxb}}{f_{yd}} = \frac{27{,}76 \times 10^3}{435} = 64 \text{ mm}^2/\text{m}$$

$$A_{syb,ULS} = \frac{n_{syb}}{f_{yd}} = \frac{160{,}75 \times 10^3}{435} = 370 \text{ mm}^2/\text{m}$$