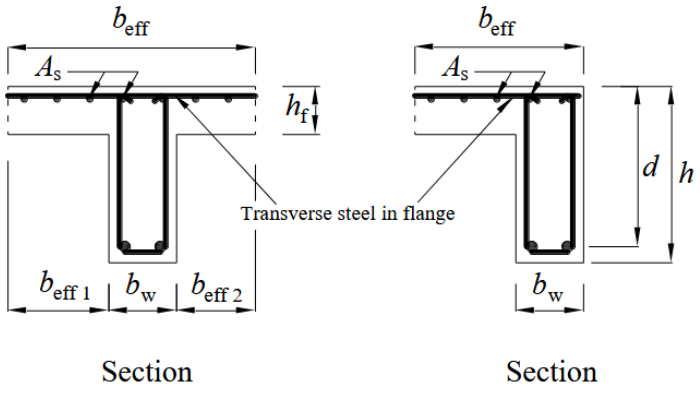
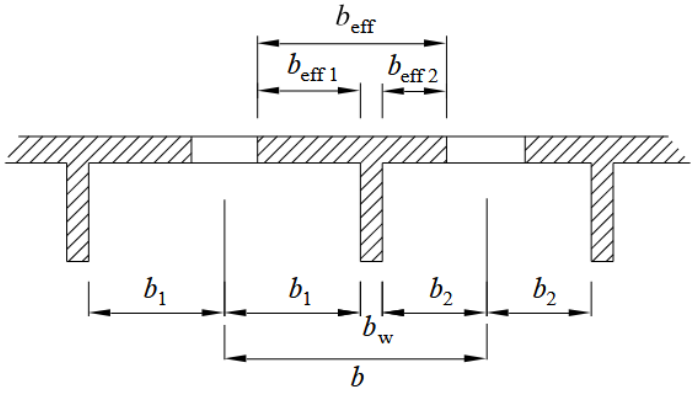
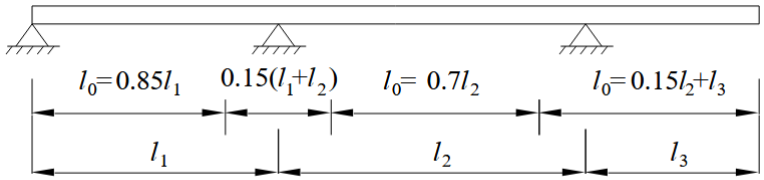
FLANGE BEAM DESIGN REPORT

Element: Flange Beam 001

Design Code: BS EN 1992-1-1:2004 | Date: 28 October 2026

REFERENCE	CALCULATIONS	OUTPUT
§5.3.2.1 Beam parameters	**Beam Parameters**  Fig 7.9 T-beam and L-beam Beam span L = 5000.0 mm Web width bw = 250.0 mm Beam depth h = 500.0 mm Flange thickness hf = 150.0 mm Concrete cover CC = 30 mm Main bar diameter H = 16 mm Link diameter = 8 mm $d = h - \frac{\phi_{main}}{2} - CC - \phi_{link}$ $d = 500.0 - \frac{16}{2} - 30 - 8 = 454.0mm$	**L = 5000.0 mm** **bw = 250.0 mm** **h = 500.0 mm** **hf = 150.0 mm** **CC = 30 mm** **d = 454.0 mm**
§5.3.2.1 Effective Flange Width	**FLANGE WIDTH CALCULATIONS**  Fig.7.11 Effective flange width parameters Left slab clear distance between supports, L1 = 3000.0 mm Right slab clear distance between supports, L2 = 3000.0 mm $b_1 = \frac{L_1}{2} = \frac{3000.0}{2} = 1500.0mm$ $b_2 = \frac{L_2}{2} = \frac{3000.0}{2} = 1500.0mm$	**b1 = 1500.0 mm** **b2 = 1500.0 mm**

REFERENCE	CALCULATIONS	OUTPUT
§5.3.2.1 Effective Flange Width	**FLANGE WIDTH CALCULATIONS (continued)**  Fig 7.10 Dimensions to be used in the calculation of effective flange widths Assumed point of zero moment, lo = β × L = 0.85 × 5000.0 = 4250.0 mm **Flange width, b_{eff1}** $b_{eff1} = 0.2b_1 + 0.1l_0 \le 0.2l_0$ $b_{eff1} \le b_1$ $b_{eff1} = 0.2 \times 1500.0 + 0.1 \times 4250.0 = 725.0$ $0.2l_0 = 0.2 \times 4250.0 = 850.0$ $b_{eff1} \le 1500.0$ $b_{eff1} = min(725.0, 850.0, 1500.0) = 725.0mm$ **Flange width, b_{eff2}** $b_{eff2} = 0.2b_2 + 0.1l_0 \le 0.2l_0$ $b_{eff2} \le b_2$ $b_{eff2} = 0.2 \times 1500.0 + 0.1 \times 4250.0 = 725.0$ $0.2l_0 = 0.2 \times 4250.0 = 850.0$ $b_{eff2} \le 1500.0$ $b_{eff2} = min(725.0, 850.0, 1500.0) = 725.0mm$ **Effective flange width, b_{eff}** $b = b_1 + b_w + b_2 = 1500.0 + 250.0 + 1500.0 = 3250.0mm$ $b_{eff} = b_w + b_{eff1} + b_{eff2} \le b$ $b_{eff} = 250.0 + 725.0 + 725.0 = 1700.0mm$ $b_{eff} = min(1700.0, 3250.0) = 1700.0mm$ $\frac{b_{eff}}{b_w} = 6.8$	**lo = 4250.0 mm** **beff1 = 725.0 mm** **beff2 = 725.0 mm** **beff = 1700.0 mm** **beff/bw = 6.8**

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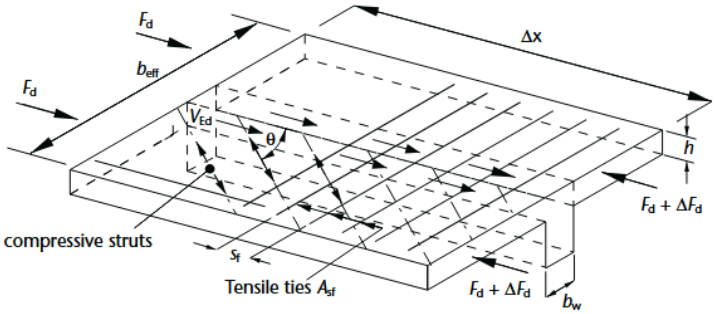
§6.1 Design Parameters	**FLEXURAL DESIGN** Design moment MEd = 200.0 kNm Concrete fck = 30.0 N/mm², Steel fyk = 500.0 N/mm² Consider 0% moment redistribution and fck ≤ C50/60 Moment redistribution factor δ = 1.0 $k_{bal} = \frac{0.454(1.0-0.44)}{1.25} - \frac{0.182(1.0-0.44)^2}{1.25^2} = 0.167$ $k = \frac{M_{Ed}}{b_{eff} d^2 f_{ck}} = \frac{200.0 \times 10^6}{1700.0 \times 454.0^2 \times 30.0} = 0.019$ Since k = 0.019 < 0.167 → Singly reinforced **Lever arm z** $\frac{z}{d} = 0.5 + \sqrt{0.25 - \frac{0.019}{1.134}} = 0.98$ $z = 0.98 \times 454.0 = 445.0mm$ Limiting value of z $z_{lim} = 0.95d = 0.95 \times 454.0 = 431.0mm$ Adopted value of z = 431.0 mm **Neutral axis depth check** Check if depth of neutral axis lies within the flange, S ≤ hf Neutral axis check: S = 2 × (d - z) $S = 2(d-z) = 2(454.0-431.0) = 45.0mm$ S = 45.0 mm ≤ hf = 150.0 mm → Neutral axis within flange,Design beam as a rectangular section of breadth beff	**k = 0.019** **kbal = 0.167** **MEd = 200.0 kNm** **z = 431.0 mm** **S = 45.0 mm** ✓ **SINGLY REINFORCED**
§6.1 Required Reinforcement	**LONGITUDINAL REINFORCEMENT IN THE WEB** $Required-Area, A_{s,req} = \frac{M_{Ed}}{0.87 f_{yk} z} = \frac{200.0 \times 10^6}{0.87 \times 30.0 \times 431.0} = 1066mm^2$ **Minimum reinforcement required** $f_{ctm} = 0.3 f_{ck}^{2/3} = = 0.3 \times 30.0^{2/3} = 2.896N/mm^2$ $A_{s,min} = 0.26 \frac{f_{ctm}}{f_{yk}} b_w d = 0.26 \times \frac{2.896}{500.0} \times 250.0 \times 454.0 = 171mm^2$ $0.0013 b_w d = 0.0013 \times 250.0 \times 454.0 = 148mm^2$ $As, min = max(148, 171) = 171mm^2$ **Maximum reinforcement** $As, max = 0.04 b_w h = 0.04 \times 250.0 \times 500.0 = 5000mm^2$ **Required reinforcement** $As, min = 171mm^2 \leq As, req = 1066mm^2 \leq As, max = 5000mm^2$ $As, req, final = 1066mm^2$	**As,req = 1066 mm²** **As,min = 171 mm²** **As,max = 5000 mm²**
§8.3 Provided Reinforcement	**PROVIDED REINFORCEMENT** $A_{s,prov,main} = \frac{\pi \phi_{main}^2}{4} \times Q_{main} = \frac{\pi \times 16^2}{4} \times 2 = 402mm^2$ $A_{s,prov,extra} = \frac{\pi \phi_{extra}^2}{4} \times Q_{extra} = \frac{\pi \times 16^2}{4} \times 1 = 201mm^2$ $As, prov = 603mm^2$ **Provide:** 2 H16 bottom steel + 1 H16 extra **Checks:** As,min ≤ As,prov ≤ As,max → INADEQUATE	**Provided Main: 2 H16** **Provided Extra: 1 H16** **Provided Area= 603 mm²** **Status: INADEQUATE**

REFERENCE	CALCULATIONS	OUTPUT
§6.2.4 Transverse Reinforcement in Flange	**TRANSVERSE REINFORCEMENT IN THE FLANGE**  **Step 1: Calculate design longitudinal shear stress V_{Ed}** For a sagging moment the longitudinal shear stresses are the greatest over a distance of Δx measured from the point of zero moment and Δx is taken as half the distance to the maximum moment at mid-span. $\Delta x = 0.5 \times \frac{L}{2} = 0.5 \times \frac{5000.0}{2} = 1250.0mm$ Therefore the change in moment ΔM over distance Δx from the zero moment is given by: $\Delta M = \frac{wL\Delta x}{2} - \frac{w(\Delta x)^2}{2}$ $\Delta M = \frac{44.0 \times 5000.0 \times 1250.0}{2 \times 10^6} - \frac{44.0 \times 1250.0^2}{2 \times 10^6} = 103.125kNm$ The change in longitudinal force ΔF at the flange web interface is given by: $\Delta F = \frac{\Delta M}{d - \frac{h_f}{2}} \times \frac{b_{f0}}{b_{eff}}$ $b_{f0} = \frac{b_{eff} - b_w}{2} = \frac{1700.0 - 250.0}{2} \times 10^{-3} = 0.725m$ $d - \frac{h_f}{2} = (454.0 - \frac{150.0}{2}) \times 10^{-3} = 0.379m$ $\Delta F = \frac{103.125 \times 10^3}{0.379} \times \frac{0.725}{1700.0 \times 10^{-3}} = 116.042kN$ **Design shear stress:** $V_{Ed} = \frac{\Delta F}{h_f \times \Delta x}$ $V_{Ed} = \frac{116.042 \times 10^3}{150.0 \times 1250.0} = 0.619N/mm^2$	**V_{Ed} = 0.619 N/mm²**

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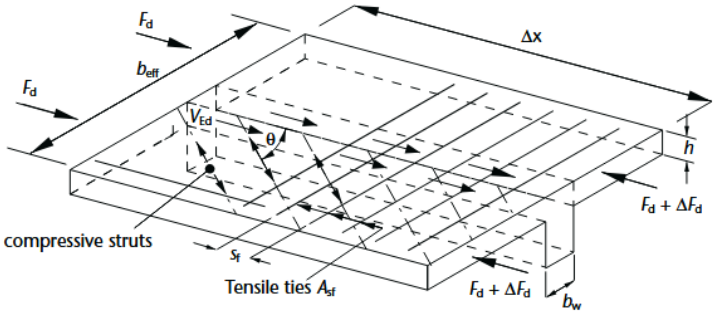
§6.2.4 Transverse Reinforcement in Flange	**TRANSVERSE REINFORCEMENT IN THE FLANGE**  **Step 2: Check if $V_{Ed} \leq 0.4f_{ctd}$** $f_{ctm} = 0.3 \times f_{ck}^{2/3} = 0.3 \times 30.0^{2/3} = 2.896 N/mm^2$ $f_{ctk,0.05} = 0.7 \times f_{ctm} = 0.7 \times 2.896 = 2.028 N/mm^2$ $f_{ctd} = \frac{f_{ctk,0.05}}{\gamma_c} = \frac{2.028}{1.5} = 1.352 N/mm^2$ $0.4 f_{ctd} = 0.4 \times 1.352 = 0.541 N/mm^2$ Check: $V_{Ed} = 0.619 > 0.541$ $V_{Ed} = 0.619 > 0.4f_{ctd} = 0.541$ but $< V_{Rd,max}$ at (26.5°) = 4.217 **Step 3: Check concrete strut with θ=26.5°** $v_1 = 0.6\left(1 - \frac{f_{ck}}{250}\right) = 0.6\left(1 - \frac{30.0}{250}\right) = 0.528$ $v_{Rd,max}(26.5°) = \frac{v_1 f_{ck}}{1.5(\cot 26.5° + \tan 26.5°)}$ $= \frac{0.528 \times 30.0}{1.5 \times (\cot 26.5° + \tan 26.5°)} = 4.217 N/mm^2$ Check: $V_{Ed} = 0.619 \leq 4.217$ Outcome: ✓ Concrete strut has sufficient strength with θ = 26.5° **Step 4: Calculate required transverse reinforcement** $\frac{A_{sf}}{s_f} \geq \frac{V_{Ed} h_f}{0.87 f_{yk} \cot 26.5°}$ $= \frac{0.619 \times 150.0}{0.87 \times 500.0 \times 2.0} = 226 mm²/m$ **Provided Transverse Reinforcement** Provide H12.0 @ 250.0 mm c/c $A_{sf,prov} = \pi \times \left(\frac{12.0}{2}\right)^2 \times \frac{1000}{250.0} = 452 mm²/m$ Provided A_{sf} = 452 mm²/m ≥ Required A_{sf} = 226 mm²/m → Adequate transverse reinforcement provided	**Required A_{sf} = 226 mm²/m** **Provided A_{sf} = 452 mm²/m** **Status: Adequate transverse reinforcement provided**

REFERENCE	CALCULATIONS	OUTPUT
§7.4.2 Deflection Check	**DEFLECTION CHECK** **Step 1: Reference reinforcement ratio** $\rho_0 = \sqrt{f_{ck}} \times 10^{-3} = \sqrt{30.0} \times 10^{-3} = 0.0055$ **Step 2: Tension reinforcement ratio** $\rho = \frac{A_{s,req}}{b_w d} = \frac{1066}{250.0 \times 454.0} = 0.0094$ **Step 3: Structural system factor** K = 1.0 **Step 4: Basic L/d ratio** $\rho > \rho_0 \rightarrow \frac{L}{d} = K\left[11 + 1.5\sqrt{f_{ck}} \times \frac{\rho_0}{\rho}\right]$ $L/d)_{basic} = 15.79$ **Step 5: Modification factors** **(i) Steel stress modification factor** $\beta_s = \frac{A_{s,prov}}{A_{s,req}} = \frac{603}{1066} = 0.57$ $\beta_s = \min(1.5, 0.57) = 0.57$ **(ii) Span modification factor** $\beta_L = \frac{7}{L_m} = \frac{7}{5.00} = 1.00$ $\beta_L = \min(1.0, 1.00) = 1.00$ **(iii) Flange modification factor** $\beta_F = \frac{b_{eff}}{b_w} = \frac{1700.0}{250.0} = 6.80$ $\beta_F = 0.80$ → Flanged beam with beff/bw > 3 → mod_factor = 0.8 **Step 6: Permitted L/d** $L/d)_{permitted} = \beta_F \times \beta_L \times \beta_s \times (L/d)_{basic}$ $= 0.80 \times 1.00 \times 0.57 \times 15.79 = 7.15$ **Step 7: Actual L/d** $L/d)_{actual} = \frac{L}{d} = \frac{5000.0}{454.0} = 11.01$ **Step 8: Check** 11.01 > 7.15 (inadequate reinforcement) → FAIL Message: Deflection check fails due to inadequate reinforcement	**Permitted L/d = 7.15** **Actual L/d = 11.01** **Status: FAIL**

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§6.2.1-6.2.3 Shear Design – Part 1	**SHEAR DESIGN** **Step 1: Shear resistance of concrete ($V_{Rd,c}$)** $C_{Rd,c} = \frac{0.18}{\gamma_c} = \frac{0.18}{1.5} = 0.12$ $k = 1 + \sqrt{\frac{200}{d}} \leq 2.0$ $k = 1 + \sqrt{\frac{200}{454.0}} = 1.664$ $\rho_1 = \frac{A_{s,prov}}{b_w d} \leq 0.02$ $\rho_1 = \frac{603}{250.0 \times 454.0} = 0.0053$ $\rho_1 = min(0.0053, 0.02) = 0.0053$ $V_{Rd,c} = [C_{Rd,c} \cdot k \cdot (100 \cdot \rho_1 \cdot f_{ck})^{1/3}] \cdot b_w \cdot d$ $= [0.12 \times 1.664 \times (100 \times 0.0053 \times 30.0)^{1/3}] \times 250.0 \times 454.0 \times 10^{-3} = 57.03kN$ $V_{Rd,c,min} = 0.035 \cdot k^{3/2} \cdot \sqrt{f_{ck}} \cdot b_w \cdot d$ $= 0.035 \times 1.664^{3/2} \times \sqrt{30.0} \times 250.0 \times 454.0 = 46.69kN$ $V_{Rd,c} = \max(57.03, 46.69) = 57.03kN$ **Step 2: Check requirement for shear reinforcement** $V_{Ed} = 146.0kN$ $Check: 146.0kN > 57.03kN$ Since: VEd (146.00 kN) > VRd,c (57.03 kN) → Shear reinforcement required **Step 3: Shear forces at critical sections** At face of support: V_{sf} UDL: w_u = 44.0 kN/m Support member width:bs = 300.0 mm $V_{sf} = V_{Ed} - \frac{w_u \cdot b_s}{2}$ $= 146.0 - \frac{44.0 \times 300.0}{2000} = 139.4kN$ $V_{sf} = 139.4kN$ At distance d from face of supporting member: V_{sd} $V_{sd} = V_{sf} - w_u \cdot d$ $= 139.4 - \frac{44.0 \times 454.0}{1000} = 119.42kN$ $V_{sd} = 119.42kN$	**$V_{Rd,c}$ = 57.03 kN** **V_{Ed} = 146.0 kN** **Shear reinforcement required: YES** **V_{sf} = 139.4 kN** **V_{sd} = 119.42 kN**

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§6.2.3 Concrete Strut & Minimum Links	**SHEAR DESIGN** **Step 4: Check crushing strength of concrete strut** $At, \theta = 22° : V_{Rd,max} = 0.124 \cdot b_w \cdot d \cdot \left(1 - \frac{f_{ck}}{250}\right) \cdot f_{ck}$ $= 0.124 \times 250.0 \times 454.0 \times \left(1 - \frac{30.0}{250}\right) \times 30.0 \times 10^{-3} = 371.55kN$ $Check : V_{sf} = 139.4kN \leq 371.55kN$ $At, \theta = 45° : V_{Rd,max} = 0.18 \cdot b_w \cdot d \cdot \left(1 - \frac{f_{ck}}{250}\right) \cdot f_{ck}$ $= 0.18 \times 250.0 \times 454.0 \times \left(1 - \frac{30.0}{250}\right) \times 30.0 \times 10^{-3} = 539.35kN$ $Check : V_{sf} = 139.4kN \leq 539.35kN$ **Step 5: Determine strut angle θ** $V_{sf} = 139.4kN \leq V_{Rd,max}(22°) = 371.55kN$ Strut adequate with θ = 22° $\theta = 22.0$ $\cot\theta = 2.5$ **Step 6: Required shear reinforcement near supports** $\frac{A_{sw}}{s} = \frac{V_{sd}}{0.78 \cdot f_{yk} \cdot d \cdot \cot\theta}$ $= \frac{119.42 \times 10^3}{0.78 \times 500.0 \times 454.0 \times 2.5} = 0.2698mm^2/m$ **Step 7: Minimum shear reinforcement** Near supports: $\frac{A_{sw,min}}{s} = 0.00085 \times b_w = 0.00085 \times 250.0 = 0.2125mm^2/m$ Midspan: $\frac{A_{sw,min}}{s} = \frac{0.08 \cdot \sqrt{f_{ck}} \cdot b_w}{f_{yk}} = \frac{0.08 \times \sqrt{30.0} \times 250.0}{500.0} = 0.2191mm^2/m$	**$V_{Rd,max}$(22°) = 371.55 kN** **$V_{Rd,max}$(45°) = 539.35 kN** **Strut angle θ = 22.0** **cotθ = 2.5** **Result: Vsf (139.40 kN) ≤ VRd,max(22°) (371.55 kN) → θ = 22°** **Required A_{sw}/s = 0.2698 mm²/m** **Min A_{sw}/s (support) = 0.2125 mm²/m** **Min A_{sw}/s (midspan) = 0.2191 mm²/m**

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§9.2.2 Spacing & Provided Links	**SHEAR DESIGN** **Step 8: Maximum spacing of shear links** $s_{max} = \min(0.75d, 600) = \min(0.75 \times 454.0, 600) = 340.0mm$ Provided spacing near support = 150.0 mm Check: Provided 150.0 mm ≤ 340.0 mm → OK Provided spacing midspan = 150.0 mm **Step 9: Provided shear reinforcement** **Near support:** 2.0 legs of H8 @ 150.0 mm c/c $Provided; \frac{A_{sw}}{s} = 0.6702mm^2/m$ Check: 0.6702 ≥ 0.2698 → Adequate **Midspan:** 2.0 legs of H8 @ 150.0 mm c/c $Provided; \frac{A_{sw}}{s} = 0.6702mm^2/m$ Check: 0.6702 ≥ 0.2191 → Adequate **Step 10: Shear resistance of provided links : VRd,s** $V_{Rd,s} = \frac{A_{sw}}{s} \cdot 0.78 \cdot f_{yk} \cdot d \cdot cot\theta$ $= 0.6702 \times 0.78 \times 500.0 \times 454.0 \times 2.5$ $V_{Rd,s} = 296.67kN$ $V_{Rd,s} = 296.67kN > V_{sd} = 119.42kN$ Implying → Midspan links are sufficient across the whole span. Therefore provide H8 @ 150.0 mm c/c throughout the beam span. Additional longitudinal force: ΔF_{td} $\Delta F_{td} = 0.5 \times V_{sd} \times \cot\theta$ $= 0.5 \times 119.42 \times 2.5 = 149.3kN$ This additional longitudinal tensile force is provided for by extending the curtailment point of longitudinal reinforcement.	**Max spacing = 340.0 mm** **Provided spacing (support) = 150.0 mm** **Provided A_{sw}/s = 0.6702 mm²/m** **Provided A_{sw}/s (midspan) = 0.6702 mm²/m** **Status support: Adequate** **Status midspan: Adequate** **$V_{Rd,s}$ = 296.67 kN** **ΔF_{td} = 149.3 kN** **Status: Adequate shear reinforcement provided**