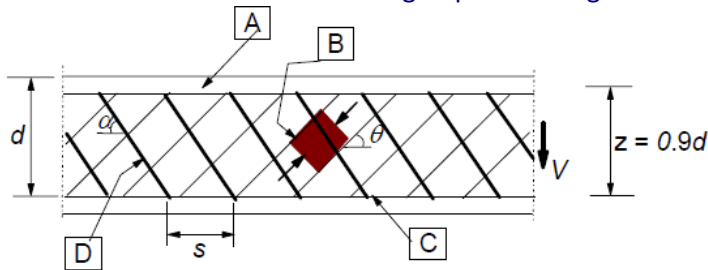


Shear solid slabs (rectangular cross-section)

– Truss model with no axial loading or prestressing –



[A] - compression chord, [B] - struts, [C] - tensile chord, [D] - shear reinforcement

Ref. EN 1992-1-1
Sec. 6.2.2 – Sec. 6.2.3
Cl. 9.2.1.2(3)
Sec. 9.2.2

Figure 6.5

Geometry cross-section

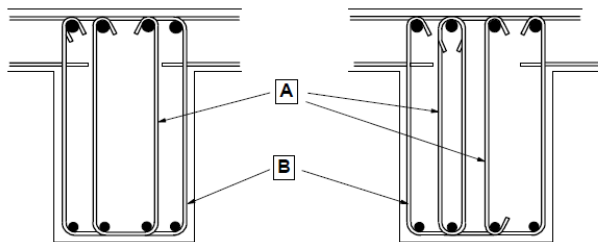
Rectangular shape:

Width $b = b_w = 350$ mm

Height $h = 600$ mm

Effective depth $d = 550$ mm

Lever arm: $z = 0,9d = 495$ mm



[A] Inner link alternatives [B] Enclosing link

Figure 9.5

Analysis

Design shear occurring at cross-section being considered:

$$V_{Ed} = 340 \text{ kN.}$$

Design shear stress @ cross-section:

$$v_{Ed} = V_{Ed}/(b_w d) = 1,77 \text{ MPa}$$

Materials – characteristic/design strengths

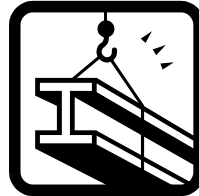
Concrete C30/37

Strength class for concrete:

$$f_{ck} = 30 \text{ N/mm}^2 = 30 \text{ MPa}$$

$$f_{cd} = \alpha_{cc} f_{ck} / \gamma_c = 0,85 f_{ck} / 1,50 = 17,00 \text{ N/mm}^2$$

Table 3.1



Steel

Strength of shear reinforcement (Class B and C):

$$f_{yk} = 500 \text{ N/mm}^2 = 500 \text{ MPa}$$

$$f_{ywd} = f_{yk}/\gamma_s = f_{yk}/1,15 = 0,87f_{yk} = 435 \text{ N/mm}^2$$

Durability and cover to reinforcement

Nominal cover (for enclosing vertical links):

$$c_{nom} = c_{min} + \Delta c_{dev} = 25 \text{ mm}$$

Tensile reinforcement

Area of the tensile reinforcement, which extends $\geq (l_{bd} + d)$ beyond the section considered (see figure above):

$$A_{sl} = 600 \text{ mm}^2$$

Shear resistance (without shear reinforcement)

Design value for the shear stress resistance:

$$v_{Rd,C} = \max[C_{Rd,c}k(100\rho f_{ck})^{1/3}; 0,035k^{3/2}f_{ck}^{1/2}] = 0,41 \text{ MPa}$$

$$C_{Rd,c} = 0,12; k = 1 + (200/d)^{1/2} = 1,60 \leq 2,0; \rho_l = A_{sl}/(b_w d) = 0,003 \leq 0,02$$

$$V_{Ed} \leq 0,5b_w d v_{fcd} = 864 \text{ kN (satisfactory)}$$

Shear reinforcement required

$$V_{Ed} = 1,77 \text{ MPa} \geq v_{Rd,C} = 0,41 \text{ MPa}$$

Detailing

Shear reinforcement for beam (stirrups and bent-up bars):

$$\beta_3 = 0,50 \text{ (chosen)}$$

Design shear stress occurring at cross-section being considered $v_{Ed} = 1,77 \text{ MPa}$ (with: 0,88 MPa @stirrups and 0,88 MPa @bet-up bars).

Chosen $\cot\theta = 1,00$ with $1,00 \leq \cot\theta \leq 2,50$.

Stirrups

$N = 1$ enclosing links with diameter H10 mm, and no inner links.

Longitudinal spacing (vertical links): $s = 190 \text{ mm}$ (chosen).

$\alpha = 90^\circ$ (angle between vertical links and the beam axis).

Bent-up bars

2H16 bars ($A_{sw} = 402 \text{ mm}^2$) bent-up at an angle from the bottom of the beam $\alpha = 45^\circ$ (for $n = 2$ times) with a longitudinal spacing:

$$s = \frac{Z}{n}(\cot\theta + \cot\alpha) = 495 \text{ mm}$$

Table C.1 – Annex C

Exp. (4.1)

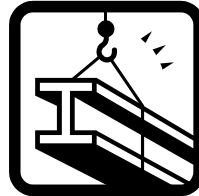
Sec. 6.2.2
Exp. (6.2.a) – (6.2.b) – (6.3N).

Cl. 6.2.2(6) – Exp. (6.5)

Cl. 6.2.1(3).

Cl. 9.2.2(4) – Note

Cl. 6.2.3(2) – Note – Exp. (6.7N)



► Maximum longitudinal spacing (vertical links):

$$s_{l,max} = 0,75d(1 + \cot\alpha) = 413 \text{ mm.}$$

Compression longitudinal reinforcement (diameter ϕ_{com}) which is included in the resistance calculation: H14

$$s_{l,max} = 15\phi_{com} = 210 \text{ mm}$$

$$\text{MIN}[413; 210] = 210 \text{ mm} \geq s = 190 \text{ mm (satisfactory)}$$

► Maximum transverse spacing of shear reinforcement (vertical links):

$$s_{t,max} = \text{MIN}[0,75d; 600 \text{ mm}] = 413 \text{ mm}$$

Transverse vertical spacing:

$$s_t = \frac{b_w - 2c_{nom} - \phi_{Enclink}}{N_{InnerLink} + 1} = 290 \text{ mm} \leq s_{t,max} \text{ (satisfactory)}$$

(where $N_{innerLink}$ = number of inner links).

► Minimum shear reinforcement (for $\sin\alpha = 1$):

$$\left(\frac{A_{sw}}{s}\right)_{min} = \rho_{w,min} b_w \sin\alpha = \frac{0,08\sqrt{f_{ck}}}{f_{ywk}} b_w = 0,307 \text{ mm}^2/\text{mm} = 307 \text{ mm}^2/\text{m.}$$

$$A_{sw}/s = 0,827 \text{ mm}^2/\text{mm} = 827 \text{ mm}^2/\text{m} \geq (A_{sw}/s)_{min} \text{ (satisfactory).}$$

Shear capacity

Capacity of the concrete section with vertical and inclined shear reinforcement to act as a strut:

$$V_{Rd,max} = \alpha_{cw} b_w z v_1 f_{cd} / (\cot\theta + \tan\theta) = 777546 \text{ N (stirrups)}$$

$$(\cot\theta + \tan\theta) = 2,00$$

$$V_{Rd,max} = \alpha_{cw} b_w z v_1 f_{cd} (\cot\theta + \cot\alpha) / (1 + \cot^2\theta) = 1555092 \text{ N (inclined bars)}$$

$$(\cot\theta + \cot\alpha) = 2,00$$

$$(1 + \cot^2\theta) = 2,00$$

$$V_{Rd,max} = \text{MIN}[777546; 1555092] = 777546 \text{ N (used in calculations).}$$

Shear reinforcement (stirrups)

$$\text{With: } A_{sw}/s = 0,827 \text{ mm}^2/\text{mm} = 827 \text{ mm}^2/\text{m}$$

$$\cot\theta = 1,00$$

$$V_{Rd,s} = (A_{sw}/s) z f_{ywd} \cot\theta = 177928 \text{ N}$$

$$\text{MIN}[V_{Rd,s}; V_{Rd,max}] / (b_w d) = 0,92 \text{ MPa} > v_{Ed} = 0,88 \text{ MPa (satisfactory).}$$

Shear reinforcement (bent-up bars)

$$\text{With: } A_{sw}/s = 0,812 \text{ mm}^2/\text{mm} = 812 \text{ mm}^2/\text{m}$$

$$(\cot\theta + \cot\alpha) = 2,00$$

Cl. 9.2.2(6) - Exp.(9.6N)

Cl. 9.2.1.2(3)

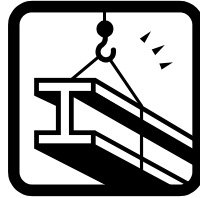
Cl. 9.2.2(8) – Exp. (9.8N)

Cl. 9.2.2(5) – Exp. (9.4) – (9.5N)

Exp. (6.9)

Exp. (6.14)

Exp. (6.8)



$$\sin \alpha = 0,71$$

$$V_{Rd,s} = (A_{sw}/s)z f_{ywd}(\cot \theta + \cot \alpha) \sin \alpha = 247256 \text{ N}$$

$$\text{MIN}[V_{Rd,s}; V_{Rd,max}]/(b_w d) = 1,28 \text{ MPa} > v_{Ed} = 0,88 \text{ MPa (satisfactory).}$$

Note

Provide H10 mm diameter enclosing links, (and no inner links) at 190 mm centres.

Provide 2H16 bent-up at $\alpha = 45^\circ$ for $n = 2$ times with a longitudinal spacing $s \leq 495$ mm.

Exp. (6.13)

Maximum effective cross-sectional area of the shear reinforcement ($\cot \theta = 1$)

► Stirrups:

$$\left(\frac{A_{sw,max}}{s} \right) \leq \frac{1}{2} \alpha_{cv} v_1 \frac{f_{cd}}{f_{ywd}} b_w = 3,613 \text{ mm}^2/\text{mm} = 3613 \text{ mm}^2/\text{m}$$

Cl. 6.2.3(3) – Note 4

Exp. (6.12)

► Bent-up bars:

$$\left(\frac{A_{sw,max}}{s} \right) \leq \frac{1}{2 \sin \alpha} \alpha_{cv} v_1 \frac{f_{cd}}{f_{ywd}} b_w = 5,109 \text{ mm}^2/\text{mm} = 5109 \text{ mm}^2/\text{m}.$$

Cl. 6.2.3(3) – Note

Exp. (6.15)