The RC Desktop Toolkit

BAR BRITISH ASSOCIATION OF REINFORCEMENT

The Concrete Centre™
PART OF THE MINERAL PRODUCTS ASSOCIATION

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CELSA GROUP™

CELSA STEEL UK

BS 8110 Design – Shear

Table 3 Form and area of shear reinforcements in beams

Value of v N/mm^2	Form of shear reinforcement to be provided	Area of shear reinforcement to be provided
Less than $0.5\,v_c$ throughout the beam	See NOTE 1	—
$0.5\,v_c < v < (v_c + 0.4)$	Minimum links for whole length of beam	$A_{sv} \geq 0.4\,b_v s_v / 0.87 f_{yv}$ (see NOTE 2)
$(v_c + 0.4) < v < 0.8\sqrt{f_{cu}}$ or 5 N/mm^2	Links or links combined with bent-up bars. Not more than 50% of the shear resistance provided by the steel may be in the form of bent-up bars (see NOTE 3)	Where links only provided: $A_{sv} \geq b_v s_v (v - v_c) / 0.87 f_{yv}$ Where links and bent-up bars provided: see 3.4.5.6 of BS 8110

NOTE 1 While minimum links should be provided in all beams of structural importance, it will be satisfactory to omit them in members of minor structural importance such as lintels or where the maximum design shear stress is less than half v_c.

NOTE 2 Minimum links provide a design shear resistance of 0.4 N/mm^2.

NOTE 3 See 3.4.5.5 of BS 8110 for guidance on spacing of links and bent-up bars.

Based on Table 3.7 of BS 8110

Table 4 Values of v_c design concrete shear stress

$\frac{100A_s}{b_v d}$	Effective depth mm							
	125 N/mm^2	150 N/mm^2	175 N/mm^2	200 N/mm^2	225 N/mm^2	250 N/mm^2	300 N/mm^2	400 N/mm^2
≤ 0.15	0.45	0.43	0.41	0.40	0.39	0.38	0.36	0.34
0.25	0.53	0.51	0.49	0.47	0.46	0.45	0.43	0.40
0.50	0.67	0.64	0.62	0.60	0.58	0.56	0.54	0.50
0.75	0.77	0.73	0.71	0.68	0.66	0.65	0.62	0.57
1.00	0.84	0.81	0.78	0.75	0.73	0.71	0.68	0.63
1.50	0.97	0.92	0.89	0.86	0.83	0.81	0.78	0.72
2.00	1.06	1.02	0.98	0.95	0.92	0.89	0.86	0.80
≥ 3.00	1.22	1.16	1.12	1.08	1.05	1.02	0.98	0.91

NOTE 1 Allowance has been made in these figures for a γm of 1.25.

NOTE 2 For characteristic concrete strength greater than 25 N/mm^2, the values in this table may be multiplied by $(f_{cu}/25)^{1/3}$, the value of f_{cu} should not be taken as greater than 40.

Based on Table 3.8 of BS 8110

BS 8110 Design – Flexure

Procedure for determining flexural reinforcement

Carry out analysis of beam to determine design moments (M) (see Table 1)

Concrete class ≤ C50/60?

No → Outside scope of this guide

Yes → Determine K from $K = \frac{M}{bd^2 f_{cu}}$

$K' = 0.156$ where redistribution ≤10%
$K' = 0.402\,(\beta_b - 0.4) - 0.18\,(\beta_b - 0.4)^2$ where redistribution >10%

is $K \leq K'$?

No → Compression reinforcement required

Calculate lever arm z from $z = d\left\{0.5 + \sqrt{0.25 - \frac{K'}{0.9}}\right\}$

Calculate compression reinforcement required from $A_{s'} = (K-K') f_{cu} bd^2 / 0.87 f_y (d-d')$

Calculate tension reinforcement required from $A_{s'} = (K' f_{cu} bd^2 / 0.87 f_y z) + As'$

Yes → No compression reinforcement required

Obtain lever arm z from Table 2 or use $z = d\left\{0.5 + \sqrt{0.25 - \frac{K}{0.9}}\right\} \leq 0.95d$

Calculate tension reinforcement required from $A_s = \frac{M}{0.87\, f_y\, z}$

Check minimum reinforcement requirements

Check maximum reinforcement requirements $A_{s,max} = 0.04\, A_c$ for tension or compression reinforcement outside lap locations

Design complete

Table 1 Design ultimate bending moments and shear forces for beams

	At outer support	Near middle of end span	At first interior support	At middle of interior spans	At interior supports
Moment	0	$0.09Fl$	$-0.11Fl$	$0.07Fl$	$-0.08Fl$
Shear	$0.45F$	—	$0.6F$	—	$0.55F$

NOTE
l is the effective span;
F is the total design ultimate load ($1.4G_k + 1.6Q_k$).
No redistribution of the moments calculated from this table should be made.

Characteristic imposed load Qk may not exceed characteristic dead load Gk;
Loads should be substantially uniformaly distributed over three or more spans;
Variations in span length should not exceed 15% of longest.

To be used for BS8110 design only. For EC2 design, please refer to Table 1 on page 6.

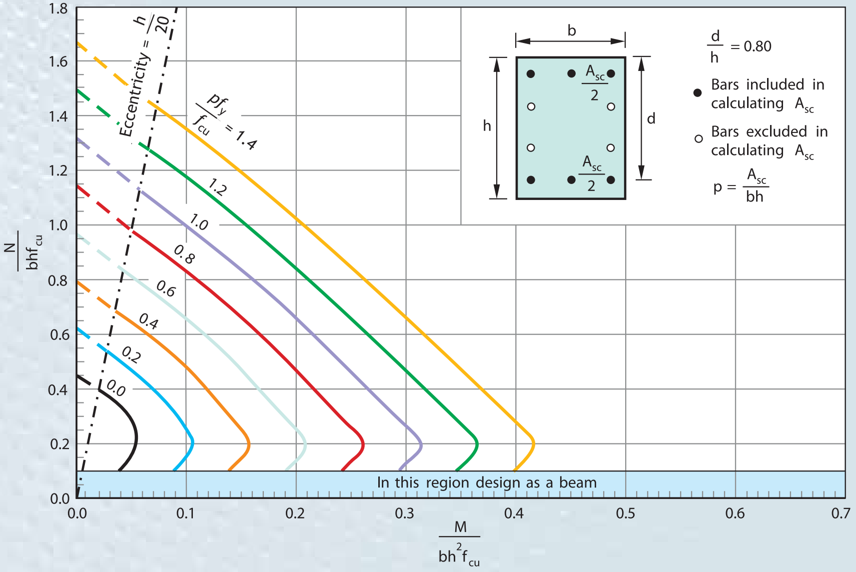
Based on Table 3.5 of BS 8110

Table 2 z/d for singly reinforced rectangular sections

K	z/d	K	z/d
0.05	0.94	0.11	0.86
0.06	0.93	0.12	0.84
0.07	0.91	0.13	0.82
0.08	0.90	0.14	0.81
0.09	0.89	0.15	0.79
0.10	0.87	0.156	0.78

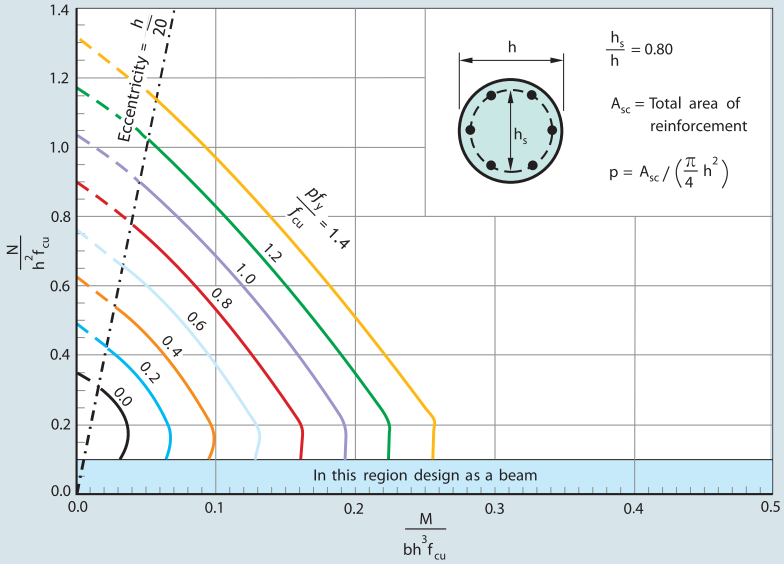
BS 8110 Design – Axial

Column design chart for rectangular column *d/h* = 0.80



Based on figures C.4d and C.5b of "Concrete Buildings Scheme Design Manual."

Column design chart for circular column h_s/h = 0.8



BS 8110 Design – Deflection

Table 5 Modification factor for tension reinforcement

Service stress	M/bd^2								
	0.50	**0.75**	**1.00**	**1.50**	**2.00**	**3.00**	**4.00**	**5.00**	**6.00**
100	2.00	2.00	2.00	1.86	1.63	1.36	1.19	1.08	1.01
150	2.00	2.00	1.98	1.69	1.49	1.25	1.11	1.01	0.94
(f_y = 250) 167	2.00	2.00	1.91	1.63	1.44	1.21	1.08	0.99	0.92
200	2.00	1.95	1.76	1.51	1.35	1.14	1.02	0.94	0.88
250	1.90	1.70	1.55	1.34	1.20	1.04	0.94	0.87	0.82
300	1.60	1.44	1.33	1.16	1.06	0.93	0.85	0.80	0.76
(f_y = 500) 333	1.41	1.28	1.18	1.05	0.96	0.86	0.79	0.75	0.72

NOTE 1 The values in the table derive from the equation:

$$\text{Modification factor} = 0.55 + \frac{(477 - f_s)}{120\left(0.9 + \dfrac{M}{bd^2}\right)} \leq 2.0$$

where

M is the design ultimate moment at the centre of the span or, for a cantilever, at the support.

NOTE 2 The design service stress in the tension reinforcement in a member may be estimated from the equation:

$$f_s = \frac{2 f_y A_{s\,req}}{3 A_{s\,prov}} \times \frac{1}{\beta_b}$$

NOTE 3 For a continuous beam, if the percentage of redistribution is not known but the design ultimate moment at mid-span is obviously the same as or greater than the elastic ultimate moment, the stress f_s in this table may be taken as $2/3 f_y$.

Based on Table 3.10 of BS 8110

Table 6 Modification factor for compression reinforcement

$100 \dfrac{A'_{s\,prov}}{bd}$	Factor
0.00	1.00
0.15	1.05
0.25	1.08
0.35	1.10
0.50	1.14
0.75	1.20
1.0	1.25
1.5	1.33
2.0	1.40
2.5	1.45
≥3.0	1.50

NOTE 1 The area of compression reinforcement A used in this table may include all bars in the compression zone, even those not effectively tied with links.

Based on Table 3.11 of BS 8110

Table 7 Basic span/effective depth ratio for rectangular or flanged beams

Support conditions	Rectangular section	Flanged beams with $\frac{b_w}{b} \leq 0.3$
Cantilever	7	5.6
Simply supported	20	16.0
Continuous	26	20.8

NOTE 1 For spans exceeding 10m, Table 7 should be used only if it is not necessary to limit the increase in deflection after the construction of partitions and finishes. Where limitation is necessary, the values in Table 7 should be multiplied by 10/span except for cantilevers where the design should be justified by calculation.

Based on Table 3.9 of BS 8110

EC2 Design – Flexure

Table 2	*z/d* for singly reinforced rectangular sections		
K	*z/d*	K	*z/d*
0.01	0.950a	0.11	0.891
0.02	0.950a	0.12	0.880
0.03	0.950a	0.13	0.868
0.04	0.950a	0.14	0.856
0.05	0.950a	0.15	0.843
0.06	0.944	0.16	0.830
0.07	0.934	0.17	0.816
0.08	0.924	0.18	0.802
0.09	0.913	0.19	0.787
0.10	0.902	0.20	0.771

KEY

a Limiting *z* to 0.95*d* is not a requirement of Eurocode 2, but is considered to be good practice.

EC2 Design – Shear

Procedure for determining vertical shear reinforcement

Determine v_{Ed} where:
v_{Ed} = design shear stress $[v_{Ed} = V_{Ed}/(b_w z) = V_{Ed}/(0.9\, b_w d)]$

Determine the concrete stut capacity $v_{Rd,\,max\,\cot\theta = 2.5?}$ from Table 3

Is $v_{Ed} < v_{Rd,\,max\,\cot\theta = 2.5?}$

- **Yes** → $(\cot\theta = 2.5)$ → Calculate area of shear reinforcement
- **No** → Is $v_{Ed} < v_{Rd,\,max\,\cot\theta = 1.0?}$ (see Table 3)
  - **No** → Redesign section
  - **Yes** → Determine θ from:

$$\theta = 0.5 \sin^{-1}\left[\frac{v_{Ed}}{0.20\, f_{ck}\,(1 - f_{ck}/250)}\right]$$

Calculate area of shear reinforcement

$$\frac{A_{sw}}{s} = \frac{v_{Ed}\, b_w}{f_{ywd} \cot\theta}$$

Check maximum spacing for vertical shear reinforcement:
$s_{l,\,max} = 0.75d$

Table 3	Minimum and maximum concrete strut capacity in terms of stress	
f_{ck}	$v_{Rd,\,max\,\cot\theta = 2.5}$	$v_{Rd,\,max\,\cot\theta = 1.0}$
20	2.54	3.68
25	3.10	4.50
28	3.43	4.97
30	3.64	5.28
32	3.84	5.58
35	4.15	6.02
40	4.63	6.72
45	5.08	7.38
50	5.51	8.00

Based on guidance in "How to Design Concrete Structures Using Eurocode 2" by The Concrete Centre.

EC2 Design – Flexure

Procedure for determining flexural reinforcement

Carry out analysis of beam to determine design moments (M) (see Table 1)

Concrete class ≤ C50/60?

No → Outside scope of this guide

Yes ↓

Determine K from $K = \frac{M}{bd^2 f_{ck}}$

Determine K' from $K' = 0.60\delta - 0.18\delta^2 - 0.21$ where $\delta \leq 1.0$

is $K \leq K'$?

No → Compression reinforcement required

Calculate lever arm z from $z = \frac{d}{2}\left\{1 + \sqrt{1 - 3.53\,K'}\right\}$

Calculate compression reinforcement required from $A_s' = \frac{(K-K')f_{ck}bd^2}{f_{sc}(d-d_2)}$

where

$f_{sc} = \frac{700\,[x_u - d_2]}{x_u} \leq f_{yd}$ & $x_u = (\delta - 0.4)d$

Calculate tension reinforcement required from $A_s = \frac{K' f_{ck} bd^2}{f_{yd} z} + \frac{A_s' f_{sc}}{f_{yd}}$

Yes → No compression reinforcement required

Obtain lever arm z from Table 2 or $z = \frac{d}{2}\left\{1 + \sqrt{1 - 3.53K}\right\} \leq 0.95d$

Calculate tension reinforcement required from $A_s = \frac{M}{f_{yd} z}$

Check minimum reinforcement requirements $A_{s,\,min} = \frac{0.26\,f_{ctm}\,b_t d}{f_{yk}}$ where $f_{ck} \geq 25$

Check maximum reinforcement requirements $A_{s,max} = 0.04\,A_C$ for tension or compression reinforcement outside lap locations

Design complete

Table 1 Bending moment and shear coefficients for beams

	Moment	Shear
Outer support	25% of span moment	0.45 (G + Q)
Near middle of end span	0.090 Gl + 0.100 Ql	
At first interior support	– 0.094 (G + Q) l	0.63 (G + Q)[a]
At middle of interior spans	0.066 Gl + 0.086 Ql	
At interior supports	– 0.075 (G + Q) l	0.50 (G + Q)

KEY

a 0.55 (G + Q) may be used adjacent to the interior span.

NOTES

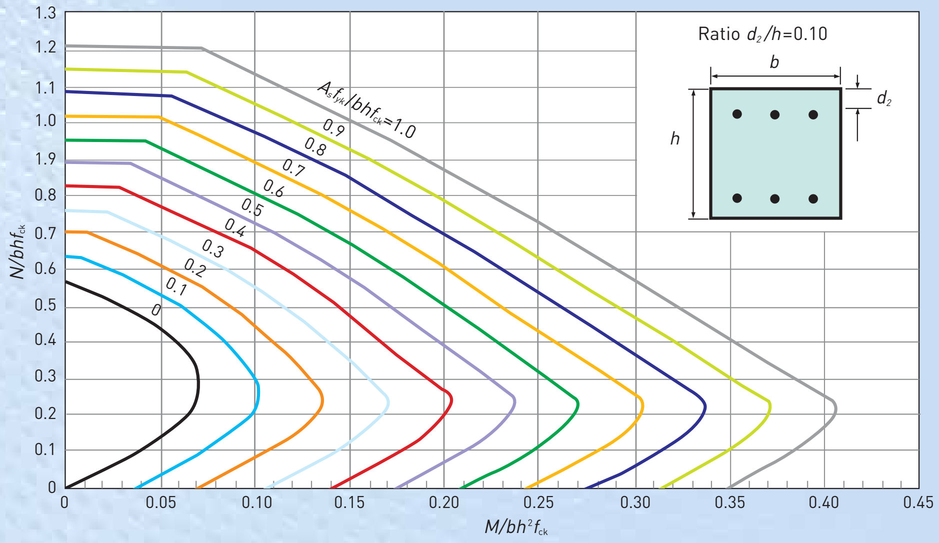
1 Redistribution of support moments by 15% has been included.
2 Applicable to 3 or more spans only and where $Q_k \geq G_k$.
3 Minimum span ≥ 0.85 longest span.
4 l is the span, G is the total of the ULS permanent actions, Q is the total of the ULS variable actions.

Based on guidance in "How to Design Concrete Structures Using Eurocode 2" by The Concrete Centre.

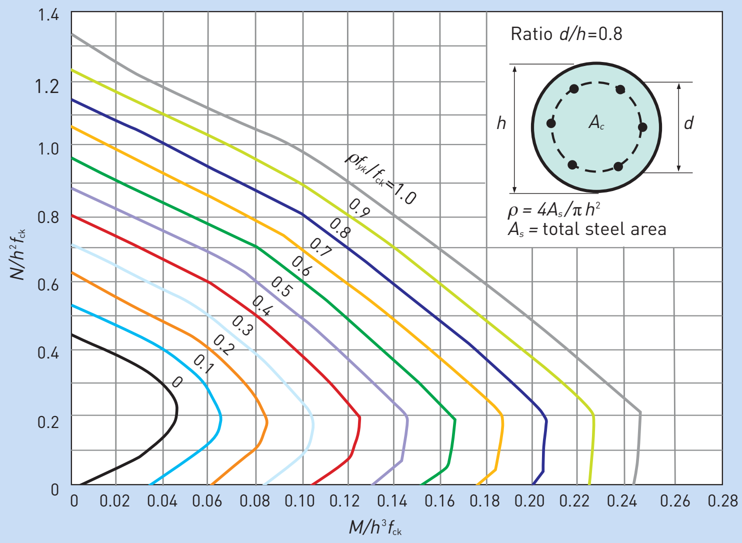
eurocode 2

EC2 Design – Axial

Column design chart 1



Column design chart 2



Further column charts can be found at www.eurocode2.info

eurocode2

EC2 Design – Deflection

Procedure for assessing deflection

Determine basic l/d and k from Figure 1

▼

Determine Factor 1 (F1)
For Flanged sections
$F1 = 1 - 0.1\ ((b_f/b_w) - 1) \geq 0.8$†
(b_f is flange breadth and b_w is rib breadth)
Otherwise F1 = 1.0

▼

Determine Factor 2 (F2)
Where the slab span exceeds 7m and it supports brittle partitions,
$F2 = 7/l_{eff} \leq 1.0$
Otherwise F2 = 1.0

►

Determine Factor 3 (F3)
$F3 = 310/\sigma_s$
Where σ_s = Stress in reinforcement at serviceability limit state σ_s may assumed to be 310 MPa (i.e. F3 = 1.0)
where $A_{s,\,prov} = A_{s,\,req'd}$
Note: $A_{s,\,prov} \leq 1.5\ A_{s,\,req'd}$
(UK National Annex)

▲

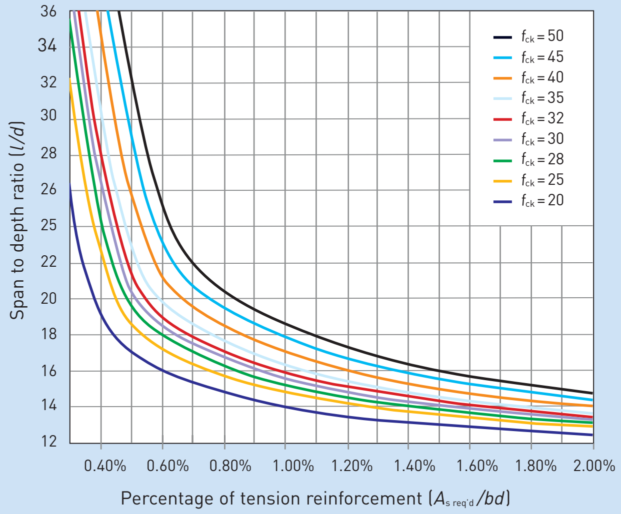
Is basic l/d x K x F1 x F2 x F3 ≤ Actual l/d?

Yes ▲ **Check complete**

No → Increase $A_{s,\,prov}$ or f_{ck} ◄ (back to Determine Factor 3)

† The Eurocode is ambiguous regarding linear interpolation. It is understood that it was the intention of the drafting committee that linear interpolation be used and this is in line with current UK practice.

Figure 1 Basic span-to-effective-depth ratios



NOTES

1 This graph assumes simply supported span condition (K = 1.0)
K = 1.5 for interior span condition
K = 1.3 for end span condition
K = 1.2 for flat slabs
K = 0.4 for cantilevers

2 Compression reinforcement, ρ', has been taken as 0.

3 Curves based on the following expressions:

$$\frac{l}{d} = K\left[11 + \frac{1.5\sqrt{f_{ck}}\,\rho_0}{\rho} + 3.2\sqrt{f_{ck}}\left(\frac{\rho_0}{\rho} - 1\right)^{1.5}\right]$$

where $\rho \leq \rho_0$

$$\frac{l}{d} = K\left[11 + \frac{1.5\sqrt{f_{ck}}\,\rho_0}{(\rho - \rho')} + \frac{\sqrt{f_{ck}}}{12}\sqrt{\frac{\rho}{\rho_0}}\right]$$

where $\rho > \rho_0$

Based on guidance in "How to Design Concrete Structures Using Eurocode 2" by The Concrete Centre.

Rebar Tables BS 8666:2005 User Guide

Notation of steel reinforcement

Type of steel reinforcement	Notation
For diameters ≤ 12mm, Grade B500A, Grade B500B or Grade B500C conforming to BS 4449:2005 For diameters > 12mm, Grade B500B or Grade B500C conforming to BS 4449:2005	H
Grade B500A conforming to BS 4449:2005	A
Grade B500B or Grade B500C conforming to BS 4449:2005	B
Grade B500C conforming to BS 4449:2005	C
A specified grade and type of ribbed stainless steel conforming to BS 6744:2001	S
Reinforcement of a type not included in the above list having material properties that are defined in the design or contract specification	X

NOTE: In the Grade description B500A, etc., "B" indicates reinforcing steel.

BS5400 Ultimate anchorage bond lengths and lap lengths as a multiple bar size (for grade 500, type 2 deformed bars)

Condition	Tension for Values of f_{cu} (N/mm^2)				Compression for Values of f_{cu} (N/mm^2)			
	20	25	30	≥ 40	20	25	30	≥ 40
Anchorage length	50	44	39	33	41	35	31	27
Lap length (α_1=1.0)	50	44	39	33	41	35	31	27
Lap length (α_1=1.4)	70	62	55	47	57	49	44	37
Lap length (α_1=2.0)	100	88	78	66	81	70	62	53

NOTE: 1. ∝ = 1.0 for lapped bars in the corner of a section where the cover to both faces is at least 2ϕ and, for sets of bars in the same layer, the gaps between the sets are at least 150mm.
2. ∝ = 2.0 if either or both of the conditions above are not satisfied and the bars are at the top of a section as cast.
3. ∝ = 1.4 for all other conditions.

Sectional areas per metre width for various bar spacings (mm^2/m)

Bar Size (mm)	Number of Bars									
	1	2	3	4	5	6	7	8	9	10
6*	28.3	56.6	84.9	113	142	170	198	226	255	283
8	50.3	101	151	201	252	302	352	402	453	503
10	78.5	157	236	314	393	471	550	628	707	785
12	113	226	339	452	566	679	792	905	1020	1130
16	201	402	603	804	1010	1210	1410	1610	1810	2010
20	314	628	943	1260	1570	1890	2200	2510	2830	3140
25	491	982	1470	1960	2450	2950	3440	3930	4420	4910
32	804	1610	2410	3220	4020	4830	5630	6430	7240	8040
40	1260	2510	3770	5030	6280	7540	8800	10100	11300	12600
50	1960	3930	5890	7850	9820	11800	13700	15700	17700	19600

Sectional areas of groups of bars (mm^2)

Bar Size (mm)	Spacing of Bars									
	75	100	125	150	175	200	225	250	275	300
6*	377	283	226	189	162	142	126	113	103	94.3
8	671	503	402	335	287	252	224	201	183	168
10	1050	785	628	523	449	393	349	314	285	262
12	1510	1130	905	754	646	566	503	452	411	377
16	2680	2010	1610	1340	1150	1010	894	804	731	670
20	4190	3140	2510	2090	1800	1570	1400	1260	1140	1050
25	6550	4910	3930	3270	2810	2450	2180	1960	1790	1640
32	10700	8040	6430	5360	4600	4020	3570	3220	2920	2680
40	16800	12600	10100	8380	7180	6280	5580	5030	4570	4190
50	26200	19600	15700	13100	11200	9820	8730	7850	7140	6540

NOTE: The above Tables have been calculated to three significant figures according to the B.S.I. recommendations.
* Denotes non-preferred sizes.