Detailing

Lecture 9

16th November 2017

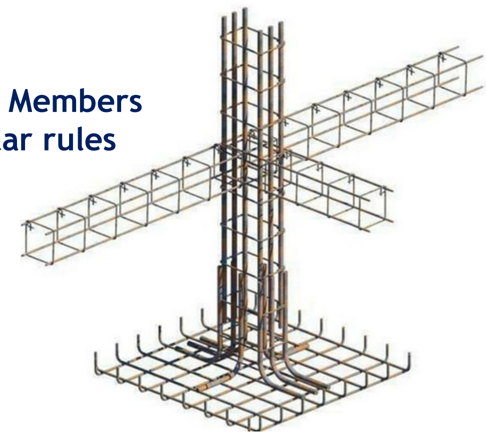
Reinforced Concrete Detailing to Eurocode 2

EC2 Section 8 - Detailing of Reinforcement - General Rules

Bar spacing, Minimum bend diameter
Anchorage of reinforcement
Lapping of bars
Large bars, bundled bars

EC2 Section 9 - Detailing of Members and Particular rules

Beams
Solid slabs
Flat slabs
Columns
Walls
Deep beams
Foundations
Discontinuity regions
Tying Systems

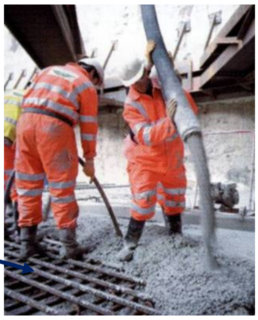


Section 8 - General Rules
Spacing of bars

EC2: Cl. 8.2 Concise: 11.2

- Clear horizontal and vertical distance ≥ ϕ, (d_g +5mm) or 20mm
- For separate horizontal layers the bars in each layer should be located vertically above each other. There should be room to allow access for vibrators and good compaction of concrete.

Detail Min
75 mm gap



Min. Mandrel Dia. for bent bars

EC2: Cl. 8.3 Concise: 11.3

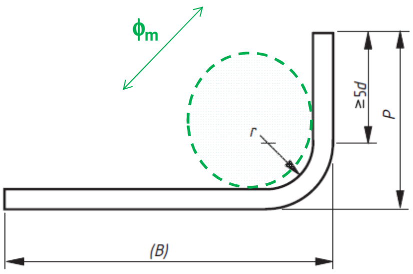
Minimum mandrel size, ϕ_m

- To avoid damage to bar is

  Bar dia ≤ 16mm Mandrel size 4 x bar diameter

  Bar dia > 16mm Mandrel size 7 x bar diameter

  The bar should extend at least 5 diameters beyond a bend



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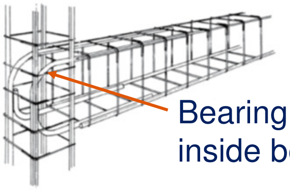
Min. Mandrel Dia. for bent bars

EC2: Cl. 8.3 Concise: 11.3

Minimum mandrel size, ϕ_m



- To avoid failure of the concrete inside the bend of the bar:

  $\phi_{m,min} \geq F_{bt} ((1/a_b) + 1/(2\ \phi)) / f_{cd}$

  F_{bt} ultimate force in a bar at the start of a bend

  a_b for a given bar is half the centre-to-centre distance between bars. For a bar adjacent to the face of the member, a_b should be taken as the cover plus ϕ /2

Mandrel size need not be checked to avoid concrete failure if :

- anchorage does not require more than 5ϕ past end of bend
- bar is not the closest to edge face and there is a cross bar $\geq\phi$ inside bend
- mandrel size is at least equal to the recommended minimum value

Anchorage of reinforcement

EC2: Cl. 8.4

Ultimate bond stress

EC2: Cl. 8.4.2 Concise: 11.5

The design value of the ultimate bond stress,

$f_{bd} = 2.25\ \eta_1 \eta_2 f_{ctd}$

where

f_{ctd} should be limited to C60/75

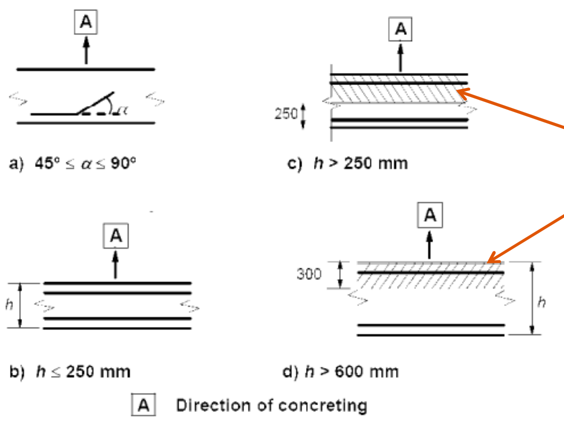
η_1 = 1 for ‘good’ and 0.7 for ‘poor’ bond conditions

η_2 = 1 for $\phi \leq 32$, otherwise $(132 - \phi)/100$

Ultimate bond stress

EC2: Cl. 8.4.2, Fig 8.2 Concise: 11.5

Good and ‘bad’ bond conditions



Top is ‘poor’
Bond condition

unhatched zone - ‘good’ bond conditions
hatched zone - ‘poor’ bond conditions

Basic required anchorage length

EC2: Cl. 8.4.3

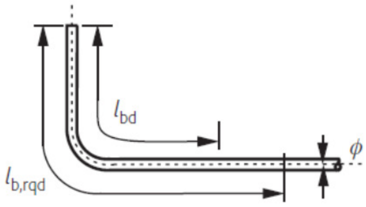
Concise: 11.4.3

$l_{b,rqd} = (\phi / 4)\ (\sigma_{sd} / f_{bd})$

where

σ_{sd} = the design stress of the bar at the position from where the anchorage is measured.

For bent bars $l_{b,rqd}$ should be measured along the centreline of the bar



EC2 Figure 8.1
Concise Fig 11.1

a) Basic anchorage length $l_{b,rqd}$, for any shape measured along the centreline

Design Anchorage Length, l_{bd}

EC2: Cl. 8.4.4

Concise: 11.4.2

$l_{bd} = \alpha_1\ \alpha_2\ \alpha_3\ \alpha_4\ \alpha_5\ l_{b,rqd} \geq l_{b,min}$

However: $(\alpha_2\ \alpha_3\ \alpha_5) \geq 0.7$

$l_{b,min} > \max(0.3 l_{b,rqd}\ ;\ 10\phi,\ 100\text{mm})$

Alpha values are in EC2: Table 8.2

To calculate α_2 and α_3 Table 8.2 requires values for:

C_d Value depends on cover and bar spacing, see Figure 8.3

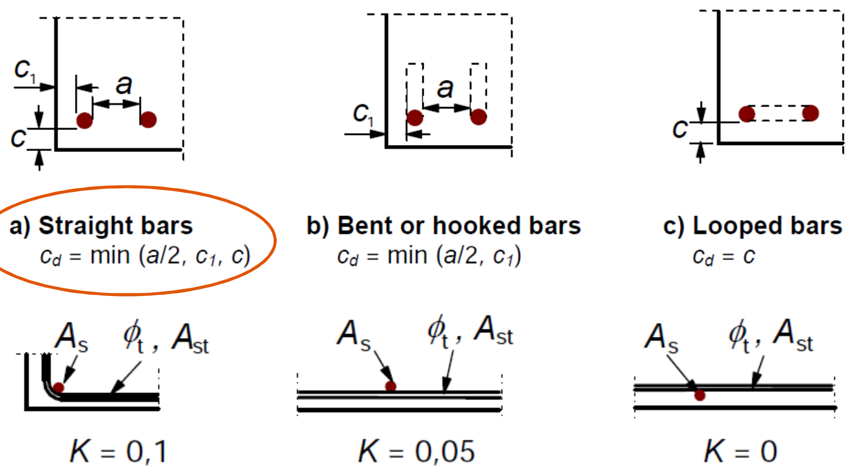
K Factor depends on position of confinement reinforcement, see Figure 8.4

λ $= (\Sigma A_{st} - \Sigma A_{st,min}) / A_s$ Where A_{st} is area of transverse reinf.

Table 8.2 - C_d & K factors

EC2: Figure 8.3

Concise: Figure 11.3



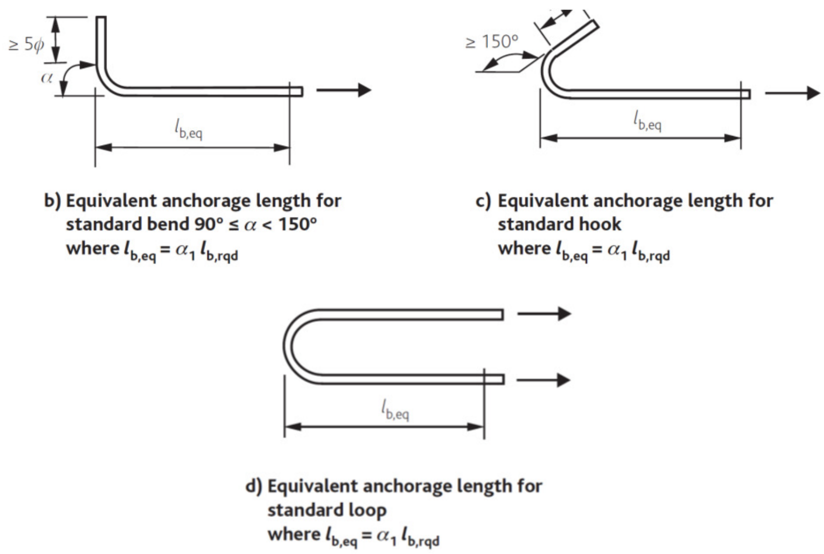
EC2: Figure 8.4

Beam corner bar?

Table 8.2 - Other than straight shapes

EC2: Figure 8.1

Concise: Figure 11.1



Alpha values

EC2: Table 8.2

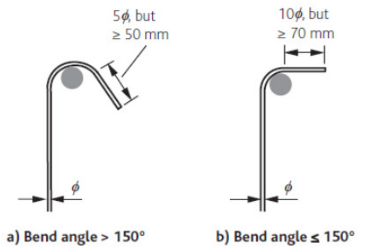
Concise: 11.4.2

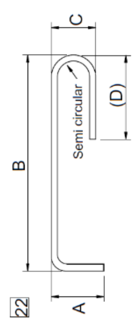
	Influencing factor	Type of anchorage	Reinforcement bar In tension	Reinforcement bar In compression
α_1	Shape of bars	Straight	$\alpha_1 = 1,0$	$\alpha_1 = 1,0$
		Other than straight (see Figure 8.1 (b), (c) and (d)	$\alpha_1 = 0,7$ if $c_d > 3\phi$ otherwise $\alpha_1 = 1,0$ (see Figure 8.3 for values of c_d)	$\alpha_1 = 1,0$
α_2	Concrete cover	Straight	$\alpha_2 = 1 - 0,15 (c_d - \phi)/\phi$ $\geq 0,7$ $\leq 1,0$	$\alpha_2 = 1,0$
		Other than straight (see Figure 8.1 (b), (c) and (d))	$\alpha_2 = 1 - 0,15 (c_d - 3\phi)/\phi$ $\geq 0,7$ $\leq 1,0$ (see Figure 8.3 for values of c_d)	$\alpha_2 = 1,0$
α_3	Confinement by transverse reinforcement not welded to main reinforcement	All types	$\alpha_3 = 1 - K\lambda$ $\geq 0,7$ $\leq 1,0$	$\alpha_3 = 1,0$
α_4	Confinement by welded transverse reinforcement*	All types, position and size as specified in Figure 8.1 (e)	$\alpha_4 = 0,7$	$\alpha_4 = 0,7$
α_5	Confinement by transverse pressure	All types	$\alpha_5 = 1 - 0,04p$ $\geq 0,7$ $\leq 1,0$	-

Anchorage of links

EC2: Cl. 8.5

Concise: Fig 11.2





Laps

EC2: Cl. 8.7

Design Lap Length, l_0 (8.7.3)

EC2: Cl. 8.7.3, Table 8.3

Concise: 11.6.2

$l_0 = \alpha_1\ \alpha_2\ \alpha_3\ \alpha_5\ \alpha_6\ l_{b,rqd} \geq l_{0,min}$

$\alpha_1\ \alpha_2\ \alpha_3\ \alpha_5$ are as defined for anchorage length

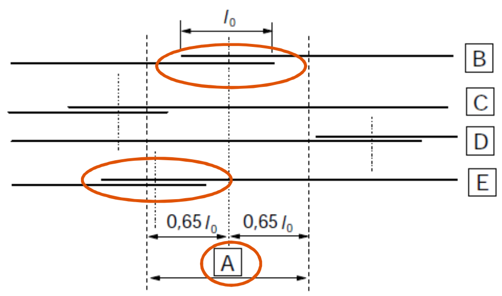
$\alpha_6 = (\rho_1/25)^{0,5}$ but between 1.0 and 1.5
where ρ_1 is the % of reinforcement lapped within $0.65 l_0$ from the centre of the lap

Percentage of lapped bars relative to the total cross-section area	< 25%	33%	50%	>50%
α_6	1	1.15	1.4	1.5
Note: Intermediate values may be determined by interpolation.				

$l_{0,min} \geq \max\{0.3\ \alpha_6\ l_{b,rqd};\ 15\phi;\ 200\}$

Arrangement of Laps

EC2: Cl. 8.7.3, Fig 8.8



A Section considered   B Bar I   C Bar II   D Bar III   E Bar IV

Example: Bars II and III are outside the section being considered: % = 50 and α_6 =1,4

Figure 8.8: Percentage of lapped bars in one lapped section

Worked example

Anchorage and lap lengths

Anchorage Worked Example

Calculate the tension anchorage for an H16 bar in the bottom of a slab:

a) Straight bars

b) Other shape bars (Fig 8.1 b, c and d)

Concrete strength class is C25/30

Nominal cover is 25mm

Assume maximum design stress in the bar

Bond stress, f_{bd}

$f_{bd} = 2.25\ \eta_1\ \eta_2\ f_{ctd}$ — EC2 Equ. 8.2

$\eta_1 = 1.0$ 'Good' bond conditions

$\eta_2 = 1.0$ bar size ≤ 32

$f_{ctd} = \alpha_{ct}\ f_{ctk,0,05}/\gamma_c$ — EC2 cl 3.1.6(2), Equ 3.16

$\alpha_{ct} = 1.0 \qquad \gamma_c = 1.5$

$f_{ctk,0,05} = 0.7 \times 0.3\ f_{ck}^{2/3}$ — EC2 Table 3.1

$= 0.21 \times 25^{2/3}$

$= 1.795$ MPa

$f_{ctd} = \alpha_{ct}\ f_{ctk,0,05}/\gamma_c = 1.795/1.5 = 1.197$

$f_{bd} = 2.25 \times 1.197 = 2.693$ MPa

Basic anchorage length, $l_{b,req}$

$l_{b.req}$ = $(Ø/4)\ (\sigma_{sd}/f_{bd})$ EC2 Equ 8.3

Max stress in the bar, σ_{sd} = f_{yk}/γ_s = 500/1.15

= 435MPa.

$l_{b.req}$ = $(Ø/4)\ (435/2.693)$

= 40.36 Ø

For concrete class C25/30

Design anchorage length, l_{bd}

$l_{bd} = \alpha_1\ \alpha_2\ \alpha_3\ \alpha_4\ \alpha_5\ l_{b.req} \geq l_{b,min}$

$l_{bd} = \alpha_1\ \alpha_2\ \alpha_3\ \alpha_4\ \alpha_5\ (40.36Ø)$ For concrete class C25/30

Alpha values

EC2: Table 8.2

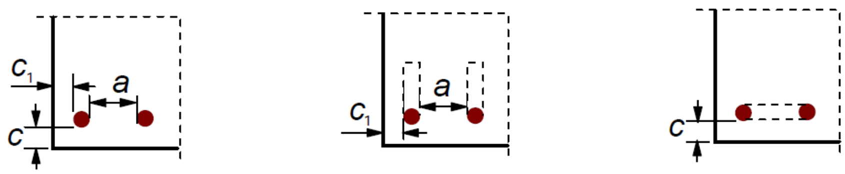
Concise: 11.4.2

Influencing factor	Type of anchorage	Reinforcement bar	
		In tension	In compression
Shape of bars	Straight	$\alpha_1 = 1{,}0$	$\alpha_1 = 1{,}0$
	Other than straight (see Figure 8.1 (b), (c) and (d)	$\alpha_1 = 0{,}7$ if $c_d > 3\phi$ otherwise $\alpha_1 = 1{,}0$ (see Figure 8.3 for values of c_d)	$\alpha_1 = 1{,}0$
Concrete cover	Straight	$\alpha_2 = 1 - 0{,}15\,(c_d - \phi)/\phi$ $\geq 0{,}7$ $\leq 1{,}0$	$\alpha_2 = 1{,}0$
	Other than straight (see Figure 8.1 (b), (c) and (d))	$\alpha_2 = 1 - 0{,}15\,(c_d - 3\phi)/\phi$ $\geq 0{,}7$ $\leq 1{,}0$ (see Figure 8.3 for values of c_d)	$\alpha_2 = 1{,}0$
Confinement by transverse reinforcement not welded to main reinforcement	All types	$\alpha_3 = 1 - K\lambda$ $\geq 0{,}7$ $\leq 1{,}0$	$\alpha_3 = 1{,}0$
Confinement by welded transverse reinforcement*	All types, position and size as specified in Figure 8.1 (e)	$\alpha_4 = 0{,}7$	$\alpha_4 = 0{,}7$
Confinement by transverse pressure	All types	$\alpha_5 = 1 - 0{,}04p$ $\geq 0{,}7$ $\leq 1{,}0$	-

Table 8.2 - C_d & K factors

EC2: Figure 8.3

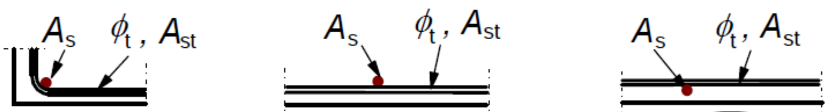
Concise: Figure 11.3



a) Straight bars $c_d = \min(a/2, c_1, c)$

b) Bent or hooked bars $c_d = \min(a/2, c_1)$

c) Looped bars $c_d = c$



$K = 0{,}1$ $K = 0{,}05$ $K = 0$

EC2: Figure 8.4

Design anchorage length, l_{bd}

$l_{bd} = \alpha_1\ \alpha_2\ \alpha_3\ \alpha_4\ \alpha_5\ l_{b.req} \geq l_{b,min}$

$l_{bd} = \alpha_1\ \alpha_2\ \alpha_3\ \alpha_4\ \alpha_5\ (40.36Ø)$ For concrete class C25/30

a) Tension anchorage - ***straight bar***

$\alpha_1 = 1.0$

$\alpha_3 = 1.0$ conservative value with K= 0

$\alpha_4 = 1.0$ N/A

$\alpha_5 = 1.0$ conservative value

$\alpha_2 = 1.0 - 0.15\ (C_d - Ø)/Ø$

$\alpha_2 = 1.0 - 0.15\ (25 - 16)/16 = 0.916$

$l_{bd} = 0.916 \times 40.36Ø = 36.97Ø = 592\text{mm}$

Design anchorage length, l_{bd}

$l_{bd} = \alpha_1\ \alpha_2\ \alpha_3\ \alpha_4\ \alpha_5\ l_{b.req} \geq l_{b,min}$

$l_{bd} = \alpha_1\ \alpha_2\ \alpha_3\ \alpha_4\ \alpha_5\ (40.36Ø)$ For concrete class C25/30

b) Tension anchorage - ***Other shape bars***

$\alpha_1 = 1.0$ $C_d = 25$ is $\leq 3\ Ø = 3 \times 16 = 48$

$\alpha_3 = 1.0$ conservative value with K= 0

$\alpha_4 = 1.0$ N/A

$\alpha_5 = 1.0$ conservative value

$\alpha_2 = 1.0 - 0.15\ (C_d - 3Ø)/Ø \leq 1.0$

$\alpha_2 = 1.0 - 0.15\ (25 - 48)/16 = 1.25 \leq 1.0$

$l_{bd} = 1.0 \times 40.36Ø = 40.36Ø = 646\text{mm}$

Worked example - summary

H16 Bars - Concrete class C25/30 - 25 Nominal cover

Tension anchorage - straight bar $l_{bd} = 36.97\text{Ø} = 592\text{mm}$

Tension anchorage - Other shape bars $l_{bd} = 40.36\text{Ø} = 646\text{mm}$

l_{bd} is measured along the centreline of the bar

Compression anchorage ($\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 1.0$)

$l_{bd} = 40.36\text{Ø} = 646\text{mm}$

Anchorage for 'Poor' bond conditions, l_{bd} = 'Good value' /0.7

Lap length, l_0 = anchorage length x α_6

Anchorage & lap lengths

How to design concrete structures using Eurocode 2

Table 2
Anchorage and lap lengths for concrete class C25/30 (mm)

		Bond condition, (see Figure 1)	Reinforcement in tension, bar diameter, ϕ (mm)								Reinforcement in compression
			8	10	12	16	20	25	32	40	
Anchorage length, l_{bd}	Straight bars only	Good	230	320	410	600	780	1010	1300	1760	40ϕ
		Poor	330	450	580	850	1120	1450	1850	2510	58ϕ
	Other bars	Good	320	410	490	650	810	1010	1300	1760	40ϕ
		Poor	460	580	700	930	1160	1450	1850	2510	58ϕ
Lap length, l_0	50% lapped in one location ($\alpha_6 = 1.4$)	Good	320	440	570	830	1090	1420	1810	2460	57ϕ
		Poor	460	630	820	1190	1560	2020	2590	3520	81ϕ
	100% lapped in one location ($\alpha_6 = 1.5$)	Good	340	470	610	890	1170	1520	1940	2640	61ϕ
		Poor	490	680	870	1270	1670	2170	2770	3770	87ϕ

Notes

1 Nominal cover to all sides ≥ 25 mm, [i.e. $a_2 \leq 1$]. At laps, clear distance between bars ≤ 50mm.
2 $\alpha_1 = \alpha_3 = \alpha_4 = \alpha_5 = 1.0$. For the beneficial effects of shape of bar, cover and confinement see Eurocode 2, Table 8.2.
3 Design stress has been taken as 435 MPa. Where the design stress in the bar at the position from where the anchorage is measured, σ_{sd}, is less than 435 MPa the figures in this table can be factored by $\sigma_{sd}/435$. The minimum lap length is given in cl 8.7.3 of Eurocode 2.
4 The anchorage and lap lengths have been rounded up to the nearest 10 mm.
5 Where 33% of bars are lapped in one location, decrease the lap lengths for '50% lapped in one location' by a factor of 0.82.
6 The figures in this table have been prepared for concrete class C25/30; refer to Table 13 for other classes or use the following factors for other concrete classes.

Concrete class	C20/25	C28/35	C30/37	C32/40	C35/45	C40/50	C45/55	C50/60
Factor	1.16	0.93	0.89	0.85	0.80	0.73	0.68	0.63

Column lap length for 100% laps & grade C40/50 = $0.73 \times 61\Phi = 44.5\ \Phi$

Anchorage /lap lengths for slabs

Manual for the design of concrete structures to Eurocode 2

Table 5.25: Typical values of anchorage and lap lengths for slabs

	Bond conditions	Length in bar diameters f_{ck}/f_{cu} 25/30	f_{ck}/f_{cu} 28/35	f_{ck}/f_{cu} 30/37	f_{ck}/f_{cu} 32/40
Full tension and compression anchorage length, l_{bd}	'good'	40	37	36	34
	'poor'	58	53	51	49
Full tension and compression lap length, l_0	'good'	46	43	42	39
	'poor'	66	61	59	56

Note: The following is assumed:
- bar size is not greater than 32mm. If >32 then the anchorage and lap lengths should be increased by a factor (132 - bar size)/100
- normal cover exists
- no confinement by transverse pressure
- no confinement by transverse reinforcement
- not more than 33% of the bars are lapped at one place

Lap lengths provided (for nominal bars, etc.) should not be less than 15 times the bar size or 200mm, whichever is greater.

Arrangement of Laps

EC2: Cl. 8.7.2

Concise: Cl 11.6

Laps between bars should normally be staggered and not located in regions of high stress.

Arrangement of laps should comply with Figure 8.7:

Distance 'a' is used in cl 8.7.4.1 (3), Transverse reinf.

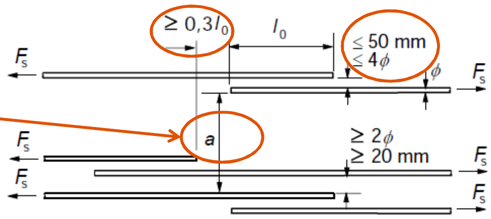


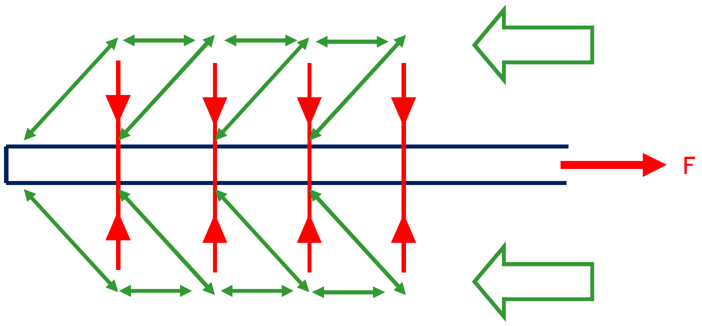
Figure 8.7: Adjacent laps

All bars in compression and secondary (distribution) reinforcement may be lapped in one section.

Strut-and-tie models

STM models help us understand:

- The anchorage of bars



There is transverse tension

Transverse Reinforcement at Laps
Bars in tension

Concise: Cl 11.6.4

EC2: Cl. 8.7.4, Fig 8.9

- Transverse reinforcement is required in the lap zone to resist transverse tension forces.
- Any Transverse reinforcement provided for other reasons will be sufficient if the lapped bar Ø < 20mm or laps< 25%
- If the lapped bar Ø ≥ 20mm the transverse reinforcement should have a total area, $\Sigma A_{st} \geq 1{,}0 A_s$ of one spliced bar. It should be placed perpendicular to the direction of the lapped reinforcement. Also it should be positioned at the outer sections of the lap as shown.

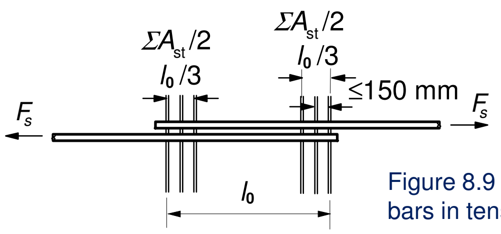


Figure 8.9 (a) - bars in tension

Transverse Reinforcement at Laps
Bars in tension

Concise: Cl 11.6.4

EC2: Cl. 8.7.4, Fig 8.9

- Also, if the lapped bar Ø ≥ 20mm and more than 50% of the reinforcement is lapped at one point and the distance between adjacent laps at a section, a, ≤ 10ϕ, then transverse bars should be formed by links or U bars anchored into the body of the section.

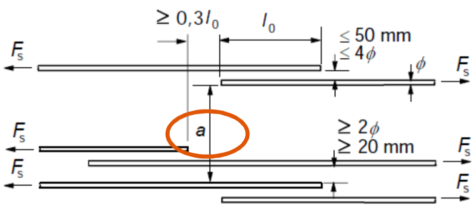


Figure 8.7: Adjacent laps

Transverse Reinforcement at Laps
Bars in compression

Concise: Cl 11.6.4

EC2: Cl. 8.7.4, Fig 8.9

In addition to the rules for bars in tension one bar of the transverse reinforcement should be placed outside each end of the lap length.

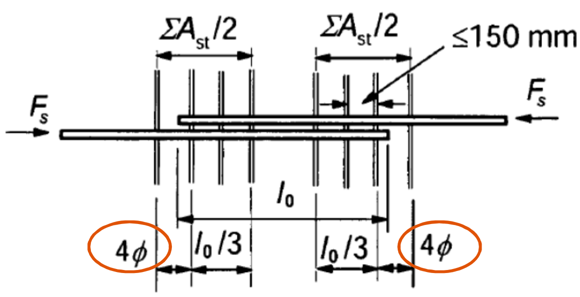


Figure 8.9 (b) - bars in compression

Detailing of members and particular rules

EC2 Section 9

Beams

EC2: Cl. 9.2

- $A_{s,min} = 0{,}26\ (f_{ctm}/f_{yk})b_t d$ but $\geq 0{,}0013 b_t d$

Strength class	C12/15	C16/20	C20/25	C25/30	C30/37	C35/45	C40/50	C45/55	C50/60	C28/35	C32/40
$A_{s,min}$ as a % of $b_t d$	0.130	0.130	0.130	0.135	0.151	0.166	0.182	0.198	0.213	0.146	0.156

- $A_{s,max} = 0{,}04\ A_c$
- Section at supports should be designed for a hogging moment $\geq 0{,}25$ max. span moment
- Any design compression reinforcement (ϕ) should be held by transverse reinforcement with spacing $\leq 15\ \phi$

Beams

EC2: Cl. 9.2

- Tension reinforcement in a flanged beam at supports should be spread over the effective width (see 5.3.2.1)

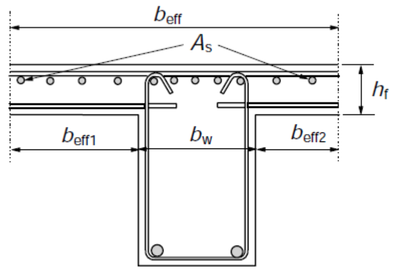


Figure 9.1: Placing of tension reinforcement in flanged cross-section.

Curtailment

EC2: Cl. 9.2.1.3

(1) Sufficient reinforcement should be provided at all sections to resist the envelope of the acting tensile force, including the effect of inclined cracks in webs and flanges.

(2) For members with shear reinforcement the additional tensile force, ΔF_{td}, *should be* calculated according to 6.2.3 (7). For members without shear reinforcement ΔF_{td} *may be* estimated by shifting the moment curve a distance $a_l = d$ *according to 6.2.2 (5). This "shift rule"* may also be used as an alternative for members with shear reinforcement, where:

$a_l = z (\cot \theta - \cot a)/2 = 0.5 z \cot \theta$ for vertical shear links

z= lever arm, θ = angle of compression strut

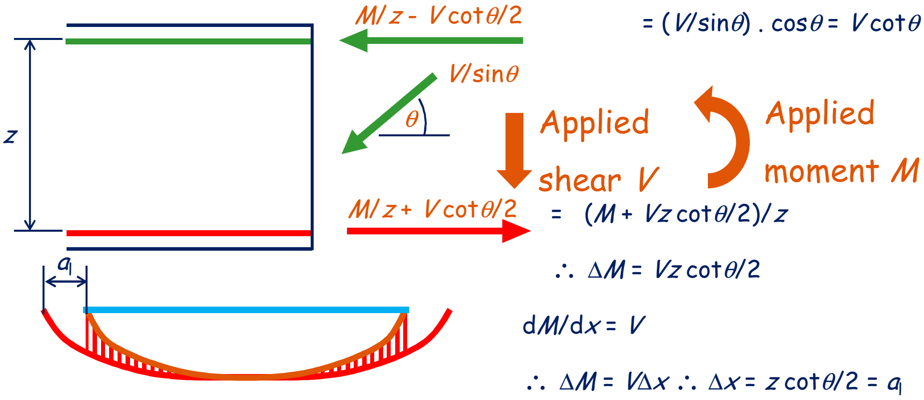
a_l = 1.125 d when cot θ = 2.5 and 0.45 d when cot θ = 1

'Shift Rule' for Shear

Curtailment of longitudinal tension reinforcement

Horizontal component of diagonal shear force

$= (V/\sin\theta) \,.\, \cos\theta = V\cot\theta$



$= (M + Vz\cot\theta/2)/z$

$\therefore\ \Delta M = Vz\cot\theta/2$

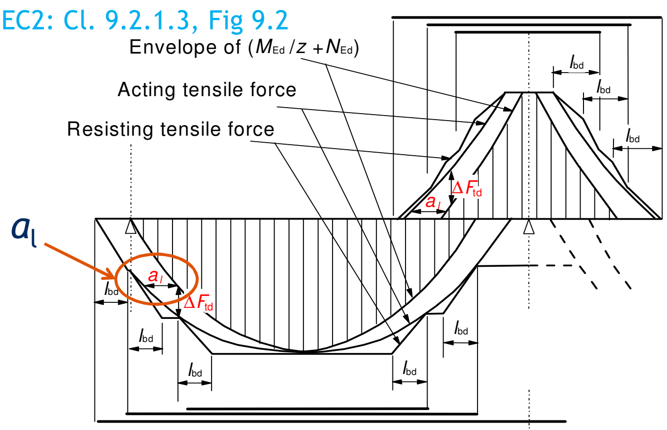
$dM/dx = V$

$\therefore\ \Delta M = V\Delta x\ \therefore\ \Delta x = z\cot\theta/2 = a_l$

'Shift Rule'
Curtailment of reinforcement

EC2: Cl. 9.2.1.3, Fig 9.2

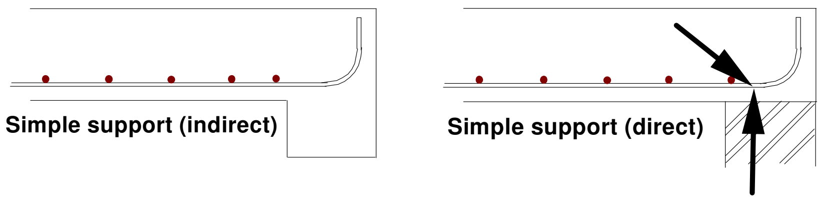
Concise: 12.2.2



- For members without shear reinforcement this is satisfied with $a_l = d$
- For members with shear reinforcement: $a_l = 0.5\ z\ \text{Cot}\ \theta$
  But it is always conservative to use $a_l = 1.125d$ (for $\theta = 45^o$, $a_l = 0.45d$)

Anchorage of Bottom Reinforcement at End Supports

EC2: Cl. 9.2.1.4



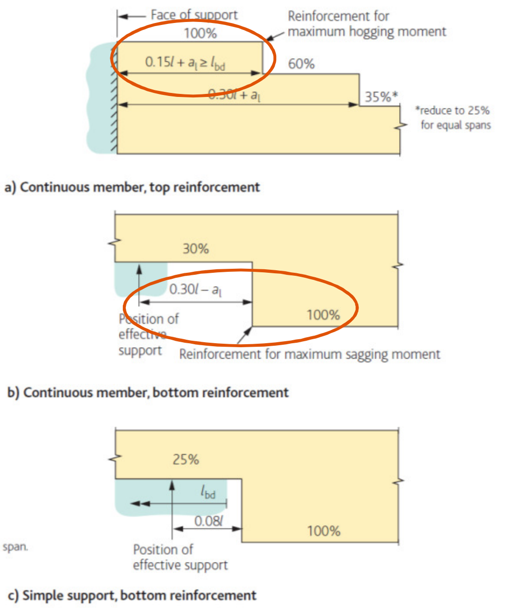
- A_s bottom steel at support $\geq 0.25\ A_s$ provided in the span
- l_{bd} is required from the line of contact of the support.
- Transverse pressure may only be taken into account with a 'direct' support. α_5 anchorage coefficient

Simplified Detailing Rules for Beams

Concise: Cl 12.2.4

How to….EC2

Detailing section



Notes

1. l is the effective length.
2. a_l is the distance to allow for tensile force due to shear force.
3. l_{bd} is the design anchorage length.
4. $Q_k \leq G_k$
5. Minimum of two spans required.
6. Applies to uniformly distributed loads only.
7. The shortest span must be greater than or equal to 0.85 times the longest span.
8. Applies where 15% redistribution has been used.

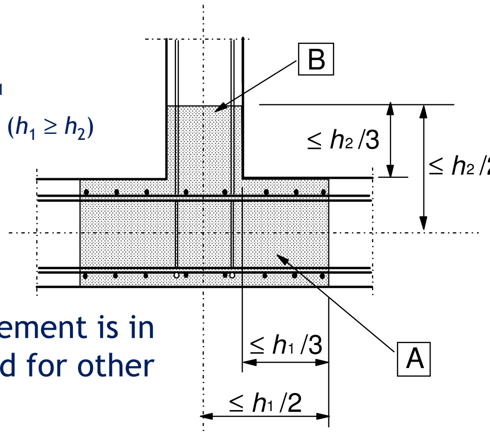
Supporting Reinforcement at 'Indirect' Supports

Concise: Cl 12.2.8

EC2: Cl. 9.2.5

A	supporting beam with height h_1
B	supported beam with height h_2 ($h_1 \geq h_2$)

Plan view

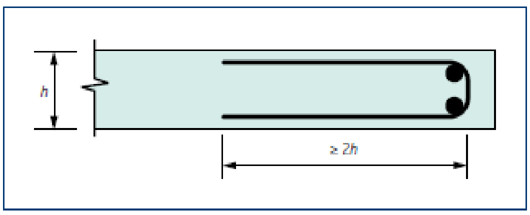


- The supporting reinforcement is in addition to that required for other reasons
- The supporting links may be placed in a zone beyond the intersection of beams

Solid slabs

EC2: Cl. 9.3

- Curtailment - as beams except for the "Shift" rule a_l = d may be used
- Flexural Reinforcement - min and max areas as beam
- Secondary transverse steel not less than 20% main reinforcement
- Reinforcement at Free Edges



Detailing Comparisons

Beams	EC2	BS 8110
Main Bars in Tension	***Clause / Values***	***Values***
$A_{s,min}$	9.2.1.1 (1): $0.26\ f_{ctm}/f_{yk}bd \geq 0.0013\ bd$	$0.0013\ bh$
$A_{s,max}$	9.2.1.1 (3): $0.04\ bd$	$0.04\ bh$
Main Bars in Compression		
$A_{s,min}$	--	$0.002\ bh$
$A_{s,max}$	9.2.1.1 (3): $0.04\ bd$	$0.04\ bh$
Spacing of Main Bars		
s_{min}	8.2 (2): d_g + 5 mm or ϕ or 20mm	d_g + 5 mm or ϕ
S_{max}	Table 7.3N	Table 3.28
Links		
$A_{sw,min}$	9.2.2 (5): $(0.08\ b\ s\ \sqrt{f_{ck}})/f_{yk}$	$0.4\ b\ s/0.87\ f_{yv}$
$s_{l,max}$	9.2.2 (6): $0.75\ d$	$0.75d$
$s_{t,max}$	9.2.2 (8): $0.75\ d \leq 600$ mm	d or 150 mm from main bar
	9.2.1.2 (3) or 15ϕ from main bar	

Detailing Comparisons

Slabs	EC2 *Clause / Values*	BS 8110 *Values*
Main Bars in Tension		
$A_{s,min}$	9.2.1.1 (1): $0.26\ f_{ctm}/f_{yk}bd \geq 0.0013\ bd$	$0.0013\ bh$
$A_{s,max}$	$0.04\ bd$	$0.04\ bh$
Secondary Transverse Bars		
$A_{s,min}$	9.3.1.1 (2): $0.2A_s$ for single way slabs	$0.002\ bh$
$A_{s,max}$	9.2.1.1 (3): $0.04\ bd$	$0.04\ bh$
Spacing of Bars		
s_{min}	8.2 (2): d_g + 5 mm or ϕ or 20mm	d_g + 5 mm or ϕ
	9.3.1.1 (3): main $3h \leq 400$ mm	
S_{max}	secondary: $3.5h \leq 450$ mm	$3d$ or 750 mm
	places of maximum moment: main: $2h \leq 250$ mm; secondary: $3h \leq 400$ mm	

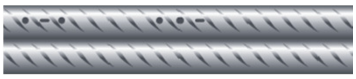
Detailing Comparisons

Punching Shear	EC2 *Clause / Values*	BS 8110 *Values*
Links		
$A_{sw,min}$	9.4.3 (2): Link leg = $0.053 s_r\, s_t \sqrt{(f_{ck})}/f_{yk}$	Total = $0.4ud/0.87fyv$
S_r	9.4.3 (1): $0.75d$	$0.75d$
S_t	9.4.3 (1): within 1st control perim.: $1.5d$ outside 1st control perim.: $2d$	$1.5d$
Columns		
Main Bars in Compression		
$A_{s,min}$	9.5.2 (2): $0.10 N_{Ed}/f_{yk} \le 0.002bh$	$0.004\,bh$
$A_{s,max}$	9.5.2 (3): $0.04\,bh$	$0.06\,bh$
Links		
Min size	9.5.3 (1) 0.25ϕ or 6 mm	0.25ϕ or 6 mm
$S_{cl,tmax}$	9.5.3 (3): min(12ϕmin; $0.6b$; 240 mm)	12ϕ
	9.5.3 (6): 150 mm from main bar	150 mm from main bar

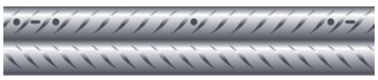
Identification of bars on site

Current BS 4449

Class A



Class B

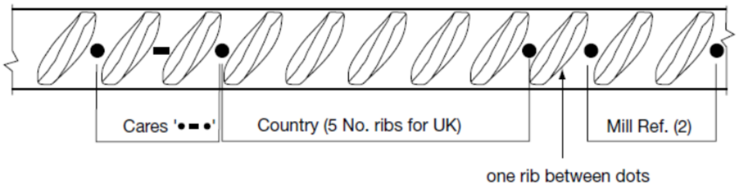


Class C

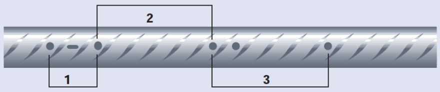
www.ukcares.co.uk
www.uk-bar.org

Identification on site

Current BS 4449



CARES Identification System



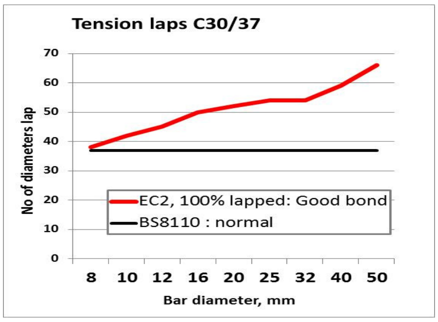
Country or Regional Grouping is as follows:-

Germany	1 rib
Belgium, Netherlands, Luxembourg	2 ribs
France	3 ribs
Italy	4 ribs
United Kingdom, Eire	5 ribs
Scandinavia	6 ribs
Spain, Portugal	7 ribs
Greece, Turkey	8 ribs
Outside Europe	9 ribs

UK CARES (Certification - Product & Companies)

1. Reinforcing bar and coil
2. Reinforcing fabric
3. Steel wire for direct use of for further processing
4. Cut and bent reinforcement
5. Welding and prefabrication of reinforcing steel

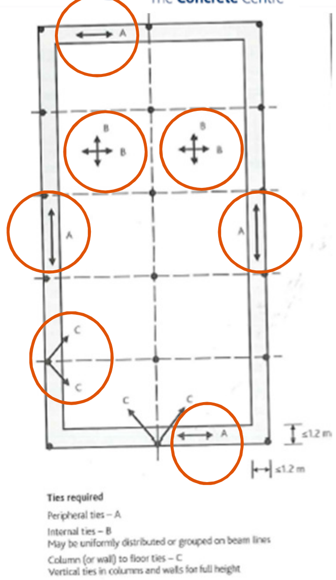
Detailing Issues

EC2 *Clause*	*Issue*	Possible resolve in 2018?
8.4.4.1	Lap lengths	
Table 8.3	α_6 varies depending on amount staggered	α_6 should always = 1.5. Staggering doesn't help at ULS
8.7.2(3) & Fig 8.7	0.3 l_o gap between ends of lapped bars is onerous.	For ULS, there is no advantage in staggering bars(fib bulletin Mar 2014). For SLS staggering at say 0.5 l_o might be helpful.

Detailing Issues

EC2 *Clause*	*Issue*	Possible resolve in 2018?
Table 8.2	α_2 for compression bars	Should be the same as for tension. Initial test suggests α_2 = 0.7
Table 8.2	α_2 for bent bars	Currently, anchorage worse than for straight bars
8.7.4.1(4) & Fig 8.9	Requirements for transverse bars are impractical	Requirement only makes 10-15% difference in strength of lap (Corrigendum 1 no longer requires transverse bars to be between lapped bar and surface.)
Fig 9.3	l_{bd} anchorage into support	May be OTT as compression forces increase bond strength. Issue about anchorage beyond CL of support
6.4	Numbers of perimeters of punching shear links	Work of CEN TC 250.SC2/WG1/TG4

Tying systems



Tying systems

- *Peripheral ties* (9.10.2.2) & NA*:*
  $F_{\text{tie,per}} = (20 + 4n_0) \leq 60\text{kN}$
  where n_0 is the number of storeys

- *Internal ties (including transverse ties)* (9.10.2.3) & NA *:*
  $F_{\text{tie,int}} = ((g_k + q_k) / 7.5)(l_r/5)F_t \geq F_t$ kN/m

  where $(g_k + q_k)$ is the sum of the average permanent and variable floor loads (kN/m²), l_r is the greater of the distances (m) between the centres of the columns, frames or walls supporting any two adjacent floor spans in the direction of the tie under consideration and $F_t = (20 + 4n_0) \leq 60$kN.
  Maximum spacing of internal ties = 1.5 l_r

- *Horizontal ties to columns or walls* (9.10.2.4) & NA *:*
  $F_{\text{tie,fac}} = F_{\text{tie,col}} \geq (2\,F_t \leq (l_s/2.5)F_t)$ and $\geq$ 3% of N_{Ed}

  N_{Ed} = the total design ultimate vertical load carried by the column or wall at that level. Tying of external walls is only required if the peripheral tie is not located within the wall. $F_{\text{tie,fac}}$ in kN per metre run of wall, $F_{\text{tie,col}}$ in kN per column and l_s is the floor to ceiling height in m.

Tying Systems

Internal Ties: EC2 specifies a 20kN/m requirement which is significantly less than BS8110.

UK NA requirements similar to BS 8110

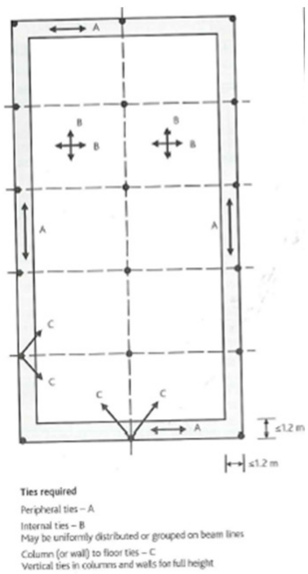

How to design concrete buildings to satisfy disproportionate collapse requirements

O Brooker

Introduction

Current requirements

Classifying a building



Tying Systems

- *Vertical ties* (9.10.2.5):
  In panel buildings of 5 storeys or more, ties should be provided in columns and/or walls to limit damage of collapse of a floor.

  Normally continuous vertical ties should be provided from the lowest to the highest level.

  Where a column or wall is supported at the bottom by a beam or slab accidental loss of this element should be considered.

- *Continuity and anchorage ties* (9.10.3):
  Ties in two horizontal directions shall be effectively continuous and anchored at the perimeter of the structure.

  Ties may be provided wholly in the insitu concrete topping or at connections of precast members.

Exercise

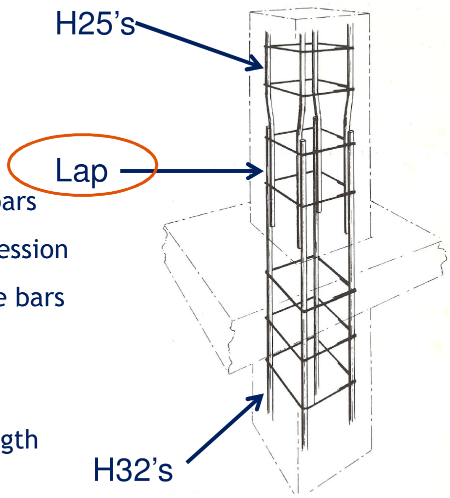
Lecture 9

Lap length for column longitudinal bars

Column lap length exercise

Design information

- C40/50 concrete
- 400 mm square column
- 45mm nominal cover to main bars
- Longitudinal bars are in compression
- Maximum ultimate stress in the bars is 390 MPa



Exercise:

Calculate the minimum lap length using EC2 equation 8.10:

$$l_0 = \alpha_1 \alpha_2 \alpha_3 \alpha_5 \alpha_6 l_{b,rqd} \geq l_{0,min}$$

Column lap length exercise

Procedure

- Determine the ultimate bond stress, f_{bd} — EC2 Equ. 8.2
- Determine the basic anchorage length, $l_{b,req}$ — EC2 Equ. 8.3
- Determine the design anchorage length, l_{bd} — EC2 Equ. 8.4
- Determine the lap length, l_0 = anchorage length x α_6

Working space

End of Lecture 9

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