



## Preface

### **Content**

Interactive design aids for concrete elements in accordance to BS EN 1992

### **Guidelines of use**

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The examples provided have been created using VCmaster. All annotated and illustrated design aids can be used as a basis to create own templates. In order to do this a full version of VCmaster is necessary.

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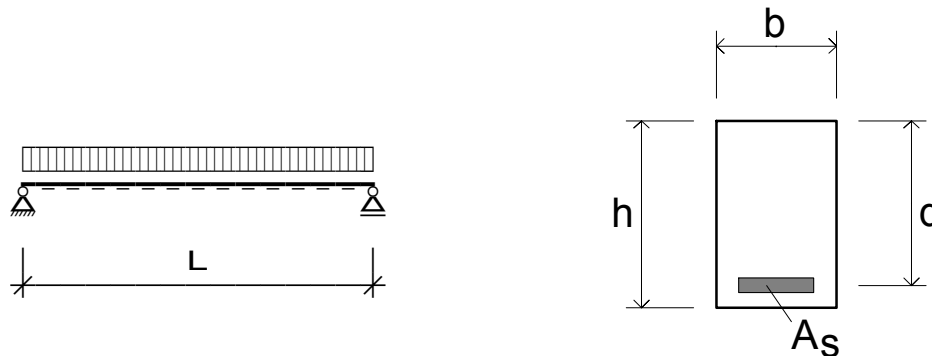
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## Chapter 1: Beams

### Design of beam for bending ULS



#### Data given

Beam width $b =$	200.0 mm
Overall depth $h =$	300.0 mm
Effective depth $d =$	252.5 mm
Beam span $L =$	5.00 m

#### Loads

Dead load excluding beam self weight $g_k =$	12.00 kN/m
Imposed load $q_k =$	5.00 kN/m

#### Material properties

Concrete grade C	=	C30/37
$f_{ck}$	=	30.0 N/mm <sup>2</sup>
$f_{yk}$	=	500.0 N/mm <sup>2</sup>

#### Loading

Beam self weight $g_b =$	$b * h * 25 * L = 0.2 * 0.3 * 25 * 5.00$	=	7.5 kN
Total dead load $G_k =$	$g_b + g_k * L$	=	67.5 kN
Total imposed load $Q_k =$	$q_k * L$	=	25.0 kN
Ultimate load $F =$	$1.35 * G_k + 1.50 * Q_k$	=	128.6 kN

#### Bending ULS

$M =$	$F * \frac{L}{8}$	=	80.4 kNm
$K =$	$\text{MIN}\left(\frac{M}{b * d^2 * f_{ck}}; 0.167\right)$	=	0.167
$f_{[z/d]} =$	$\text{MIN}\left(0.5 * \left(1 + \sqrt{1 - 3.53 * K}\right); 0.95\right)$	=	0.820
$z =$	$\frac{d * f_{[z/d]}}{M}$	=	207.1 mm
$A_s =$	$\frac{M}{0.87 * z * f_{yk}}$	=	892.5 mm <sup>2</sup>
$\text{min.} A_s =$	$b * h * 0.016 / 100 * f_{ck}^{2/3}$	=	92.7 mm <sup>2</sup>



### Reinforcing bars

Diameter  $d_s$  = 20 mm

Group = 3H20

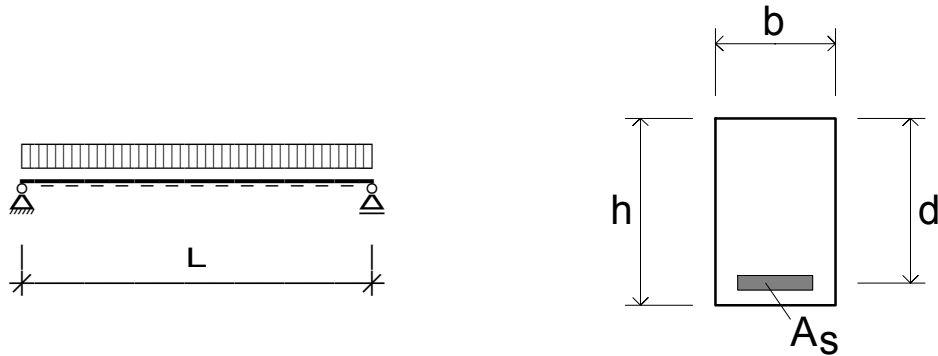
### Maximum amount of reinforcement

$A_{s,prov}$  = 942.0 mm<sup>2</sup>

$A_{s,max} = \frac{A_{s,prov} * 100}{b * h} = \frac{942.0 * 100}{200.0 * 300.0} = 1.57 \% < 4\%$



### Design of beam for deflection SLS



#### Data given

Beam width $b =$	200.0 mm
Effective depth $d =$	352.5 mm
Beam span $L =$	5.00 m

#### Area of reinforcement

Required $A_{s,req} =$	800.0 mm <sup>2</sup>
Diameter $d_s =$	= 20 mm
Group	= 3H20
Provided $A_{s,prov} =$	= 942.0 mm <sup>2</sup>

#### Span/effective depth ratio calculations

$$\text{Percentage of reinforcement } \rho_1 = \frac{100 * A_{s,req}}{b * d} = \frac{100 * 800.0}{200.0 * 352.5} = 1.13 \%$$

$$\text{Basic ratio } r = 16.22$$

$$\text{Multiply factor } f = \text{MIN}\left(\frac{A_{s,prov}}{A_{s,req}}; 1.50\right) = 1.178$$

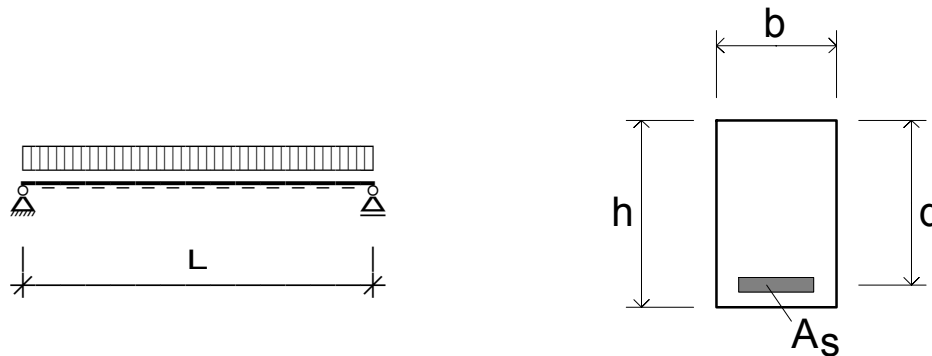
$$\text{Permitted ratio } r_{perm} = r * f = 19.11$$

$$\text{Actual ratio } r_{act} = \frac{L}{d} = \frac{5000}{352.5} = 14.18$$

$$\frac{r_{act}}{r_{perm}} = 0.74 \leq 1$$



### Example: Design of beam



#### Data given

Beam width $b =$	250.0 mm
Overall depth $h =$	400.0 mm
Beam span $L =$	5.00 m
With of support $w =$	250.0 mm

#### Loading

Dead load excluding beam self weight $g_k =$	20.00 kN/m
Imposed load $q_k =$	10.00 kN/m

Beam self weight $g_b =$	$b \cdot h \cdot 25 \cdot L = 0.25 \cdot 0.4 \cdot 25 \cdot 5.00$	=	12.5 kN
Total dead load $G_k =$	$g_b + g_k \cdot L$	=	112.5 kN
Total imposed load $Q_k =$	$q_k \cdot L$	=	50.0 kN
Ultimate load $F =$	$1.35 \cdot G_k + 1.50 \cdot Q_k$	=	226.9 kN

#### Material properties

Main bar diameter $d_{bar}$	=	20 mm
Shear link diameter $d_{link}$	=	10 mm
Concrete grade C	=	C30/37
$f_{ck}$	=	30.0 N/mm <sup>2</sup>
$f_{yk}$	=	500.0 N/mm <sup>2</sup>

#### Cover to bars

Exposure class	=	XC1	
Resistance to fire	=	R60	
Minimum concrete covers [mm]			
Side $c_{side} =$	$\text{MAX}(d_{link} + 10 ; \text{nom.}c_{side} ; c_{fire,side})$	=	25 mm
Soffit $c_{soffit} =$	$\text{MAX}(d_{link} + 10 ; \text{nom.}c_{soffit} ; c_{fire,soffit})$	=	25 mm

#### Provided $c =$

Cover to main bars $c_{bar} =$	$\text{MAX}(d_{bar} + 10 ; c + d_{link})$	=	<b>30 mm</b> 40 mm
Axis distance to the main bar / Effective depth			
$a_{soffit} =$	$\text{MAX}(c_{bar} + d_{bar} / 2 ; \text{min.}a_{soffit})$	=	50 mm
Effective depth $d =$	$h - a_{soffit}$	=	<b>350.0 mm</b>



### Bending ULS

$$\begin{aligned} M &= F \cdot \frac{L}{8} &= & 141.8 \text{ kNm} \\ K &= \text{MIN}\left(\frac{M}{b \cdot d^2 \cdot f_{ck}}; 0.167\right) &= & 0.154 \\ f_{[z/d]} &= \text{MIN}\left(0.5 \cdot \left(1 + \sqrt{1 - 3.53 \cdot K}\right); 0.95\right) &= & 0.838 \\ z &= d \cdot f_{[z/d]} &= & 293.3 \text{ mm} \\ A_s &= \frac{M}{0.87 \cdot z \cdot f_{yk}} &= & 1111.4 \text{ mm}^2 \\ \text{min. } A_s &= b \cdot h \cdot 0.016/100 \cdot f_{ck}^{2/3} &= & 154.5 \text{ mm}^2 \\ \text{Reinforcing bars} \\ \text{Diameter } d_s &= d_{\text{bar}} &= & 20 \text{ mm} \\ \text{Group} & &= & \mathbf{4H20} \\ \text{Maximum amount of reinforcement} \\ A_{s,\text{prov}} & &= & 1257.0 \text{ mm}^2 \\ A_{s,\text{max}} &= \frac{A_{s,\text{prov}} \cdot 100}{b \cdot h} = \frac{1257.0 \cdot 100}{250.0 \cdot 400.0} &= & 1.26 \% < 4\% \end{aligned}$$

### Span / Effective depth ratio calculation for deflection SLS

$$\begin{aligned} \text{Area of reinforcement} \\ \text{Required } A_{s,\text{req}} &= A_s &= & 1111.4 \text{ mm}^2 \\ \text{Provided } A_{s,\text{prov}} & &= & 1257.0 \text{ mm}^2 \\ \text{Span/effective depth ratio calculations} \\ \text{Percentage of reinforcement } \rho_1 &= \frac{100 \cdot A_{s,\text{req}}}{b \cdot d} = \frac{100 \cdot 1111.4}{250.0 \cdot 350.0} &= & 1.27 \% \\ \text{Basic ratio } r & &= & 15.38 \\ \text{Multiply factor } f &= \text{MIN}\left(\frac{A_{s,\text{prov}}}{A_{s,\text{req}}}; 1.50\right) &= & 1.131 \\ \text{Permitted ratio } r_{\text{perm}} &= r \cdot f &= & 17.39 \\ \text{Actual ratio } r_{\text{act}} &= \frac{L}{d} = \frac{5000}{350.0} &= & 14.29 \\ \frac{r_{\text{act}}}{r_{\text{perm}}} & &= & \mathbf{0.82 \leq 1} \end{aligned}$$



### Shear reinforcement

Shear force  
 $\Theta = 21.80^\circ$

$$V_{Rd} = 0.36 * (1 - f_{ck}/250) * f_{ck} / ((1/\tan(\Theta)) + \tan(\Theta)) / 0.9 = 3.64 \text{ N/mm}^2$$
$$V_{Ed1} = V_{Ed} - \frac{q_d * w}{2} = 113.5 - \frac{45.38 * 0.25}{2} = 107.83 \text{ kN}$$
$$v_{Ed1} = \frac{V_{Ed1}}{0.9 * b * d} = \frac{107830}{0.9 * 250.0 * 350.0} = 1.37 \text{ N/mm}^2$$
$$\frac{v_{Ed1}}{v_{Rd}} = 0.38 \leq 1$$

$V_{Ed2} = V_{Ed1} - q_d * d = 107.83 - 45.38 * 0.35 = 91.95 \text{ kN}$

$$v_{Ed2} = \frac{V_{Ed2}}{0.9 * b * d} = \frac{91950}{0.9 * 250.0 * 350.0} = 1.17 \text{ N/mm}^2$$

Reinforcement

$$\text{requ. } A_{[sw/s]} = \frac{0.4 * v_{Ed2} * b * 10^3}{0.87 * f_{yk}} = \frac{0.4 * 1.17 * 250.0 * 10^3}{0.87 * 500.0} = 268.97 \text{ mm}^2/\text{m}$$
$$\text{min. } A_{[sw/s]} = \frac{0.08 * \sqrt{f_{ck}} * b * 10^3}{f_{yk}} = \frac{0.08 * \sqrt{30.0} * 250.0 * 10^3}{500.0} = 219.09 \text{ mm}^2/\text{m}$$
$$A_{[sw/s]} = \text{MAX}(\text{requ. } A_{[sw/s]}; \text{min. } A_{[sw/s]}) = 268.97 \text{ mm}^2/\text{m}$$

Max. link spacing  $e = 0.75 * d = 262.50 \text{ mm}$

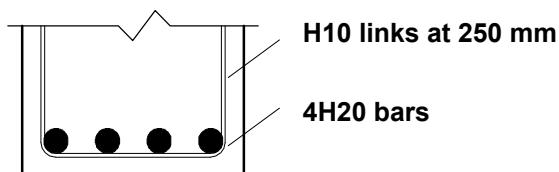
Diameter  $D = d_{\text{link}} = 10.00 \text{ mm}$

Legs per link  $n = 2$

Link  $L = \text{H10 at 250}$

$$a_{s, \text{prov}} = 628.0 \text{ mm}^2/\text{m}$$

### Reinforcement details

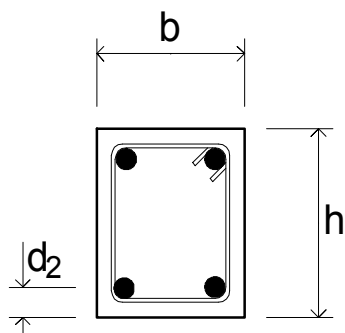






## Chapter 2: Columns

### Column with axial load (simplified)



#### Data given

Axial load $N_{Ed}$ =	1200.00 kN
Clear high $l$ =	2.80 m
$b$ =	250.00 mm
$h$ =	300.00 mm

#### Material properties

Concrete grade C	=	C30/37
$f_{ck}$	=	30.0 N/mm <sup>2</sup>
$f_{yk}$	=	500.0 N/mm <sup>2</sup>

#### Effective height factor

Condition at top =	1
Condition at bottom =	1
Height factor $f$	= 0.75
Effective height $l_0 = f * l$	= 2100.0 mm

#### Limiting $l_0/b$ ratio

$$i = 0.289 * b = 0.289 * 250.00 = 72.25 \text{ mm}$$

$$\lambda = \frac{l_0}{i} = \frac{2100.0}{72.25} = 29.07$$

$$ABC = 0.7 * 1.1 * 1.7 = 1.31$$

$$n = \frac{N_{Ed}}{0.67 * b * h * f_{ck}} = \frac{1200000}{0.67 * 250.00 * 300.00 * 30.0} = 0.80$$

$$\lambda_{lim} = \frac{20 * ABC}{\sqrt{n}} = \frac{20 * 1.31}{\sqrt{0.80}} = 29.29$$

$$\frac{\lambda}{\lambda_{lim}} = \frac{29.07}{29.29} = 0.99 \leq 1$$

The column is not slender



### Reinforcement

$$v = \frac{N_{Ed}}{b * h * f_{ck}} = \frac{1200000}{250.00 * 300.00 * 30.0} = 0.53$$

$$\omega = 0.1360$$

$$A_s = \omega * b * h * \frac{f_{ck}}{f_{yk}} = 0.1360 * 250.00 * 300.00 * \frac{30.0}{500.0} = 612 \text{ mm}^2$$

### Reinforcing bars

$$\text{Diameter } d_s = 16 \text{ mm}$$

$$\text{Group} = \mathbf{4H16}$$

### Limits of longitudinal reinforcement

$$A_{s,min1} = \frac{0.12 * N_{Ed}}{f_{yk}} = \frac{0.12 * 1200000}{500.0} = 288.0 \text{ mm}^2$$

$$A_{s,min2} = 0.002 * b * h = 0.002 * 250.00 * 300.00 = 150.0 \text{ mm}^2$$

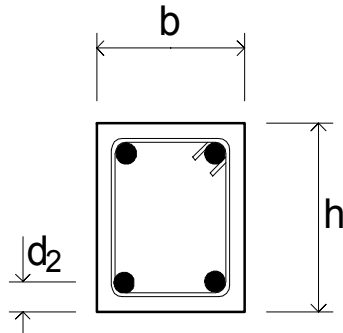
$$A_{s,min} = \text{MAX}( A_{s,min1} ; A_{s,min2} ) = 288.0 \text{ mm}^2$$

$$A_{s,prov} = 804.0 \text{ mm}^2$$

$$\frac{A_{s,min}}{A_{s,prov}} = \frac{288.0}{804.0} = \mathbf{0.36 \leq 1}$$



### Column with axial load



#### Data given

Axial load $N_{Ed}$ =	1000.00 kN
Clear high $l$ =	3.00 m
$b$ =	250.00 mm
$h$ =	300.00 mm
$d_2$ =	$30 + 8 + 12/2 = 44.00$ mm

#### Material properties

Concrete grade C	=	C30/37
$f_{ck}$	=	30.0 N/mm <sup>2</sup>
$f_{yk}$	=	500.0 N/mm <sup>2</sup>

#### Effective height factor

Condition at top =	1	
Condition at bottom =	1	
Height factor $f$	=	0.75
Effective height $l_0 = f \cdot l = 0.75 \cdot 3000$	=	2250.0 mm

#### Limiting $l_0/b$ ratio

$$i = 0.289 \cdot b = 0.289 \cdot 250.00 = 72.25 \text{ mm}$$

$$\lambda = \frac{l_0}{i} = \frac{2250.0}{72.25} = 31.14$$

$$ABC = 0.7 \cdot 1.1 \cdot 1.7 = 1.31$$

$$n = \frac{N_{Ed}}{0.67 \cdot b \cdot h \cdot f_{ck}} = \frac{1000000}{0.67 \cdot 250.00 \cdot 300.00 \cdot 30.0} = 0.66$$

$$\lambda_{lim} = \frac{20 \cdot ABC}{\sqrt{n}} = \frac{20 \cdot 1.31}{\sqrt{0.66}} = 32.25$$

$$\frac{\lambda}{\lambda_{lim}} = \frac{31.14}{32.25} = 0.97 \leq 1$$

The column is not slender



### Eccentricity

$$e_1 = \frac{h}{30} = \frac{300.00}{30} = 10.0 \text{ mm}$$

$$e_2 = \frac{l_0}{400} = \frac{2250.0}{400} = 5.6 \text{ mm}$$

$$e_3 = 20.0 \text{ mm}$$

$$e_{\text{nom}} = \text{MAX}(e_1; e_2; e_3) = 20.0 \text{ mm}$$

Additional bending Moment

$$M = N_{\text{Ed}} * e_{\text{nom}} = 1000.00 * 0.02 = 20.0 \text{ kNm}$$

### Reinforcement

$$v = \frac{N_{\text{Ed}}}{b * h * f_{\text{ck}}} = \frac{1000000}{250.00 * 300.00 * 30.0} = 0.444$$

$$\mu = \frac{M}{b * h^2 * f_{\text{ck}}} = \frac{20000000}{250.00 * 300.00^2 * 30.0} = 0.030$$

$$d_2 / h = 0.15$$

From the chart  $\omega = 0.08$

$$A_s = \omega * b * h * \frac{f_{\text{ck}}}{f_{\text{yk}}} = 0.08 * 250.00 * 300.00 * \frac{30.0}{500.0} = 360 \text{ mm}^2$$

### Reinforcing bars

Diameter  $d_s = 12 \text{ mm}$

Group = **4H12**

### Limits of longitudinal reinforcement

$$A_{s,\text{min}1} = \frac{0.12 * N_{\text{Ed}}}{f_{\text{yk}}} = \frac{0.12 * 1000000}{500.0} = 240.0 \text{ mm}^2$$

$$A_{s,\text{min}2} = 0.002 * b * h = 0.002 * 250.00 * 300.00 = 150.0 \text{ mm}^2$$

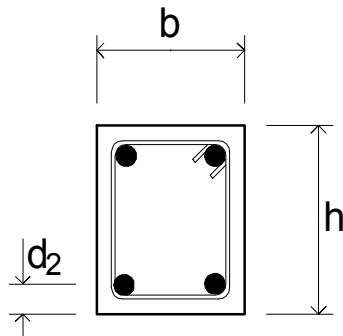
$$A_{s,\text{min}} = \text{MAX}(A_{s,\text{min}1}; A_{s,\text{min}2}) = 240.0 \text{ mm}^2$$

$$A_{s,\text{prov}} = 452.0 \text{ mm}^2$$

$$\frac{A_{s,\text{min}}}{A_{s,\text{prov}}} = \frac{240.0}{452.0} = 0.53 \leq 1$$



### Column with axial load and bending moment



#### Data given

Axial load $N_{Ed}$ =	1000.00 kN
Bending moment $M_{Ed}$ =	200.0 kNm
Clear high $l$ =	3.00 m
$b$ =	300.00 mm
$h$ =	400.00 mm
$d_2$ =	$30 + 8 + 25/2 = 50.50$ mm

#### Material properties

Concrete grade C	=	C30/37
$f_{ck}$	=	30.0 N/mm <sup>2</sup>
$f_{yk}$	=	500.0 N/mm <sup>2</sup>

#### Effective height factor

Condition at top =	1
Condition at bottom =	1
Height factor $f$	= 0.75
Effective height $l_0 = f \cdot l = 0.75 \cdot 3000$	= 2250.0 mm

#### Limiting $l_0/b$ ratio

$i$ =	$0.289 \cdot b = 0.289 \cdot 300.00$	=	86.70 mm
$\lambda$ =	$\frac{l_0}{i} = \frac{2250.0}{86.70}$	=	25.95
ABC =	$0.7 \cdot 1.1 \cdot 1.7$	=	1.31
$n$ =	$\frac{N_{Ed}}{0.67 \cdot b \cdot h \cdot f_{ck}} = \frac{1000000}{0.67 \cdot 300.00 \cdot 400.00 \cdot 30.0}$	=	0.41
$\lambda_{lim}$ =	$\frac{20 \cdot ABC}{\sqrt{n}} = \frac{20 \cdot 1.31}{\sqrt{0.41}}$	=	40.92
$\frac{\lambda}{\lambda_{lim}} = \frac{25.95}{40.92}$	=	<b>0.63 ≤ 1</b>	

The column is not slender



### Eccentricity

$$e_1 = \frac{h}{30} = \frac{400.00}{30} = 13.3 \text{ mm}$$

$$e_2 = \frac{l_0}{400} = \frac{2250.0}{400} = 5.6 \text{ mm}$$

$$e_3 = 20.0 \text{ mm}$$

$$e_{\text{nom}} = \text{MAX}(e_1; e_2; e_3) = 20.0 \text{ mm}$$

Additional bending Moment

$$M = M_{\text{Ed}} + N_{\text{Ed}} * e_{\text{nom}} = 200.0 + 1000.00 * 0.02 = 220.00 \text{ kNm}$$

### Reinforcement

$$v = \frac{N_{\text{Ed}}}{b * h * f_{\text{ck}}} = \frac{1000000}{300.00 * 400.00 * 30.0} = 0.278$$

$$\mu = \frac{M}{b * h^2 * f_{\text{ck}}} = \frac{220000000}{300.00 * 400.00^2 * 30.0} = 0.153$$

$$d_2 / h = 0.13$$

From the chart  $\omega = 0.27$

$$A_s = \omega * b * h * \frac{f_{\text{ck}}}{f_{\text{yk}}} = 0.27 * 300.00 * 400.00 * \frac{30.0}{500.0} = 1944 \text{ mm}^2$$

### Reinforcing bars

Diameter  $d_s = 25 \text{ mm}$

Group = **4H25**

### Limits of longitudinal reinforcement

$$A_{s,\text{min}1} = \frac{0.12 * N_{\text{Ed}}}{f_{\text{yk}}} = \frac{0.12 * 1000000}{500.0} = 240.0 \text{ mm}^2$$

$$A_{s,\text{min}2} = 0.002 * b * h = 0.002 * 300.00 * 400.00 = 240.0 \text{ mm}^2$$

$$A_{s,\text{min}} = \text{MAX}(A_{s,\text{min}1}; A_{s,\text{min}2}) = 240.0 \text{ mm}^2$$

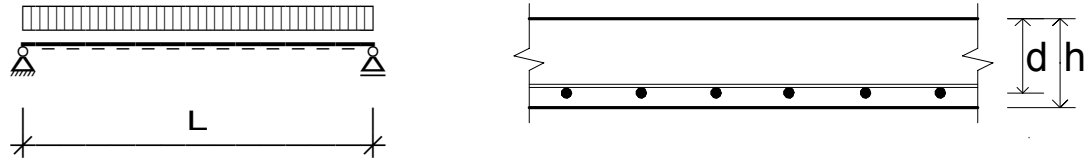
$$A_{s,\text{prov}} = 1963.0 \text{ mm}^2$$

$$\frac{A_{s,\text{min}}}{A_{s,\text{prov}}} = \frac{240.0}{1963.0} = 0.12 \leq 1$$



## Chapter 3: Slabs

### Design of a solid slab



#### Data given

Beam span  $L = 5.00$  m

Overall depth  $h = 200.0$  mm  
 With of support  $w = 300.0$  mm

#### Loading

Imposed load  $Q_k = 2.50$  kN/m<sup>2</sup>

Finishes  $g_k = 0.50$  kN/m<sup>2</sup>

Slab self weight  $g_b = h \cdot 25 = 0.2 \cdot 25 = 5.00$  kN/m<sup>2</sup>

Total dead load  $G_k = g_b + g_k = 5.50$  kN/m<sup>2</sup>

Total load for ULS  $q = 1.35 \cdot G_k + 1.50 \cdot Q_k = 11.2$  kN/m<sup>2</sup>

Ultimate load  $F = q \cdot L = 56.0$  kN

#### Material properties

Concrete grade  $C = C25/30$

$f_{ck} = 25.0$  N/mm<sup>2</sup>

$f_{yk} = 500.0$  N/mm<sup>2</sup>

#### Cover to bars

Assumed diameter  $d_s = 10$  mm

Exposure class  
 Exp.Class = XC1

Resistance to fire  
 Fire resistance  $R = R60$

Minimum concrete covers [mm]  
 $\text{min.c} = \text{MAX}(\text{nom.c}; c_{\text{fire}}) = 25$  mm

**Provided  $c = 25$  mm**

Axis distance to reinforcement / Effective depth  
 $a_{\text{prov}} = c + d_s / 2 = 30$  mm

Effektiv depth  $d = h - a_{\text{prov}} = 170.0$  mm

#### Bending ULS

$M = F \cdot \frac{L}{8} = 35.0$  kNm

$K = \text{MIN}\left(\frac{M}{b \cdot d^2 \cdot f_{ck}}; 0.167\right) = 0.048$

$f_{[z/d]} = \text{MIN}\left(0.5 \cdot \left(1 + \sqrt{1 - 3.53 \cdot K}\right); 0.95\right) = 0.950$

$z = d \cdot f_{[z/d]} = 161.5$  mm



$$A_{s,req} = \frac{M}{0.87 * z * f_{yk}} = 498.2 \text{ mm}^2$$
$$\text{min. } A_s = b * h * 0.016 / 100 * f_{ck}^{2/3} = 273.6 \text{ mm}^2$$
$$\text{Steel stress } f_s = 435 * \frac{G_k + 0.80 * Q_k}{1.35 * G_k + 1.5 * Q_k} = 291.9 \text{ N/mm}^2$$

Provide diameter  $d_s = 8 \text{ mm}$

Reinf = **H8 at 100**

$$A_{s,prov} = 503.0 \text{ mm}^2/\text{m}$$

### Span / Effective depth ratio calculation for deflection SLS

$$\text{Percentage of reinforcement } \rho_1 = \frac{100 * A_{s,req}}{b * d} = \frac{100 * 498.2}{1000.0 * 170.0} = 0.29 \%$$

$$\text{Basic ratio } r = 30.00$$

$$\text{Multiply factor } f = \text{MIN}\left(\frac{A_{s,prov}}{A_{s,req}}; 1.50\right) = 1.010$$

$$\text{Permitted ratio } r_{perm} = r * f = 30.30$$

$$\text{Actual ratio } r_{act} = \frac{L}{d} = \frac{5000}{170.0} = 29.41$$

$$\frac{r_{act}}{r_{perm}} = 0.97 \leq 1$$

### Shear ULS

$$k = \text{MIN}(1 + \sqrt{(200/d)}; 2.0) = 2.00$$

$$V_{Rd} = 0.12 * k * (\rho_1 * f_{ck})^{1/3} * (f_{ck}/25)^{1/3} = 0.46 \text{ N/mm}^2$$

$$V_{Ed1} = V_{Ed} - \frac{q_d * w}{2} = 28.0 - \frac{11.20 * 0.3}{2} = 26.32 \text{ kN}$$

$$V_{Ed1} = \frac{V_{Ed1}}{0.9 * b * d} = \frac{26320}{0.9 * 1000.0 * 170.0} = 0.17 \text{ N/mm}^2$$

$$\frac{V_{Ed1}}{V_{Rd}} = 0.37 \leq 1$$

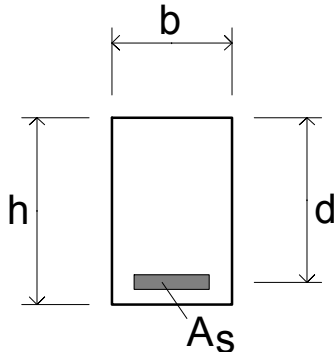
Slab does not require shear reinforcement





## Chapter 4: Reinforcement

### Bending reinforcement



#### Data given

Beam width $b =$	300.0 mm
Overall depth $h =$	500.0 mm
Effective depth $d =$	450.0 mm
Required Moment $M =$	200.0 kNm

#### Material properties

Concrete grade C	=	C30/37
$f_{ck}$	=	30.0 N/mm <sup>2</sup>
$f_{yk}$	=	500.0 N/mm <sup>2</sup>

#### Bending reinforcement calculation

$K =$	$\text{MIN}\left(\frac{M}{b \cdot d^2 \cdot f_{ck}}; 0.167\right)$	=	0.110
$f_{[z/d]} =$	$\text{MIN}\left(0.5 \cdot \left(1 + \sqrt{1 - 3.53 \cdot K}\right); 0.95\right)$	=	0.891
$z =$	$\frac{d \cdot f_{[z/d]}}{M}$	=	400.9 mm
$A_s =$	$\frac{M}{0.87 \cdot z \cdot f_{yk}}$	=	1146.8 mm <sup>2</sup>
$\text{min.}A_s =$	$b \cdot h \cdot 0.016/100 \cdot f_{ck}^{2/3}$	=	231.7 mm <sup>2</sup>

#### Reinforcing bars

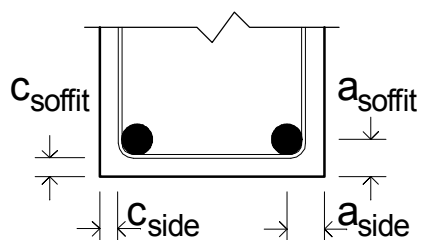
Diameter $d_s$	=	20 mm
Group	=	<b>4H20</b>

#### Maximum amount of reinforcement

$A_{s,prov}$	=	1257.0 mm <sup>2</sup>	
$A_{s,max} =$	$\frac{A_{s,prov} \cdot 100}{b \cdot h} = \frac{1257.0 \cdot 100}{300.0 \cdot 500.0}$	=	0.84 % < 4%



### Nominal concrete cover



#### Data given

Beam width $b$ =		300.0 mm
Main bar diameter $d_{bar}$	=	32 mm
Shear link diameter $d_{link}$	=	12 mm
Concrete grade $C$	=	C30/37

#### Exposure class

Exp. Class	=	XC1
nom. $c_{side}$	=	25 mm
nom. $c_{soffit}$	=	25 mm

#### Resistance to fire

Fire resistance $R$	=	R60
min. $a_{side}$	=	25 mm
min. $a_{soffit}$	=	25 mm

#### Placing

Minimum concrete covers [mm]		
Side $c_{side}$ =	$\text{MAX}(d_{link} + 10; \text{nom. } c_{side}; c_{fire, side})$	= 25 mm
Soffit $c_{soffit}$ =	$\text{MAX}(d_{link} + 10; \text{nom. } c_{soffit}; c_{fire, soffit})$	= 25 mm

**Provided  $c$  = 30 mm**

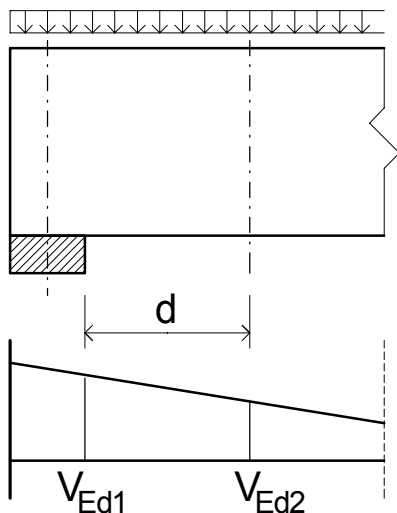
Cover to main bars  $c_{bar}$  =  $\text{MAX}(d_{bar} + 10; c + d_{link})$  = 42 mm

#### Axis distance to the main bar / Effective depth

$a_{soffit}$ =	$\text{MAX}(c_{bar} + d_{bar} / 2; \text{min. } a_{soffit})$	= 58 mm
Overall depth $h$ =		500.0 mm
Effective depth $d$ =	$h - a_{soffit}$	= <b>442.0 mm</b>



### Shear reinforcement



#### Data given

Beam width $b =$	200.0 mm
Overall depth $h =$	300.0 mm
Effective depth $d =$	252.5 mm
Width of support $w =$	150.0 mm

#### Loading

Load on beam $q_d =$	25.00 kN/m
Reaction Force $V_{Ed} =$	100.0 kN

#### Material properties

Concrete grade C	=	C30/37
$f_{ck}$	=	30.0 N/mm <sup>2</sup>
$f_{yk}$	=	500.0 N/mm <sup>2</sup>

#### Shear force

$$\begin{aligned}\theta &= 21.80^\circ \\ V_{Rd} &= 0.36 * (1 - f_{ck}/250) * f_{ck} / (1/\text{TAN}(\theta) + \text{TAN}(\theta)) / 0.9 = 3.64 \text{ N/mm}^2 \\ V_{Ed1} &= V_{Ed} - \frac{q_d * w}{2} = 100.0 - \frac{25.00 * 0.15}{2} = 98.13 \text{ kN} \\ v_{Ed1} &= \frac{V_{Ed1}}{0.9 * b * d} = \frac{98130}{0.9 * 200.0 * 252.5} = 2.16 \text{ N/mm}^2 \\ \frac{v_{Ed1}}{V_{Rd}} &= 0.59 \leq 1 \\ V_{Ed2} &= V_{Ed1} - q_d * d = 98.13 - 25.00 * 0.2525 = 91.82 \text{ kN} \\ v_{Ed2} &= \frac{V_{Ed2}}{0.9 * b * d} = \frac{91820}{0.9 * 200.0 * 252.5} = 2.02 \text{ N/mm}^2\end{aligned}$$



### Reinforcement

$$\text{requ. } A_{[sw/s]} = \frac{0.4 * v_{Ed2} * b * 10^3}{0.87 * f_{yk}} = \frac{0.4 * 2.02 * 200.0 * 10^3}{0.87 * 500.0} = 371.49 \text{ mm}^2/\text{m}$$

$$\text{min. } A_{[sw/s]} = \frac{0.08 * \sqrt{f_{ck}} * b * 10^3}{f_{yk}} = \frac{0.08 * \sqrt{30.0} * 200.0 * 10^3}{500.0} = 175.27 \text{ mm}^2/\text{m}$$

$$A_{[sw/s]} = \text{MAX}( \text{requ. } A_{[sw/s]} ; \text{min. } A_{[sw/s]} ) = 371.49 \text{ mm}^2/\text{m}$$

$$\text{Max. link spacing } e = 0.75 * d = 189.38 \text{ mm}$$

$$\text{Diameter } D = 8.00 \text{ mm}$$

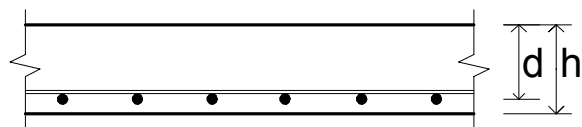
$$\text{Legs per link } n = 2$$

$$\text{Link } L = \mathbf{H8 \text{ at } 250}$$

$$a_{s,prov} = 402.0 \text{ mm}^2/\text{m}$$



### Mesh reinforcement fabrics to BS 4483



#### Data given

Overall depth h =	200.0 mm
Effective depth d =	165.0 mm
Required Moment M =	20.0 kNm/m

#### Material properties

Concrete grade C	= C30/37
$f_{ck}$	= 30.0 N/mm <sup>2</sup>
$f_{yk}$	= 500.0 N/mm <sup>2</sup>

#### Bending reinforcement calculation

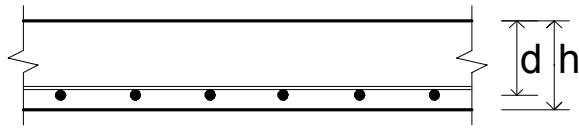
K =	$\text{MIN}\left(\frac{M}{b \cdot d^2 \cdot f_{ck}}; 0.167\right)$	= 0.024
$f_{[z/d]}$ =	$\text{MIN}\left(0.5 \cdot \left(1 + \sqrt{1 - 3.53 \cdot K}\right); 0.95\right)$	= 0.950
z =	$\frac{d \cdot f_{[z/d]}}{M}$	= 156.8 mm
$A_s$ =	$\frac{M}{0.87 \cdot z \cdot f_{yk}}$	= 293.2 mm <sup>2</sup> /m
min. $A_s$ =	$b \cdot h \cdot 0.016/100 \cdot f_{ck}^{2/3}$	= 309.0 mm <sup>2</sup> /m

#### Reinforcement with meshes

Mash type	= B
Ref	= B385
Spacing e	= 100.0 mm
Max. spacing $e_{\max} = 3 \cdot d$	= 495.0 mm
$e / e_{\max} = 0.20 \leq 1$	



### Slab reinforcement



#### Data given

Overall depth $h =$	200.0 mm
Effective depth $d =$	165.0 mm
Required Moment $M =$	30.0 kNm/m

#### Material properties

Concrete grade C	=	C20/25
$f_{ck}$	=	20.0 N/mm <sup>2</sup>
$f_{yk}$	=	500.0 N/mm <sup>2</sup>

#### Bending reinforcement calculation

$K =$	$\text{MIN}\left(\frac{M}{b \cdot d^2 \cdot f_{ck}}; 0.167\right)$	=	0.055
$f_{[z/d]} =$	$\text{MIN}\left(0.5 \cdot \left(1 + \sqrt{1 - 3.53 \cdot K}\right); 0.95\right)$	=	0.949
$z =$	$\frac{d \cdot f_{[z/d]}}{M}$	=	156.6 mm
$A_s =$	$\frac{M}{0.87 \cdot z \cdot f_{yk}}$	=	440.4 mm <sup>2</sup> /m
$\text{min. } A_s =$	$b \cdot h \cdot 0.016/100 \cdot f_{ck}^{2/3}$	=	235.8 mm <sup>2</sup> /m

#### Reinforcing

Main reinforcement

Diameter $d_s$	=	8 mm
Reinf	=	<b>H8 at 100</b>
$A_{s,prov}$	=	503.0 mm <sup>2</sup> /m
Spacing $e$	=	100.0 mm
Max. spacing $e_{max} = 3 \cdot d$	=	495.0 mm
$e / e_{max} = 0.20 \leq 1$		

Distribution reinforcement

Diameter $d_s$	=	8 mm
Reinf	=	<b>H8 at 200</b>
$A_{s,prov}$	=	251.0 mm <sup>2</sup> /m
Spacing $e$	=	200.0 mm
Max. spacing $e_{max} = 3.5 \cdot d$	=	577.5 mm
$e / e_{max} = 0.35 \leq 1$		