Beam: **SCI Worked Examples 4: Beam with intermediate restraints** **Span: 9.0 m.**

		Load name	*Loading w1*	*Start x1*	*Loading w2*	*End x2*	*R1comp*	*R2comp*
U	G	o.w.	3.0	0		L	13.50	13.50
P	G	PL1 dead	40.0	3.0			26.67	13.33
P	QA	PL1 live	60.0	3.0			40.00	20.00
P	G	PL2 dead	20.0	6.0			6.67	13.33
P	QA	PL2 live	30.0	6.0			10.00	20.00
						Total load (unfactored): 177.0 kN	**96.83**	**80.17**
						(6.10a): 211.9 kN	115.72	96.22
						(6.10b): 243.6 kN	133.48	110.16

Load types: U:UDL; P:Point load; Load positions are measured in m. from R1
Load durations: G:Dead; Qx: Imposed: QA: Residential

Maximum B.M. = 383.6 kNm (6.10b) at 3.00 m. from R1

Maximum S.F. = 133.5 kN (6.10b) at R2

Mid-span deflections: Dead: 1,033 x 10^8/EI *(E in N/mm^2, I in cm^4)*
Live: 1,164 x 10^8/EI
Total: 2,197 x 10^8/EI

Beam calculation to BS EN1993.1.1 using S275 steel

SECTION SIZE : **457 x 191 x 82 UKB S275 (Class 1, plastic)**

D=460.0 mm B=191.3 mm t=9.9 mm T=16.0 mm I_x=37,100 cm^4 r_y=4.23 cm $W_{pl,y}$=1,830 cm^3 $W_{el,y}$=1,610 cm^3

Classification: Flange: c/t = 80.5/16.0 = 5.03 <= 9ε (8.32): Class 1, plastic
Table 5.2 Web: c/t = 407.6/9.9 = 41.2 <= 72ε (66.6): Class 1, plastic

Shear

Design shear force, V_{Ed} = 133.5 kN

Shear capacity, $V_{pl,Rd} = (A_v.f_y/\sqrt{3})/\gamma_{M0}$ = ((4,763 x 275/($\sqrt{3}$ x 1000))/1.0 = 756 kN (>=133) OK [EC3 6.2.6]

Shear buckling: h_w/t_w = 460.0/9.9 = 43.23 <= 72ε (66.56): check not required [EC3 6.2.6(6)]

Moment capacity

Design moment, M_{Ed} = 383.6 kNm

Moment capacity, $M_c = f_y.W_{pl,y}$ = 275 x 1,830/1000 = 503.3 kNm OK

Beam is laterally restrained at 3.00m and 6.00m from R1

Lateral-torsional buckling check

Design buckling resistance moment, $M_{b,Rd} = \chi_{LT,mod}.M_{c,Rd}$

$\chi_{LT,mod} = \chi_{LT}/f$ (Eq.6.58) $f = 1 - 0.5(1-k_c)[1 - 2(\bar{\lambda}_{LT} - 0.8)^2]$ 6.3.2.3(2) $K_c = 1/\sqrt{C_1}$ NA2.18

Use buckling curve c: α = 0.490 [EC3 Tables 6.3/6.4 NA 2.17]

$\chi_{LT} = 1/[\phi_{LT} + \sqrt{(\phi_{LT}^2 - B\bar{\lambda}_{LT}^2)}]$ [EC3 (6.56)]

$\phi_{LT} = 0.5[1 + \alpha_{LT}(\bar{\lambda}_{LT} - \bar{\lambda}_{LT,0}) + B\bar{\lambda}_{LT}^2]$

$\bar{\lambda}_{LT,0}$ = 0.4 B = 0.75 [EC3 UK NA 2.17]

$\bar{\lambda}_{LT} = \sqrt{(W_y.f_y/M_{cr})}$ $M_{cr} = C_1(\pi^2 EI_z/(kL)^2)\{\sqrt{((k/k_w)^2 I_w/I_z + (kL)^2 GI_t/(\pi^2 EI_z)}\}$ NCCI SN003 2(1)

Segment	M_{Max}	C_1	C_2	M_{cr}	$\bar{\lambda}_{LT}$	ϕ_{LT}	χ_{LT}	$\chi_{LT.mod}$	W_v	$M_{b.Rd}$	
0.00-3.00	383.6	1.75	1.00	1886.2	0.517	0.629	0.934	1.000	503.3	503.3	OK
3.00-6.00	383.6	1.18	1.00	1270.3	0.629	0.705	0.868	0.903	503.3	454.2	OK
6.00-9.00	313.6	1.75	1.00	1880.8	0.517	0.629	0.934	1.000	503.3	503.3	OK

Combined bending and shear

V_{Ed} <= 0.5 $V_{c,Rd}$: Check for bending/shear interaction not required [EC3:6.2.8(2)]

Web capacity at bearings

Resistance of web to transverse forces, $F_{Rd} = f_{yw}.L_{eff}.t_w/\gamma_{M1}$

f_{vw} = 275 N/mm^2 $L_{eff} = \chi_F I_v$
$\chi_F = 0.5/\bar{\lambda}_F$ <= 1.0 $\bar{\lambda}_F = \sqrt{(I_v.t_w.f_{vw}/F_{cr})}$
$F_{cr} = 0.9k_f.E.(t_w^3/h_w)$ $k_F = 2 + 6((S_s + c)/h_w)^2$ <= 6
Load application taken as type (c), I_y is the least of: $S_s + 2t_f(1 + \sqrt{(m_1 + m_2)})$, $I_e + t_f\sqrt{(m_1/2 + (I_e/t_f)^2 + m_2)}$ or $I_e + t_f\sqrt{(m_1 + m_2)}$
$I_e = k_F.E.t_w^2/(2.f_{yw}.h_w)$ <= s_s + c
$m_1 = f_{yf}.b_f/(f_{yw}.t_w$ $m_2 = 0.02(h_w/t_f)^2$ if $\bar{\lambda}_F$ > 0.5 else 0.0

Reaction R1: 133.5 kN
Required minimum stiff bearing length, S_s = 10 mm
c (end of beam to stiff bearing) taken as 0.0
m_1 = 19.3 m_2 = 0.00 F_{cr} = 917 kN k_F = 2.14 I_e = 10.0 I_y = 60.7 $\bar{\lambda}_F$ = 0.425 χ_f = 1.00
Resistance of web to transverse forces, $F_{R,d}$ = 275 x 60.7 x 9.9/1000 = 165 kN OK

Reaction R2: 110.2 kN
Required minimum stiff bearing length, S_s = 10 mm
c (end of beam to stiff bearing) taken as 0.0
m_1 = 19.3 m_2 = 0.00 F_{cr} = 917 kN k_F = 2.14 l_e = 10.0 l_v = 60.7 $\bar{\lambda}_F$ = 0.425 γ_f = 1.00
Resistance of web to transverse forces, $F_{R,d}$ = 275 x 60.7 x 9.9/1000 = 165 kN OK

If the stiff bearing length(s) above cannot be provided, stiffeners will be required

Deflection

LL deflection = 1,164 x 1e8/(210,000 x 37,100) = 14.9 mm (L/602) OK
TL deflection = 2,197 x 1e8/(210,000 x 37,100) = 28.2 mm (L/319)