Worked Examples to Eurocode 2

25 February 2010
Amended 18 January 2012

Further edits added 2021 - see pages 14-19.
Amended to correct a numerical error in the wind loading calculation and to include checks required due to the limit on V_{Ed} / V_{Rdc} which was introduced to the Eurocode following publication of the Worked Examples guide.

Revisions required to **Worked Examples to Eurocode 2** due to Amendment 1 to NA to BS EN 1992-1-1:2004 dated Dec 2009.

Amended 18/1/2012 to illustrate 40*K* limit on l/d according to Table NA.5 Note 6

Page	Where	Old text	Revised text
37/38	3.1.6	Allowable $l/d = N \times K \times F1 \times F2 \times F3$ where $N = 25.6$ ($\rho = 0.41\%$, $f_{ck} = 30$) $K = 1.0$ (simply supported) $F1 = 1.0$ ($b_{eff}/b_w = 1.0$) $F2 = 1.0$ (span < 7.0 m) $F3 = 310/\sigma_s \leq 1.5$ where $\sigma_s = \sigma_{sn} (A_{s,req}/A_{s,prov})\ 1/\delta$ where $\sigma_{sn} \approx 242$ MPa (From *Concise* Figure 15.3 and $g_k/q_k = 1.79$, $\psi_2 = 0.3$, $\gamma_g = 1.25$) δ = redistribution ratio = 1.0 $\therefore \sigma_s \approx 242 \times 594/645 = 222$ $\therefore F3 = 310/222 = 1.40$ $\therefore$ Allowable $l/d = 25.6 \times 1.40 = 35.8$ Actual $l/d = 4800/144 = 33.3$ $\therefore$ OK Use H12 @ 175 B1 (645 mm²/m)	Allowable $l/d = N \times K \times F1 \times F2 \times F3$ where $N = 25.6$ ($\rho = 0.41\%$, $f_{ck} = 30$) $K = 1.0$ (simply supported) $F1 = 1.0$ ($b_{eff}/b_w = 1.0$) $F2 = 1.0$ (span < 7.0 m) $F3 = A_{s,prov}/A_{s,req} \leq 1.50$ $= 645/594 = 1.09$ $\therefore$ Allowable $l/d = 25.6 \times 1.09 = 27.9$ Actual $l/d = 4800/144 = 33.3$ $\therefore$ no good Try $33.3/27.9 \times 654 = 784$ mm²/m i.e. H12@140 (807 mm²/m) $F3 = 807/594 = 1.36$ $\therefore$ Allowable $l/d = 25.6 \times 1.36 = 34.8$ (which is < 40*K* = 40) [Table NA.5 Note 6] i.e. > 33.3 $\therefore$ OK Use H12 @ 140 B1 (807 mm²/m)
38	3.1.7	By inspection, OK However, if considered critical: V = 29.5 kN/m as before $V_{Ed} = 29.5 - 0.14 \times 12.3 = 27.8$ kN/m $v_{Ed} = 27.8 \times 10^3/144 \times 10^3 = 0.19$ MPa $v_{Rd,c} = 0.53$ MPa	By inspection, OK However, if considered critical: V = 29.5 kN/m as before $V_{Ed} = 29.5 - 0.14 \times 12.3 = 27.8$ kN/m $v_{Ed} = 27.8 \times 10^3/144 \times 10^3 = 0.19$ MPa $\rho = 804/1000 \times 144 = 0.56\%$ say 50% curtailed use 0.28% $v_{Rd,c} = 0.54$ MPa

42	3.2.6	F3 $= 310/\sigma_s \le 1.5$ where $\sigma_s = (f_{yk}/\gamma_S)(A_{s,req}/A_{s,prov})$ (SLS loads/ULS loads) $(1/\delta)$ $= f_{yd} \times (A_{s,req}/A_{s,prov}) \times (g_k + \psi_2 q_k)/(\gamma_G g_k + \gamma_Q q_k)(1/\delta)$ $= (500/1.15) \times (639/645) \times [(5.9 + 0.3 \times 3.3)/12.3] \times 1.08$[1] $= 434.8 \times 0.99 \times 0.56 \times 1.08 = 260$ MPa F3 $= 310/260 = 1.19$ **Note:** $A_{s,prov}/A_{s,req} \le 1.50$ Allowable l/d = N × K × F1 × F2 × F3 = 23.5 × 1.3 × 1.0 × 1.19 = 36.4 Max. span = 36.4 × 144 = 5675 mm, i.e. < 5795 mm ∴ No good Try H12 @ 150 B1 (754 mm²/m) $\sigma_s = 434.8 \times 639/754 \times 0.56 \times 1.08 = 223$ F3 = 310/223 = 1.39 Allowable l/d = 23.5 × 1.3 × 1.0 × 1.39 = 42.5 Max. span = 42.5 × 144 = 6120 mm, i.e. > 5795 mm OK ∴ H12 @ 150 B1 (754 mm²/m) OK	F3 = $A_{s,prov}/A_{s,req} \le 1.50$ = 645/ 639 = 1.01 Allowable l/d = N × K × F1 × F2 × F3 = 23.5 × 1.3 × 1.0 × 1.01 = 30.8 Max. span = 30.8 × 144 = 4435 mm, i.e. < 5795 mm ∴ No good Try H12 @ 125 B1 (904 mm²/m) F3 = 904/639 = 1.41 Allowable l/d = 23.5 × 1.3 × 1.0 × 1.41 = 43.1 Max. span = 43.1 × 144 = 6206 mm, i.e. > 5795 mm OK ∴ H12 @ 125 B1 (904 mm²/m) OK
43	3.2.7	F3 $= 310/\sigma_s \le 1.5$ where $\sigma_s = f_{yd} \times (A_{s,req}/A_{s,prov}) \times (g_k + \psi_2 q_k)/(\gamma_G g_k + \gamma_Q q_k)(1/\delta)$ $= (500/1.15) \times (465/502) \times [(5.9 + 0.3 \times 3.3)/12.3] \times 1.03$ $= 434.8 \times 0.93 \times 0.56 \times 1.03 = 233$ MPa F3 = 310/233 = 1.33 Allowable l/d = N × K × F1 × F2 × F3 = 35.8 × 1.5 × 1.0 × 1.33 = 71.4 Max. span = 71.4 × 144 = 10280 mm i.e. > 5795 mm OK	F3 = $A_{s,req}/A_{s,prov} \le 1.5$ = 502/ 465 = 1.08 Allowable l/d = N × K × F1 × F2 × F3 = 35.8 × 1.5 × 1.0 × 1.08 = 58.0 (which is < 40K = 40 x 1.5 =60) [Table NA.5 Note 6] Max. span = 58.0 × 144 = 8352 mm i.e. > 5795 mm OK
44	3.2.9	In Figure 3.4 H12@150	In Figure 3.4 H12@125
46	3.2.10a)	Crack control As slab < 200 mm, measures to control cracking are unnecessary.	Crack control As slab < 200 mm, measures to control cracking are unnecessary.

[1] The use of Table 15.2 from *Concise* Eurocode 2implies certain amounts of redistribution, which are defined in *Concise* Eurocode 2 Table 15.14.

		However, as a check on end span: Loading is the main cause of cracking, ∴ use Table 7.2N or Table 7.3N for w_{max} = 0.4 mm and σ = 241 MPa (see deflection check). Max. bar size = 20 mm or max. spacing = 250 mm ∴ H12 @ 150 B1 OK.	However, as a check on end span: Loading is the main cause of cracking, ∴ use Table 7.2N or Table 7.3N for w_{max} = 0.4 mm and σ = 241 MPa (see deflection check). Max. bar size = 20 mm or max. spacing = 250 mm ∴ H12 @ 125 B1 OK
		End supports: effects of partial fixity Try H12 @ 450 (251 mm^2/m) U-bars at supports	**End supports: effects of partial fixity** Try H12 @ 500 (226 mm^2/m) U-bars at supports
46	3.2.10b)	**End span, bottom reinforcement** Try H12 @ 300 (376 mm^2/m) at supports	**End span, bottom reinforcement** Try H12 @ 250 (452 mm^2/m) at supports
49	3.2.10b) iii	**Support B bottom steel at support** For convenience use H12 @ 300 B1 (376 mm^2/m)	**Support B bottom steel at support** For convenience use H12 @250 B1 (452 mm^2/m)
51	3.2.11	Figure 3.6	See A below
57/58	3.3.5b)	**Span A–B: Deflection** F3 = 310/$\sigma_s \leq$ 1.5 where σ_s = (f_{yk}/γ_S) $(A_{s,req}/A_{s,prov})$ (SLS loads/ULS loads) (1/δ) = 434.8(523/628) [(4.30 + 0.3 × 5.0)/13.38] (65.3/61.7$^{\$}$) = 434.8 × 0.83 × 0.43 × 1.06 = 164 MPa F3 = 310/σ_s = 310/164 = 1.89$^{\#}$ but ≤ 1.50 therefore say 1.50 ∴ Permissible l/d = 22.8 × 1.3 × 0.8 × 0.93 × 1.50 = 33.0 Actual l/d = 7500/257 = 29.2 ∴ OK Use 2 no. H20/rib (628 mm^2/rib)	**Span A–B: Deflection** F3 = 310/$\sigma_s \leq$ 1.5 where σ_s = (f_{yk}/γ_S) $(A_{s,req}/A_{s,prov})$ (SLS loads/ULS loads) (1/δ) = 434.8(523/628) [(4.30 + 5.0)/13.38] (65.3/61.7$^{\$}$) = 434.8 × 0.83 × 0.70 × 1.06 = 267 MPa F3 = 310/σ_s = 310/267 = 1.16 ∴ Permissible l/d = 22.8 × 1.3 × 0.8 × 0.93 × 1.16 = 25.6 Actual l/d = 7500/257 = 29.2 ∴ no good Try 1H25 + 1H20/rib (805 mm^2/rib) d = 254 mm; K = 0.028; z = 241 mm A_{sreq} = 529 mm^2 ∴ σ_s = 434.8(529/805) [(4.30 + 5.0)/13.38] (65.3/61.7$^{\$}$) = 434.8 × 0.66 × 0.70 × 1.06 = 213 MPa F3 = 310/213 = 1.45 Permissible l/d = 22.8 × 1.3 × 0.8 × 0.93 × 1.45 = 32.0 Actual l/d = 7500/254 = 29.5 ∴ OK Use 1H25 + 1H20/rib (805 mm^2/rib)

61	3.3.6b)	**Span B–C – : Deflection** F3 = $310/\sigma_s \leq 1.5$ where $\sigma_s = (f_{yk}/\gamma_s)(A_{s,req}/A_{s,prov})$ (SLS loads/ULS loads) $(1/\delta)$ = 434.8 × (474/628) [(4.30 + 0.3 × 5.0)/13.38](61.1/55.9) = 434.8 × 0.75 × 0.43 × 1.09 = 153 MPa F3 = $310/\sigma_s$ = 310/153 = 2.03, say = 1.50[2] ∴ Permissible l/d = 26.8 × 1.5 × 0.8 × 0.77 × 1.50 = 37.1 Actual l/d = 9000/257 = 35 ∴ OK ∴ Use 2 H20/rib (628 mm²/rib)	**Span B–C – : Deflection** F3 = $310/\sigma_s \leq 1.5$ where $\sigma_s = (f_{yk}/\gamma_s)(A_{s,req}/A_{s,prov})$ (SLS loads/ULS loads) $(1/\delta)$ = 434.8 × (474/628) [(4.30 + 5.0) /13.38](61.1/55.9) = 434.8 × 0.75 × 0.70 × 1.09 = 249 MPa F3 = $310/\sigma_s$ = 310/249 = 1.24 ∴ Permissible l/d = 26.8 × 1.5 × 0.8 × 0.77 × 1.24 = 30.7 Actual l/d = 9000/257 = 35 ∴ no good Try 1H25 + 1H20/rib (805 mm²/rib) d = 254 mm; K = 0.025; z = 241 mm $A_{s,req}$ = 480 mm² ∴ σ_s = 434.8(480/805) [(4.30 + 5.0)/13.38] (61.1/55.9) = 434.8 × 0.60 × 0.70 × 1.09 = 199 MPa F3 = 310/199 = 1.56 but ≤ 1.50 Permissible l/d = 26.8 × 1.5 × 0.8 × 0.77 × 1.50 = 37.1 Actual l/d = 9000/254 = 35.4 ∴ OK Use 1H25 + 1H20/rib (805 mm²/rib)
65	3.3.10	Figure 3.15	See B below
69	3.3.10b) viii	**Support B (and C): bottom steel curtailment BA and BC** To suit prefabrication 2 no. H20/rib will be curtailed at solid/rib interface, 1000 mm from B_A (B towards A) and B_C.	**Support B (and C): bottom steel curtailment BA and BC** To suit prefabrication 1 H20 + 1H25 /rib will be curtailed at solid/rib interface, 1000 mm from B_A (B towards A) and B_C.
69	3.3.10c)	**Laps** At A_B, check lap 1 no. H20 B to 2 no. H20 B in rib full tension lap: $l_0 = \alpha_1 \alpha_6 l_{b,rqd} > l_{0,min}$ where α_1 = 1.0 (c_d = 45 mm, i.e. < 3φ) α_6 = 1.5 (as > 50% being lapped) $l_{b,rqd} = (\varphi/4)(\sigma_{sd}/f_{bd})$ where φ = 20 σ_{sd} = 434.8 f_{bd} = 3.0 MPa as before	**Laps** At A_B, check lap 1 no. H20 B to 1 H20 B + 1H25 B in rib full tension lap: $l_0 = \alpha_1 \alpha_6 l_{b,rqd} > l_{0,min}$ where α_1 = 1.0 (c_d = 45 mm, i.e. < 3φ) α_6 = 1.5 (as > 50% being lapped) $l_{b,rqd} = (\varphi/4)(\sigma_{sd}/f_{bd})$ where φ = 20 σ_{sd} = 434.8 (bar assumed to be fully stressed) f_{bd} = 3.0 MPa as before
65	3.3.10d)	Figure 3.17	See C below
74	3.4.5b)	F3 = $310/\sigma_s \leq 1.5$ where	F3 = $310/\sigma_s \leq 1.5$ where

[2] Both $A_{s,prov}/A_{s,req}$ and any adjustment to N obtained from Expression (7.16a) or Expression (7.16b) is restricted to 1.5 by Note 5 to Table NA.5 in the UK NA.

		$\sigma_s = \sigma_{sn} (A_{s,req}/A_{s,prov}) 1/\delta$ where σ_{sn} = (500/1.15) × (8.5 + 0.3 × 4.0) /16.6 = 254 MPa (or ≈ 253 MPa (From *Concise* Figure 15.3 for G_k/Q_k = 2.1, ψ_2 = 0.3 and γ_g = 1.25) δ = redistribution ratio = 1.03 ∴ σ_s ≈ 253 × (1324/1570)/1.03 = 207 ∴ F3 = 310/207 = 1.50 ∴ Allowable l/d = 20.3 × 1.2 × 1.50 = 36.5 Actual l/d = 9500/260 = 36.5 ∴ OK Use H20 @ 200 B1 (1570)	$\sigma_s = \sigma_{sn} (A_{s,req}/A_{s,prov}) 1/\delta$ where σ_{sn} = (500/1.15) × (8.5 + 4.0) /16.6 = 327 MPa δ = redistribution ratio = 1.03 ∴ σ_s ≈ 327 × (1324/1570)/1.03 = 267 ∴ F3 = 310/267 = 1.16 ∴ Allowable l/d = 20.3 × 1.2 × 1.16 = 28.2 Actual l/d = 9500/260 = 36.5 ∴ no good Try H16 @100 (2010 mm²/m) and F3 = $A_{s,prov}/A_{s,req} \leq$ 1.50 = 2010/ 1340 = 1.50 ≤ 1.50 ∴ Allowable l/d = 20.3 × 1.2 × 1.50 = 36.5 Actual l/d = 36.5 ∴ OK Use H16@100B1 (2093 mm²/m)
78	3.4.7b)	Allowable l/d = N × K × F1 × F2 × F3 where N = 26.2 (ρ = 0.40%, f_{ck} = 30) K = 1.2 (flat slab) F1 = 1.0 (b_{eff}/b_w = 1.0) F2 = 1.0 (no brittle partitions) F3 = 310/σ_s where $\sigma_s = \sigma_{sn} (A_{s,req}/A_{s,prov}) 1/\delta$ where σ_{sn} ≈ 283 MPa (from *Concise* Figure 15.3 and G_k/Q_k = 3.6, ψ_2 = 0.3, γ_g = 1.25) δ = redistribution ratio = 1.08 ∴ σ_s ≈ 283 × (959/1005)/1.08 = 250 ∴ F3 = 310/250 = 1.24 ∴ Allowable l/d = 26.2 × 1.2 × 1.24 = 39.0 Actual l/d = 5900/240 = 24.5 ∴ OK Use H16 @ 200 B2 (1005 mm²/m)	Allowable l/d = N × K × F1 × F2 × F3 where N = 26.2 (ρ = 0.40%, f_{ck} = 30) K = 1.2 (flat slab) F1 = 1.0 (b_{eff}/b_w = 1.0) F2 = 1.0 (no brittle partitions) F3 = $A_{s,prov}/A_{s,req} \leq$ 1.50 = 1005/ 959 = 1.05 ≤ 1.50 ∴ Allowable l/d = 26.2 × 1.2 × 1.05 = 33.0 Actual l/d = 5900/240 = 24.5 ∴ OK Use H16 @ 200 B2 (1005 mm²/m)
90	3.4.13	Spans 1–2 and 2–3: Column strip and middle strip: H20 @ 200 B	Spans 1–2 and 2–3: Column strip and middle strip: H16 @ 100 B1
92	3.4.13	Figure 3.26	See D below
112	4.2.6	F3 = 310/$\sigma_s \leq$ 1.5 where σ_s in simple situations = (f_{yk}/γ_S) $(A_{s,req}/A_{s,prov})$ (SLS loads/ULS loads) (1/δ). However in this case separate analysis at SLS would be required to determine σ_s. Therefore as a simplification use the conservative assumption: 310/σ_s = (500/f_{yk}) $(A_{s,req}/A_{s,prov})$ = (500/500)×(4824/4158) = 1.16	F3 = $A_{s,prov}/A_{s,req} \leq$ 1.50 = 4824/4158 = 1.16

123	4.3.5b)	F3 = $310/\sigma_s \le 1.5$ where $\sigma_s = (f_{yk}/\gamma_S)(A_{s,req}/A_{s,prov})$(SLS loads/ULS loads)$(1/\delta)$ $= 434.8 \times (5835/5892)\,[(47.8+0.3\times 45.8)/(1.25\times 47.8+1.5\times 45.8)]\times(1/0.945)$ $= 434.8 \times 0.99 \times 0.48 \times 1.06$ = 219 MPa	F3 = $A_{s,prov}/A_{s,req} \le 1.50$ = 5892 / 5835 = 1.01
124	4.3.5b)	F3 = $310/\sigma_s \le 1.5$ = 310/219 = 1.41 ∴ Permissible $l/d = 17.8\times 1.3\times 0.90\times 0.95\times 1.41 = 27.9$ Actual l/d = 7500/252 = 29.8 ∴ no good Try 13 no. H25 B (6383 mm^2) F3 = $310/\sigma_s$ = 310/219 × 13/12 = 1.53[3] = say 1.50 ∴ Permissible $l/d = 17.8\times 1.3\times 0.90\times 0.95\times 1.50 = 29.7$ Actual l_{eff}/d = 7400/252 = 29.8 Say OK Use 13 no. H25 B (6383 mm^2)	∴ Permissible $l/d = 17.8\times 1.3\times 0.90\times 0.95\times 1.01 = 20.0$ Actual l/d = 7500/252 = 29.8 ∴ no good Try 12 no. H32 B (9648 mm^2) F3 = $A_{s,prov}/A_{s,req} \le 1.50$ = 9648 /5835 = 1.65[4] = say 1.50 ∴ Permissible $l/d = 17.8\times 1.3\times 0.90\times 0.95\times 1.50 = 29.7$ Actual l_{eff}/d = 7400/252 = 29.8 Say OK Use 13 no. H25 B (6383 mm^2)
124	4.3.6	Figure 4.20	See E below
127	4.3.7d)	F3 = $310/\sigma_s \le 1.5$ where $\sigma_s = (f_{yk}/\gamma_S)(A_{s,req}/A_{s,prov})$(SLS loads/ULS loads)$(1/\delta)$ $= 434.8 \times (3783/3828)[(47.8+0.3\times 45.8)/(1.25\times 47.8+1.5\times 45.8)]\times(1/0.908)$ $= 434.8 \times 0.99 \times 0.48 \times 1.10$ = 227 MPa F3 = $310/\sigma_s$ = 310/227 = 1.37 ∴ Permissible $l/d = 44.7 \times 1.37 \times 0.88 \times 0.95 \times 1.37 = 70.1$ Actual l/d = 7500/252 = 29.8 ∴ OK Use 8 no. H25 B (3928 mm^2)	F3 = $A_{s,prov}/A_{s,req} \le 1.50$ = 3828/3783 = 1.01 ∴ Permissible l/d $= 44.7 \times 1.50 \times 0.88 \times 0.95 \times 1.01 = 56.6$ (which is < 40K = 40 × 1.5 = 60) [Table NA.5 Note 6] Actual l/d = 7500/252 = 29.8 ∴ OK Use 8 no. H25 B (3928 mm^2
133	4.3.10	Figures 4.22 and 4.23	See F below
146	5.3	Figure 5.6 300 mm flat slabs All columns 400 mm sq	300 mm flat slabs All columns 500 mm sq
153	5.3.8	Changes req'd	
183	Refer-ences	**1a** National Annex to Eurocode 2- Part 1-1. BSI 2005	**1a** National Annex to Eurocode 2- Part 1-1. Incorporating Amendment No.1 BSI 2009
183	Refer-ences	**5** R S NARAYANAN & C H GOODCHILD. The Concrete Centre. Concise Eurocode 2, CCIP-005. TCC 2006	**5** R S NARAYANAN & C H GOODCHILD. The Concrete Centre. Concise Eurocode 2, CCIP-005. TCC 2006 As Amended

[3] Both $A_{s,prov}/A_{s,req}$ and any adjustment to N obtained from Expression (7.16a) or Expression (7.16b) is restricted to 1.5 by Note 5 to Table NA.5 in the UK NA.

[4] Both $A_{s,prov}/A_{s,req}$ and any adjustment to N obtained from Expression (7.16a) or Expression (7.16b) is restricted to 1.5 by Note 5 to Table NA.5 in the UK NA.

			2010
190	B1.1	Delete existing text. See G below	New text: According to Note 5 of Table NA.5 the NA to BS EN 1992-1-1[1a] the modification factor for service stress used with the l/d method of checking the SLS state of deformation (designated factor F3 in TCC publications) may be determined as either • $310/\sigma_s$ using characteristic load combinations to determine the service stress, σ_s or • $(500/f_{yk})(A_{s,prov} / A_{s,req})$ In either case the modification factor is restricted to a maximum of 1.50. In the UK f_{yk} = 500 MPa. Assuming σ_s is proportional to σ_u, and using characteristic load combinations to determine σ_s produces values of $310/\sigma_s$ = 1.00 +3% - 6%. and so is not as attractive to using $A_{s,prov} / A_{s,req}$. The use of F3 = $A_{s,prov} / A_{s,req} \leq 1.5$ is therefore advocated in checking deformation using the l/d method.
190	B1.2	See H below	
191	B1.4	See J below	
191	B1.5	See K below	
201	C7	See L below	
204	C8	See M below	

A Amends to p 51 Figure 3.7

3.2.11 Summary of reinforcement details

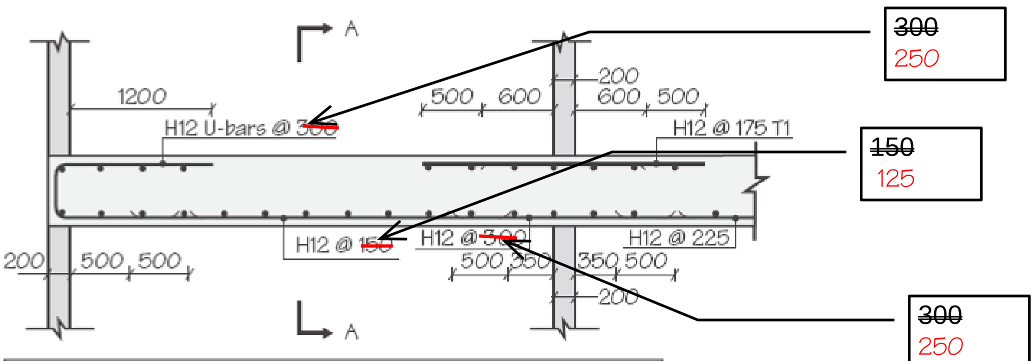


Figure 3.6 Continuous solid slab: reinforcement details

B Amends to p 65 Figure 3.15

3.3.10 Summary of design

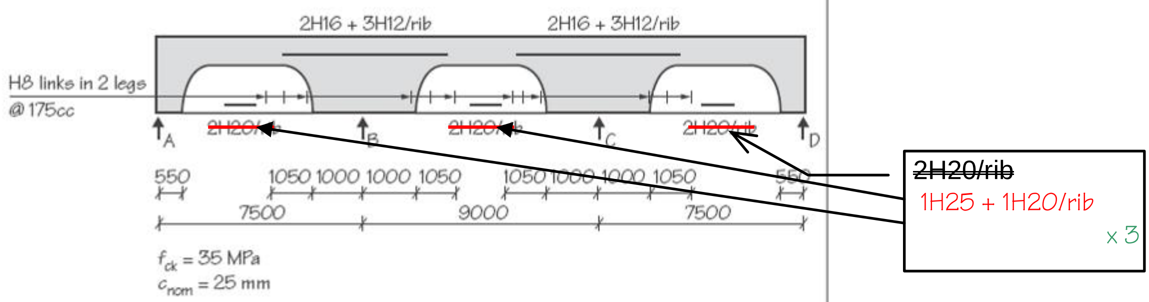
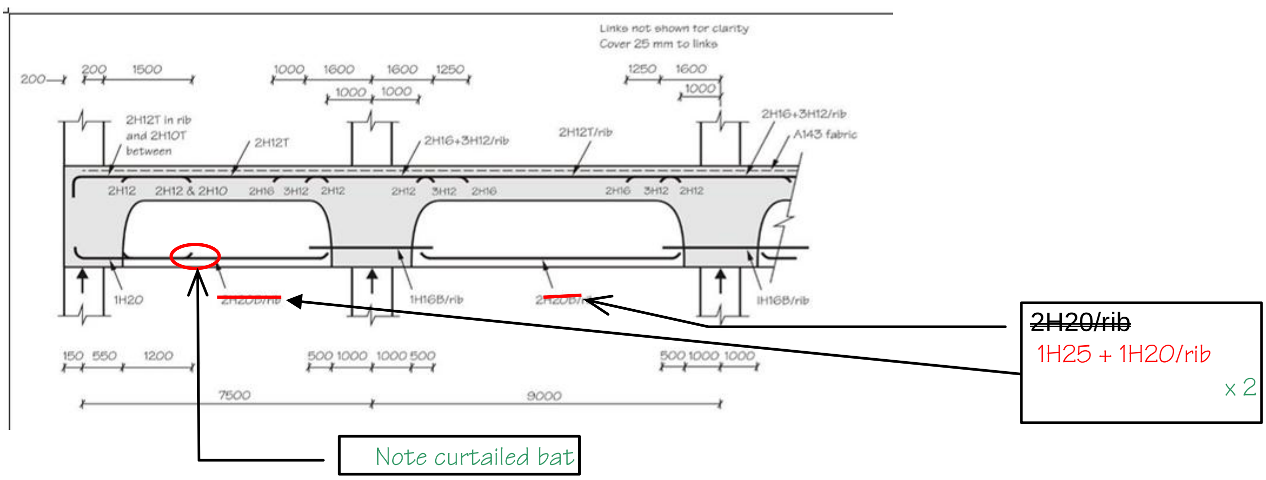
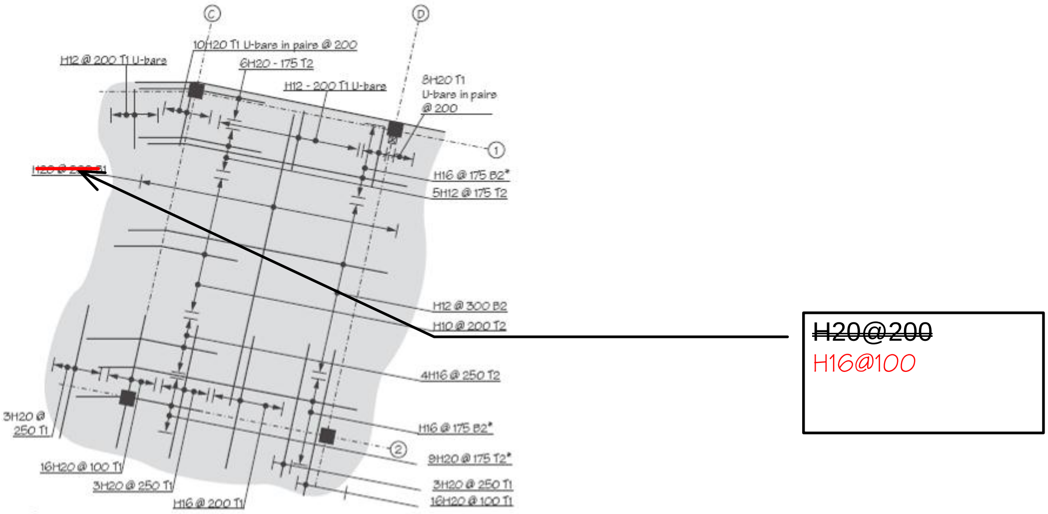


Figure 3.15 Summary of design

C Amends to p 70 Figure 3.17



D Amends to p 92 Figure 3.26



Note:* Spacing rationalised to suit punching shear links

Figure 3.26 Reinforcement details bay C–D, 1–2

E Amends to p 124 Figure 4.20

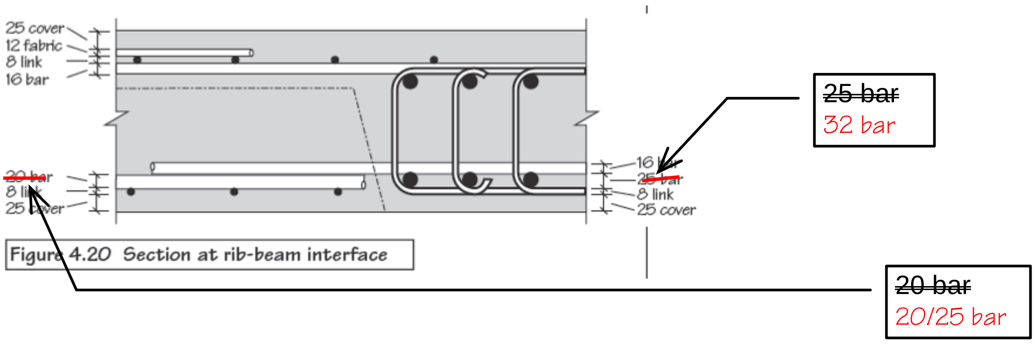


Figure 4.20 Section at rib-beam interface

F Amends to p133 Figures 4.22 and 4.23

4.3.11 Summary of design

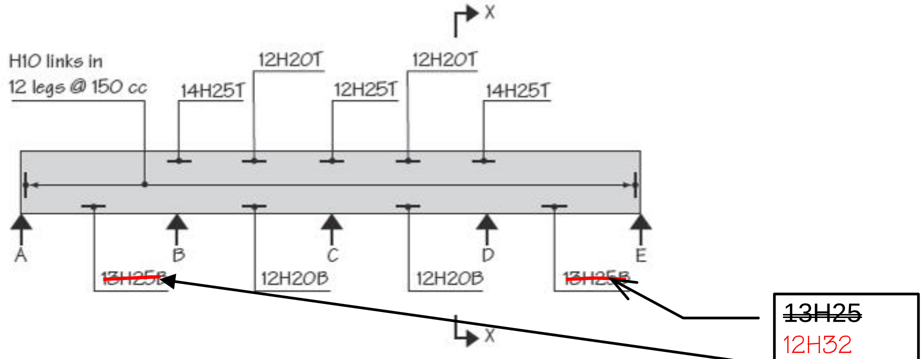


Figure 4.22 Summary of design

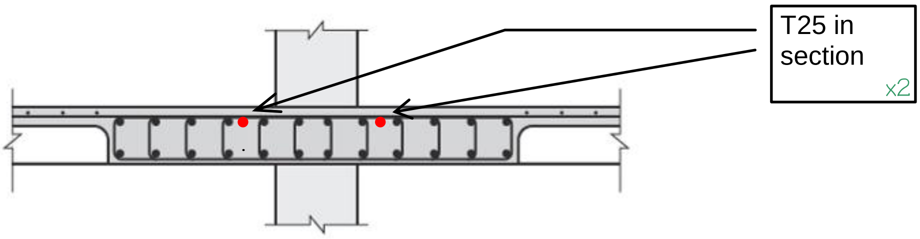


Figure 4.23 Section X–X

G Amends to p190 B1.1

B1.1 TCC method[5,19]

The in-service stress of reinforcement, σ_s, is used to determine a factor, $310/\sigma_s$, which is used to modify the basic span:effective depth ratio as allowed in Cl. 7.4.2(2) of Eurocode 2[1] and moderated by the National Annex[2a]. This method, highlighted as factor F3 in *Concise Eurocode 2*[5], is intended to be used in hand calculations to derive (conservative) values of σ_s from available ULS moments. In accordance with Note 5 of Table NA.5 of the UK NA[2a], the ratio for $A_{s,prov}/A_{s,req}$ is restricted to 1.5; in effect this limits the factor $310/\sigma_s$ to 1.5.

where‡

$$\sigma_s = (f_{yk}/\gamma_S)\,(w_{qp}/w_{ult})\,(A_{s,req}/A_{s,prov})\,/\,\delta \le 310/1.5$$

where

f_{yk} = characteristic strength of reinforcement = 500 MPa
γ_S = partial factor for reinforcement = 1.15
w_{qp} = quasi-permanent load (UDL assumed)
w_{perm} = ultimate load (UDL assumed)
$A_{s,req}$ = area of reinforcement required
$A_{s,prov}$ = area of reinforcement provided
δ = redistribution ratio

NewText

According to Note 5 of Table NA.5 the NA to BS EN 1992-1-1[1a] the modification factor for service stress used with the l/d method of checking the SLS state of deformation (designated factor F3 in TCC publications) may be determined as either

- $310/\sigma_s$ using characteristic load combinations to determine the service stress, σ_s

or

- $(500/f_{yk})(A_{s,prov}/A_{s,req})$

In either case the modification factor is restricted to a maximum of 1.50. In the UK

f_{yk} = 500 MPa.

Assuming σ_s is simply proportional to the ultimate stress, σ_u, produces values of $310/\sigma_s$ = 1.00 +/- 5% and so for hand calculations is not as attractive as using $A_{s,prov}/A_{s,req}$.

The use of F3 = $A_{s,prov}/A_{s,req} \le 1.5$ is therefore advocated in checking deformation using the l/d method by hand.

H Amends to p190 B1.2

combination values of actions

B1.2 RC Spreadsheets method[28]

The RC spreadsheets TCCxx.xls [28] use the span:depth method of checking deformation but use an accurate method for determining σ_s (see B3.2 below), which ~~again~~ is used to determine the moderating factor = $310/\sigma_s$. ~~Again, in accordance with Note 5 of Table NA.5 of the UK NA~~[2a], ~~the ratio for $A_{s,prov}/A_{s,req}$ is restricted to 1.5: in effect this limits the factor $310/\sigma_s$ to 1.5.~~

combination values of actions taking account of SLS moments, compression reinforcement, $A_{s,prov}/A_{s,req}$, etc.

Separate analyses using ~~quasi-permanent loads~~ need to be carried out. For each span, an SLS neutral axis depth is determined, then σ_c and σ_s are derived for the ~~quasi-permanent load conditions~~. The factor ~~σ_s~~ is used in accordance with Eurocode 2~~[2]~~ and the current National Annex~~[2a]~~, to modify the basic span:effective depth ratio.

[1]

$310/\sigma_s$

Whilst this method gives ~~a more accurate and less conservative~~ assessment of σ_s, it is only suitable for computer spreadsheet applications. ~~See also Appendix B5~~.

In the analysis of slabs and beams, supports are usually assumed to be pinned. In reality supports have some continuity, especially at end supports. Usually, nominal top steel is assumed and provided in the top of spans and is used in the determination of section properties.

[1a]

NewText

an accurate

J Amends to p191 B1.4

B1.4 Differing results

were

During 2008, it became increasingly apparent that there ~~are~~ inconsistencies between the results given by the rigorous calculation method and span:depth methods described in Eurocode 2. Using the rigorous method gives deflections that are greater than would be expected from the assumptions stated for L/d methods i.e. deflection limits of $L/250$ overall (see Cl. 7.4.1(4)) or $L/500$ after construction (see Cl. 7.4.1(5)). It is suspected that this disparity is the same as that experienced between span:depth and calculation methods in BS 8110: a disparity that was recognised as long ago as 1971[33]. The rigorous method described above relies on many assumptions and is largely uncalibrated against real structures. As noted in TR58, there is an urgent need for data from actual structures so that methods may be calibrated. It should be noted that the rigorous analysis method observations were made using frequent loads where, in accordance with Eurocode 2, quasi-permanent loads are called for.

Add new text

using the quasi permanent values of actions (see B.4)

~~End spans are usually critical. With respect to the rigorous analysis method, it has been suggested that for end-spans, the TCC and RC-spreadsheet methods result in deflections close to the limits stated in Eurocode 2, provided that a nominal end-support restraining moment is present where none is assumed in analysis. Caution is therefore necessary in true pinned end-support situations but where some continuity exists, this disparity may be addressed by ensuring that appropriate amounts of reinforcement, in accordance with the Code and National Annex, are provided at end supports.~~

~~The NDP for Cl. 9.2.1.2(1) in the UK NA[2a] to BS EN 1992–1–2 stipulates that 25% of end span moment should be used to determine end support reinforcement. This is usually accommodated by providing 25% of end span bottom steel as top steel at end supports. It is on this basis that the calculations in this publication are considered as being further substantiated.~~

New para

In the light of the above disparity and pending clarification, the UK NA was revised and published in December 2009 as detailed in B1.1 above.

K Amends to p191 B1.4

B1.5 Note regarding factor $310/\sigma_s$ (factor F3)

At the time of publication (December 2009) the authors were aware of a probable change to UK NA[2a] Table NA.5 which, in effect, would mean that the factor $310/\sigma_s$ (F3) = $A_{s,prov}/A_{s,req} \leq 1.5$, thus disallowing the accurate method outlined in Sections 3.1, 3.2, 3.3, 3.4, 4.3 and Appendices B1.1, B1.2 and C7.

New paras

Prior to the publication of the revised UK NA[1a] it was allowable to calculate the moderation factor using in l/d verifications of deformation(F3) by using quasi permanent loads.

Assuming σ_s due to quasi permanent actions is proportional to σ_u, the method as outlined in C8 may be used to determine σ_s in verifications of crack widths, etc.

L Amends to p201 C7

F3 = factor to account for service stress in tensile reinforcement = $310/\sigma_s \leq 1.5$

Conservatively, if a service stress, σ_s, of 310 MPa is assumed for the designed area of reinforcement, $A_{s,req}$ then F3 = $A_{s,prov}/A_{s,req} \leq 1.5$.

More accurately,‡ the serviceability stress, σ_s, may be estimated as follows:

$\sigma_s = f_{yk}/\gamma_S[(G_k + \psi_2 Q_k)/(1.25G_k + 1.5Q_k)]\,[A_{s,req}/A_{s,prov}]\,(1/\delta)$

or

$\sigma_s = \sigma_{su}\,[A_{s,req}/A_{s,prov}]\,(1/\delta)$

where

σ_{su} = the unmodified SLS steel stress, taking account of γ_M for reinforcement and of going from ultimate actions to serviceability actions
= $500/\gamma_S(G_k + \psi_2 Q_k)/(1.25G_k + 1.5Q_k)$
σ_{su} may be estimated from Figure C3 as indicated by the blue arrow

$A_{s,req}/A_{s,prov}$ = area of steel required divided by area of steel provided.

$(1/\delta)$ = factor to 'un-redistribute' ULS moments so they may be used in this SLS verification (see Table C14)

Actual l/d = actual span divided by effective depth, d.

New text:
either

- $310/\sigma_s$ using characteristic load combinations to determine the service stress, σ_s

or

- $(500/f_{yk})(A_{s,prov}/A_{s,req})$

In either case the modification factor is restricted to a maximum of 1.50.

M Amends to p204 C8

C8 Control of cracking

Cracking may be controlled by restricting either maximum bar diameter or maximum bar spacing to the relevant diameters and spacings given in Table C15. The appropriate SLS stress in reinforcement, σ_s, may be determined as outlined ~~for F3 in Section C7~~.

below

New text ex p 201:

$$\sigma_s = f_{yk}/\gamma_S[(G_k + \psi_2 Q_k)/(1.25G_k + 1.5Q_k)]\,[A_{s,req}/A_{s,prov}]\,(1/\delta)$$

or

$$\sigma_s = \sigma_{su}\,[A_{s,req}/A_{s,prov}]\,(1/\delta)$$

where

σ_{su} = the unmodified SLS steel stress, taking account of γ_M for reinforcement and of going from ultimate actions to serviceability actions

= $500/\gamma_S(G_k + \psi_2 Q_k)/(1.25G_k + 1.5Q_k)$

σ_{su} may be estimated from Figure C3 as indicated by the blue arrow

$A_{s,req}/A_{s,prov}$ = area of steel required divided by area of steel provided.

$(1/\delta)$ = factor to 'un-redistribute' ULS moments so they may be used in this SLS verification (see Table C14)

chg 25 Feb 2010

Errata – Worked Examples to Eurocode 2
Published 2009
CCIP-041

Page 13 – Wind loads

In the following extract, q_b, should be calculated at $q_b = 0.0006\ v_b^2$ kN/m^2.

2.6 Variable actions: wind loads

This Section presents a very simple interpretation of Eurocode 1[11, 11a] and is intended to provide a basic understanding with respect to rectangular-plan buildings with flat roofs. In general, maximum values are given: with more information a lower value might be used. The user should be careful to ensure that any information used is within the scope of the application envisaged. The user is referred to more specialist guidance[23, 24] or BS EN 1991–1–4[25] and its UK National Annex[25a]. The National Annex includes clear and concise flow charts for the determination of peak velocity pressure, q_p.

In essence characteristic wind load can be expressed as:

$w_k = c_f\, q_{p(z)}$

where
c_f = force coefficient, which varies, but is a max. of 1.3 for overall load
$q_{p(z)} = c_{e(z)}\, c_{eT}\, q_b$
where
$c_{e(z)}$ = exposure factor from Figure 2.3
c_{eT} = town terrain factor from Figure 2.4
q_b = $0.006 v_b^2$ kN/m^2
where
$v_b = v_{b,map} c_{alt}$
where
$v_{b,map}$ = fundamental basic wind velocity from Figure 2.2
c_{alt} = altitude factor, conservatively, $c_{alt} = 1 + 0.001A$
where
A = altitude a.m.s.l

EC1-1-4: Figs NA.7, NA.8

EC1-1-4: Fig. NA.1

Symbols abbreviations and some of the caveats are explained in the sections below, which together provide a procedure for determining wind load to BS EN 1991–1–4.

Page 83 – Flat slab: Punching shear for column C2

In accordance with clause 6.4.5 of BS EN 1992-1-1:2004+A1:2014 and the UK National Annex, $V_{Ed} \leq 2\ V_{Rd,c}$ at the basic control perimeter, u_1. This requires an additional check in section 3.4.10b (extract below) – this is as follows:

V_{Ed} = 1.17 MPa

$V_{Rd,c}$ = 0.61 MPa => 2 $V_{Rd,c}$ = 1.22 MPa > V_{Ed} => <u>OK</u>

b) Check shear stress at control perimeter u_1 (2d from face of column)	**Cl. 6.4.2**
$v_{Ed} = \beta V_{Ed}/u_1 d < v_{Rd,c}$	
where	
β, V_{Ed} and d as before	
u_1 = control perimeter under consideration.	**Fig. 6.13**
For punching shear at 2d from interior columns	
$u_1 = 2(c_x + c_y) + 2\pi \times 2d = 4741$ mm	
$v_{Ed} = 1.15 \times 1204.8 \times 10^3/4741 \times 250 = 1.17$ MPa	
$v_{Rd,c} = 0.18/\ \gamma_C\ k\ (100\ \rho_l f_{ck})^{0.333}$	**Exp. (6.47) & NA**
where	
$\gamma_C = 1.5$	
$k = 1 + (200/d)^{0.5} \leq 2$ $k = 1 + (200/250)^{0.5} = 1.89$	
$\rho_l = (\rho_{ly}\ \rho_{lz})0.5 = (0.0085 \times 0.0048)^{0.5} = 0.0064$	**Cl. 6.4.4.1(1)**
where	
ρ_{ly}, ρ_{lz} = Reinforcement ratio of bonded steel in the y and z direction in a width of the column plus 3d each side of column#	
$f_{ck} = 30$	
$v_{Rd,c} = 0.18/1.5 \times 1.89 \times (100 \times 0.0064 \times 30)^{0.333} = 0.61$ MPa	
$\therefore$ <u>Punching shear reinforcement required</u>	Table C5*

<u>Page 86 – Flat slab: Punching shear for edge column</u>

In accordance with clause 6.4.5 of BS EN 1992-1-1:2004+A1:2014 and the UK National Annex, $V_{Ed} \leq 2\ V_{Rd,c}$ at the basic control perimeter, u_1. This requires an additional check in section 3.4.11b (extract below) – this is as follows:

V_{Ed} = 1.23 MPa

$V_{Rd,c}$ = 0.64 MPa => 2 $V_{Rd,c}$ = 1.28 MPa > V_{Ed} => <u>OK</u>

b) Check shear stress at basic perimeter u_1 (2.0d from face of column)	**Cl. 6.4.2**
$v_{Ed} = \beta V_{Ed}/u_1 d < v_{Rd,c}$	
where	
β, V_{Ed} and d as before	
u_1 = control perimeter under consideration.	**Fig. 6.15**
For punching shear at 2d from edge column columns	
$u_1 = c_2 + 2c_1 + \pi \times 2d = 2771$ mm	
$v_{Ed} = 1.4 \times 609.5 \times 10^3/2771 \times 250 = 1.23$ MPa	
$v_{Rd,c} = 0.18/\ \gamma_C \times k \times (100\ \rho_l f_{ck})^{0.333}$	**Exp. (6.47) & NA**
where	
γ_C = 1.5	
k = as before = $1 + (200/250)^{0.5} = 1.89$	
$\rho_l = (\rho_{ly}\rho_{lz})^{0.5}$	
where	**Cl. 6.4.4.1(1)**
ρ_{ly}, ρ_{lz} = Reinforcement ratio of bonded steel in the y and z direction in a width of the column plus 3d each side of column.	
ρ_{ly}: (perpendicular to edge) 10 no. H20 T2 + 6 no. H12 T2 in 2 × 750 + 400, i.e. 3818 mm^2 in 1900 mm	
$\therefore \rho_{ly}$ = 3818/(250 × 1900) = 0.0080	
ρ_{lz}: (parallel to edge) 6 no. H20 T1 + 1 no. T12 T1 in 400 + 750 i.e. 1997 mm^2 in 1150 mm.	
$\therefore \rho_{lz}$ = 1997/(250 × 1150) = 0.0069	
$\rho_l = (0.0080 \times 0.0069)^{0.5} = 0.0074$	
f_{ck} = 30	
$v_{Rd,c} = 0.18/1.5 \times 1.89 \times (100 \times 0.0074 \times 30)^{0.333} = 0.64$ MPa	Table C6‡
<u>∴ Punching shear reinforcement required</u>	

<u>Page 88/89 and Figure 3.25 – Flat slab: Punching shear for edge column with hole</u>

In accordance with clause 6.4.5 of BS EN 1992-1-1:2004+A1:2014 and the UK National Annex, $V_{Ed} \leq 2\ V_{Rd,c}$ at the basic control perimeter, u_1. This requires an additional check in section 3.4.12b (extract below) – this is as follows:

V_{Ed} = 1.40 MPa

$V_{Rd,c}$ = 0.64 MPa => 2 $V_{Rd,c}$ = 1.28 MPa < V_{Ed} => <u>need to increase ρ</u>

> For the punching shear check in section 3.4.12, a reinforcement ratio greater than ρ = 0.01014 is necessary to meet the limit on V_{Ed} / V_{Rdc}. This may be achieved with H20 bars at 100mm centres. The change will affect the longitudinal reinforcement layout shown in Figures 3.25 and 3.27 but would not lead to an increase in punching shear reinforcement required.

b) **Check shear stress at basic perimeter u_1 (2.0*d* from face of column)**	**Cl. 6.4.2**
$v_{Ed} = \beta V_{Ed}/u_1 d < v_{Rd,c}$	
where	
β, V_{Ed} and *d* as before	
u_1 = control perimeter under consideration. For punching shear at 2*d* from edge column columns	**Fig. 6.15**
$u_1 = c_2 + 2c_1 + \pi \times 2d = 2771$ mm	
Allowing for hole	
$200/(c_1/2): x/(c_1/2 + 2d)$	**Fig. 6.14**
200/200: x/(200 + 500)	
∴ x = 700 mm	
$u_1 = 2771 - 700 = 2071$ mm	
$v_{Ed} = 1.4 \times 516.5 \times 10^3/2071 \times 250 = 1.40$ MPa	
$v_{Rd,c} = 0.18/\gamma_C \times k \times (100\ \rho_l f_{ck})^{0.333}$	**Exp. (6.47) & NA**
where	
γ_C = 1.5	
k = as before = $1 + (200/250)^{0.5} = 1.89$	
$\rho_l = (\rho_{ly}\rho_{lz})^{0.5}$	
where	
ρ_{ly}, ρ_{lz} = Reinforcement ratio of bonded steel in the y and z direction in a width of the column plus 3*d* each side of column	**Cl. 6.4.4.1(1)**
ρ_{ly}: (perpendicular to edge) 8 no. H20 T2 + 6 no. H12 T2 in 2 × 720 + 400 – 200, i.e. 3190 mm^2 in 1640 mm.	
$\therefore \rho_{ly} = 3190/(240 \times 1640) = 0.0081$	
ρ_{lz}: (parallel to edge) 6 no. H20 T1 (5 no. are effective) + 1 no. T12 T1 in 400 + 750 – 200, i.e. 1683 mm^2 in 950 mm.	
$\therefore \rho_{lz} = 1683/(260 \times 950) = 0.0068$	

$\rho_l = (0.0081 \times 0.0068)^{0.5} = 0.0074$	
$f_{ck} = 30$	
$v_{Rd,c} = 0.18/1.5 \times 1.89 \times (100 \times 0.0074 \times 30)^{0.33} = 0.64$ MPa	Table C6‡
∴ <u>punching shear reinforcement required</u>	

<u>Page 94 – Punching shear reinforcement: V_{Ed} / $V_{Rd,c}$</u>

After publication of the guide, a limit on V_{Ed} / V_{Rdc} was introduced. The recommended limit in accordance with clause 6.4.5 of BS EN 1992-1-1:2004+A1:2014 is 1.5 at the basic control perimeter, u_1, however the UK National Annex recommends a limit of $V_{Ed} \leq 2\ V_{Rd,c}$.

$V_{Ed}/V_{Rd,c}$

In late 2008, a proposal was made for the UK National Annex to include a limit of 2.0 or 2.5 on $V_{Ed}/V_{Rd,c}$ (or $v_{Ed}/v_{Rd,c}$) within punching shear requirements. It is apparent that this limitation could have major effects on flat slabs supported on relatively small columns. For instance in Section 3.4.12, edge column with hole, $V_{Ed}/V_{Rd,c}$ = 2.18.

Page 130/131 – Continuous wide T-beam: Punching shear for column B

In accordance with clause 6.4.5 of BS EN 1992-1-1:2004+A1:2014 and the UK National Annex, $V_{Ed} \leq 2\ V_{Rd,c}$ at the basic control perimeter, u_1. This requires an additional check in section 4.3.10 (extract below) – this is as follows:

V_{Ed} = 1.17 MPa

$V_{Rd,c}$ = 0.68 MPa => 2 $V_{Rd,c}$ = 1.36 MPa > V_{Ed} => OK

4.3.10 Check for punching shear, column B	
As the beam is wide and shallow it should be checked for punching shear.	
At B, applied shear force, V_{Ed} = 569.1 + 517.9 = 1087.0 kN.	
Check at perimeter of 400 × 400 mm column:	Cl. 6.4.3(2), 6.4.5(3)
$v_{Ed} = \beta V_{Ed}/u_i d < v_{Rd,max}$	
where	
β = factor dealing with eccentricity; recommended value 1.15	
V_{Ed} = applied shear force	Fig. 6.21N & NA
u_i = control perimeter under consideration. For punching shear adjacent to interior columns $u_0 = 2(c_x + c_y)$ = 1600 mm	Cl. 6.4.5(3)
d = mean d = (245 + 226)/2 = 235 mm	Exp. (6.32)
v_{Ed} = 1.15 × 1087.0 × 10^3/1600 × 235 = 3.32 MPa	
$v_{Rd,max} = 0.5\nu f_{cd}$	Cl. 6.4.5(3) Note
where	
$\nu = 0.6(1 - f_{ck}/250) = 0.516$	Exp. (6.6) & NA
$f_{cd} = \alpha_{cc}\lambda f_{ck}/\gamma_C$ = 1.0 × 1.0 × 35/1.5 = 23.3	
$v_{Rd,max}$ = 0.5 × 0.516 × 23.3 = 6.02 MPa ∴ OK	Table C7‡
Check shear stress at basic perimeter u_1 (2.0d from face of column):	Cl. 6.4.2
$v_{Ed} = \beta V_{Ed}/u_1 d < v_{Rd,c}$	
where	
β, V_{Ed} and d as before	Fig. 6.13
‡ In this case, at the perimeter of the column, it is assumed that the strut angle is 45°, i.e. that cot θ = 1.0. In other cases, where cot θ < 1.0, $v_{Rd,max}$ is available from Table C7.	

u_1 = control perimeter under consideration. For punching shear at $2d$ from interior columns	
$= 2(c_x + c_y) + 2\pi \times 2d$	
$= 1600 + 2\pi \times 2 \times 235 = 4553$ mm	
$v_{Ed} = 1.15 \times 1087.0 \times 10^3/4553 \times 235 = 1.17$ MPa	
$v_{Rd,c} = 0.18/\gamma_C \times k \times (100\ \rho_l f_{ck})^{0.333}$	**Exp. (6.47) & NA**
where	
$\gamma_C = 1.5$	
$k = 1 + (200/d)^{0.5} \leq 2$	
$= 1 + (200/235)^{0.5} = 1.92$	
$\rho_l = (\rho_{ly}, \rho_{lz})^{0.5}$	**Cl. 6.4.4.1(1)**
where	
ρ_{ly}, ρ_{lz} = Reinforcement ratio of bonded steel in the y and z direction in a width of the column plus $3d$ each side of column.	
$= 6874/(2000 \times 226) = 0.0152$	
$\rho_{lz} = 741/(900 \times 245) = 0.0036$	
$\rho_l = (0.0152 \times 0.0036)^{0.5} = 0.0074$	
$f_{ck} = 35$	
$v_{Rd,c} = 0.18/1.5 \times 1.92 \times (100 \times 0.0074 \times 35)^{0.333} = 0.68$ MPa§	Table C6#
$\therefore$ punching shear reinforcement required	

Page 200 – Design for punching shear

After publication of the guide, a limit on V_{Ed} / V_{Rdc} was introduced. The recommended limit in accordance with clause 6.4.5 of BS EN 1992-1-1:2004+A1:2014 is 1.5 at the basic control perimeter, u_1, however the UK National Annex recommends a limit of $V_{Ed} \leq 2\ V_{Rd,c}$.