Structural Calculations
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September 2016

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The span quoted is solely for the purpose of producing these structural calculations. Measurements must be taken on site before ordering any materials.

Beams specified for load bearing walls of cavity construction, are often two beams, one for each skin of brick/blockwork. Check the comments at the bottom of the page for each beam specified, before ordering any materials.

Loading Data

9"BRICKWORK:

215mm Brickwork	=4.80kN/m2
Plaster	=0.60kN/m2
Total Load	**=5.40kN/m2**

BRICKWORK PARTITION:

100mm Brickwork	=2.10kN/m2
2 No. Plaster Faces	=0.60kN/m2
Total Load	**=2.70kN/m2**

BLOCKWORK PARTITION:

100mm Blockwork	=1.00kN/m2
2 No. Plaster Faces	=0.50kN/m2
Total Load	**=1.50kN/m2**

TILE HANGING TO TIMBER FRAME:

Concrete Tiles	=0.55kN/m2
Battens & Felt	=0.10kN/m2
Timber Studs	=0.10kN/m2
Plasterboard	=0.15kN/m2
Insulation	=0.05kN/m2
Plaster	=0.25kN/m2
Total Load	**=1.20kN/m2**

TIMBER STUD PARTITION:

2 No. Plasterboard Faces	=0.30kN/m2
Timber Studs	=0.10kN/m2
2 No. Plaster Faces	=0.30kN/m2
Insulation	=0.05kN/m2
Total Load	**=0.75kN/m2**

PITCHED ROOF:

Concrete Tiles	=0.60kN/m2
Battens & Felt	=0.10kN/m2
Rafters	=0.15kN/m2
Total Dead Load	=0.85kN/m2
Imposed Load	=0.75kN/m2
Total Load	**=1.60kN/m2**

ROOF SPACE:

Joists & Insulation	=0.15kN/m2
Ceiling	=0.15kN/m2
Total Dead Load	=0.30kN/m2
Imposed Load	=0.25kN/m2
Total Load	**=0.55kN/m2**

SLOPING CEILING:

Plasterboard	=0.15kN/m2
Insulation	=0.10kN/m2
Total Dead Load	=0.25kN/m2
Total Load	**=0.45kN/m2**

FLAT ROOF:

Chipping & Felt	=0.35kN/m2
Boards, Joists & Firings	=0.30kN/m2
Ceiling & Insulation	=0.15kN/m2
Total Dead Load	=0.80kN/m2
Imposed Load	=0.75kN/m2
Total Load	**=1.55kN/m2**

TIMBER ROOF:

Boards & Joists	=0.35kN/m2
Ceiling	=0.15kN/m2
Total Dead Load	=0.50kN/m2
Imposed Load	=1.50kN/m2
Total Load	**=2.00kN/m2**

EXTERNAL RENDER WALL:

Render 2 No. Skins	=0.30kN/m2
100mm Blockwork	=2.00kN/m2
Insulation	=0.05kN/m2
Plaster	=0.25kN/m2
Total Load	**=2.60kN/m2**

Beam: **Beam A** **Span: 3.8 m.**

		Load name	Loading w1	Start x1	Loading w2	End x2	R1comp	R2comp
U	D	o.w.	0.55	0		L	1.04	1.04
U	D	BRICKWORK PARTITION	2.70*2.40	0		L	12.31	12.31
U	D	BRICKWORK PARTITION	2.70*2.40	0		L	12.31	12.31
U	D	BLOCKWORK PARTITION	1.5*2.4	0		L	6.84	6.84
U	D	BLOCKWORK PARTITION	1.5*2.4	0		L	6.84	6.84
U	D	TIMBER FLOOR	2.0*1.5	0		L	5.70	5.70
U	D	TIMBER FLOOR	2.0*1.7	0		L	6.46	6.46
				Unfactored reactions (kN)		**Total:**	**51.51**	**51.51**
						Dead:	*51.51*	*51.51*
						Live:	*0.00*	*0.00*
		Total load: 103.02/144.23 kN	*Unfactored/Factored*			**Factored reactions:**	**72.11**	**72.11**

Load types: U:UDL D: Dead; L: Live (positions in m. from R1)

Maximum B.M. (factored) = 68.5 kNm at 1.90 m. from R1

Maximum S.F. (factored) = 72.1 kN at R1

Live load deflection = 0.00 x 10^8/EI at R2 *(E in N/mm^2, I in cm^4)*

Total deflection = 73.6 x 10^8/EI at 1.90 m. from R1

Beam calculation to BS5950-1:2000 using S275 steel

SECTION SIZE : **152 x 152 x 51 UC S275 (compact)**

D=170.2 mm B=157.4 mm t=11.0 mm T=15.7 mm I_x=3,227 cm^4 r_y=3.96 cm S_x=438 cm^3

Shear capacity = 0.6 p_y.t.D = 0.6 x 275 x 11.0 x 170.2/1000 = 309 kN (>=72.1) OK

Maximum moment = 68.51 kNm at 1.90 m. from R1

Moment capacity, $M_c = p_y.S_x$ = 275 x 438/1000 = 120.5 kNm OK

Beam is laterally restrained at supports only: effective length = 1.0L

Effective length (L_E) = 3.80m
Slenderness, λ (L_E/r_y) = 3.80 x 100/3.96 = 95.96
Buckling parameter (u) = 0.848
Slenderness factor (v) = 0.653 (x = 10.1; λ/x = 9.50)
β_w = 1.000 (Class 1/2 compact)
Equivalent slenderness (λ_{LT}) = u.v.λ.$\sqrt{\beta_w}$ = 53.10
Bending strength, p_b = 230.4 N/mm^2

Maximum moment within segment, M_x = 68.51 kNm
Equivalent uniform moment factor, m_{LT} = 0.925 (M_2=51.4, M_3=68.5, M_4=51.4)
Equivalent uniform moment = 0.925 x 68.51 = 63.37 kNm
Buckling resistance moment, $M_b = p_b.S_x$ = 230.4 x 438/1000 = 100.9 kNm OK

Check unstiffened web capacity with load of 72.11 kN
C1 = 141 kN; C2 = 3.03 kN/mm; C4 = 1,851; K = min{0.5+(a_e/1.4d),1.0}; p_{yw} = 275N/mm^2
(for derivation of C factors see Steelwork Design Guide to BS5950-1:2000 6th ed.)
Bearing capacity, $P_w = C1+b_1C2$ (b_e taken as zero) Buckling capacity, $P_x = K\sqrt{(C4.P_w)}$
Unstiffened web bearing capacity, P_w = 141 kN: no minimum stiff bearing length required

LL deflection = 0.000 x 1e8/205,000 x 3227.000 = 0.0 mm OK
TL deflection = 73.60 x 1e8/205,000 x 3227 = 11.1 mm (L/342)

Bearing details

152x152x51 UC stiff bearing length, b_1 = t + 1.6r + 2T = 54.6 mm

R1: None

R2: 300 x 400 mm bearing plate

Factored reaction = 51.51 x 1.4 + 0.00 x 1.6 = 72.11 kN

15 mm m.s. bearing plate, size 300 x 400 mm
Local design strength of masonry (factored) = 0.700 N/mm^2 (User-ented value)
Bearing plate projection beyond stiff bearing length = (300-54.6)/2 = 122.7mm
Factored stress under plate = 72.11 x 1000/300 x 400 = 0.60 N/mm^2
Required plate thickness = $\sqrt{(3x0.60x123x123/275)}$ = 9.94 mm: use 15mm
Factored bending stress in plate = 0.60x123x(123/2)/(15x15/6) = 120.7 N/mm^2 (p_y=275 N/mm^2)

Encase beam to provide half-hour fire resistance as per specification. Weld 12mm plate to top of beam to support the full cavity.

Beam: **Beam B** **Span: 3.2 m.**

		Load name	*Loading w1*	*Start x1*	*Loading w2*	*End x2*	*R1comp*	*R2comp*
U	D	o.w.	0.5	0		L	0.80	0.80
U	D	PITCHED ROOF	1.60*5.0	0		L	12.80	12.80
U	D	ROOF SPACE	0.55*4.0	0		L	3.52	3.52
U	D	BRICKWORK PARTITION	2.70*2.40	0		L	10.37	10.37
U	D	BLOCKWORK PARTITION	1.5*2.4	0		L	5.76	5.76
U	D	TIMBER FLOOR	2.0*2.0	0		L	6.40	6.40
P	D	Beam: Beam A : R1	51.51 [B/F]	0.8			38.63	12.88
P	L	Beam: Beam A : R1	0.00 [B/F]	0.8			0.00	0.00
				Unfactored reactions (kN)		**Total:**	**78.28**	**52.53**
						Dead:	*78.28*	*52.53*
						Live:	*0.00*	*0.00*
						Factored reactions:	**109.59**	**73.54**

Total load: 130.81/183.13 kN *Unfactored/Factored*

Load types: U:UDL P:PL D: Dead; L: Live (positions in m. from R1)

Maximum B.M. (factored) = 77.9 kNm at 1.08 m. from R1

Maximum S.F. (factored) = 109.6 kN at R1

Live load deflection = 0.00 x 10^8/EI at R2 *(E in N/mm^2, I in cm^4)*

Total deflection = 58.2 x 10^8/EI at 1.52 m. from R1

Beam calculation to BS5950-1:2000 using S275 steel

SECTION SIZE : **203 x 203 x 46 UC S275 (compact)**

D=203.2 mm B=203.6 mm t=7.2 mm T=11.0 mm I_x=4,570 cm^4 r_y=5.13 cm S_x=497 cm^3

Shear capacity = 0.6 p_y.t.D = 0.6 x 275 x 7.2 x 203.2/1000 = 241 kN (>=110) OK

Maximum moment = 77.94 kNm at 1.08 m. from R1

Moment capacity, $M_c = p_y.S_x$ = 275 x 497/1000 = 136.7 kNm OK

Beam is laterally restrained at supports only: effective length = 1.0L

Effective length (L_E) = 3.20m
Slenderness, λ (L_E/r_y) = 3.20 x 100/5.13 = 62.38
Buckling parameter (u) = 0.846
Slenderness factor (v) = 0.886 (x = 17.7; λ/x = 3.52)
β_w = 1.000 (Class 1/2 compact)
Equivalent slenderness (λ_{LT}) = u.v.$\lambda.\sqrt{\beta_w}$ = 46.77
Bending strength, p_b = 245.8 N/mm^2

Maximum moment within segment, M_x = 77.94 kNm
Equivalent uniform moment factor, m_{LT} = 0.909 (M_2=76.6, M_3=73.3, M_4=47.7)
Equivalent uniform moment = 0.909 x 77.94 = 70.86 kNm
Buckling resistance moment, $M_b = p_b.S_x$ = 245.8 x 497/1000 = 122.2 kNm OK

Check unstiffened web capacities with loads of 109.6 kN and 73.54 kN
C1 = 84.0 kN; C2 = 1.98 kN/mm; C4 = 399; K = min{0.5+(a_e/1.4d),1.0}; p_{yw} = 275N/mm^2
(for derivation of C factors see Steelwork Design Guide to BS5950-1:2000 6th ed.)
Bearing capacity, $P_w = C1+b_1C2$ (b_e taken as zero) Buckling capacity, $P_x = K\sqrt{(C4.P_w)}$
R1: Minimum required stiff bearing length, b_1 = 13mm (a_e = 6.5mm; K = 0.529)
Bearing capacity, P_w = 110 kN
With b_1 = 13mm, buckling capacity, P_x = 111 kN
R2: Unstiffened web bearing capacity, P_w = 84.0 kN: no minimum stiff bearing length required

LL deflection = 0.000 x 1e8/205,000 x 4570.000 = 0.0 mm OK
TL deflection = 58.16 x 1e8/205,000 x 4570 = 6.2 mm (L/515)

Bearing details

203x203x46 UC stiff bearing length, b_1 = t + 1.6r + 2T = 45.5 mm

Local design strength of masonry (factored) = 0.700 N/mm^2 (User-entered value)

R1: 300 x 600 x 150h mm padstone

(minimum padstone height if unreinforced: 128 mm)

Factored reaction = 78.28 x 1.4 + 0.00 x 1.6 = 109.59 kN

Factored stress under padstone = 109.59 x 1000/300 x 600 = 0.61 N/mm^2

R2: 300 x 400 x 150h mm padstone

(minimum padstone height if unreinforced: 128 mm)

Factored reaction = 52.53 x 1.4 + 0.00 x 1.6 = 73.54 kN

Factored stress under padstone = 73.54 x 1000/300 x 400 = 0.61 N/mm^2

Notched beam web cleat connection check (based on SCI/BCSA Simple Connections, 2002 edition)

Location:

Factored shear at support, F_v = 72.11 kN

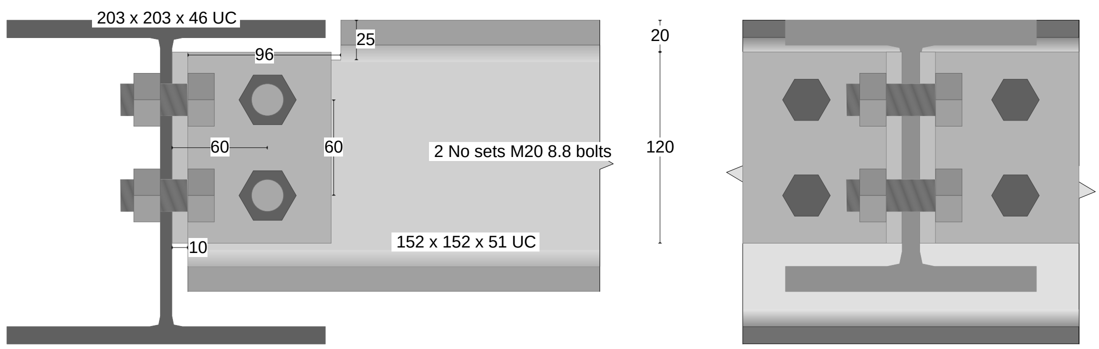
Beam: S275 152x152x51 UC connection to web of S275 203x203x46 UC

Notch dimensions: Top: 96 x 25mm

Use 2no 120mm long 100x100x10 angle cleats, 2no sets of M20 8.8 bolts at 60 mm centres

ANGLE CLEAT CONNECTION

120mm long 100 x 100 x 10mm angle cleats



Check 1: Recommended detailing requirements
All requirements satisfied

Check 2: Capacity of cleat/supported beam bolt group

Distance from face of supporting member to centre line of bolts, a = 60 mm, pitch, p_1 = 60 mm

Vertical load per bolt = $F_{sv} = F_v/n$ = 72.1/2 = 36.1 kN
Horizontal load on top and bottom bolts (from moment), $F_{sm} = B.F_v$
where $B = 6a/(n(n + 1).p_1)$ = 6 x 60/(2 x 3 x 60) = 1.00 F_{sm} = 1.00 x 72.1 = 72.1 kN
Resultant load on top and bottom bolts = $\sqrt{}(36.1^2 + 72.1^2)$ = 80.6 kN

Bolt shear capacity, P_s, per bolt = 2 x 245 x 375/1000 = 183.8 kN (double shear)

End distances, e, in load direction: Beam: e = 56 mm; Cleats: e = 45 mm
Bearing capacity, $P_{bs} = t.\min(D,e/2).p_{bs}$ p_{bs} S275: 460 N/mm²; S355: 550 N/mm²
Bearing capacity of cleats, P_{bs}, per bolt = 2 x 10 x 20 x 460/1000 = 184.0 kN
Bearing capacity of beam web, P_{bs}, per bolt = 11.0 x 20 x 460/1000 = 101.2 kN

Bolt capacity = P_{bs} = 101.2 kN/bolt (bearing capacity of beam web governs)

Bolt group capacity (single line) = $n.P_{bs}/\sqrt{}(1 + (Bn)^2)$ = 2 x 101.2/$\sqrt{}$(1 + (1.00 x 2)²) = 90.5 kN OK

Check 3: Shear capacity of cleat legs at bolt line
Plain shear capacity of each cleat, P_v = 147.8 kN (x2) OK
Block shear capacity of each cleat, P_r = 205.9 kN (x2) OK

Check 4: Capacity of supported beam at bolt line
Plain shear capacity of beam web, P_v = 257.1 kN OK
Block shear capacity of beam web, P_r = 239.2 kN OK (F_v<=0.75P_r)

Check 5: Shear and bending interaction at notch
Shear capacity at notch, P_{vN} = 239.2 kN (F_v<=0.75P_{vN})

Moment at notch = 72.1 x (96+10)/1000 = 7.64 kNm
Moment capacity at notch, $M_{cN} = p_y.Z_N$ = 275 x 61.4/1000 = 16.9 kNm OK

Moment-determined capacity = 16.9/((96+10)/1000) = 159.3 kN

Check 6: Local stability of notched beam
Not checked

Check 7: Overall stability of notched beam
Not checked

Check 8: Capacity of bolt group connection to support
Bolt shear capacity, P_s, per bolt = 245 x 375/1000 = 91.9 kN
Shear capacity of bolt group, ΣPS = 4 x 91.9 = 367.5 kN OK
Bolt bearing capacity per bolt = 20 x 10 x 460/1000 = 92.0 kN
Top pair bolt bearing capacity = 30.0 [e/2] x 10 x 460/1000 = 69.0 kN
Bearing capacity of cleats at support = 2 x 69.0 + 2 x (2 - 1) x 92.0 = 322.0 kN OK

Check 9: Shear and bearing capacity of cleats at support
Plain shear capacity, P_v = 0.7 x 275 x 1.2 x 640/1000 = 147.8 kN (x2) OK
Block shear capacity, P_r = 205.9 kN (x2) OK

Check 10: Local capacity of supporting beam web
Shear capacity, $P_v = 0.7.p_v.K_e.Av_{net}$ = 0.7 x 275 x 1.2 x 691/1000 = 159.7 kN (x2) OK
Further checking is needed if this web supports connections on both sides

Summary:

Check		**Cap kN**
1	Basic detailing requirements	OK
2	**Strength of bolt group to cleat/beam web**	**90.5**
3	Shear and bearing capacity of cleat leg at bolt line	295.7
4	Capacity of supported beam at bolt line	239.2
5	Shear and bending interaction at notch	159.3
6	Local stability of notched beam	Not checked
7	Overall stability of notched beam	Not checked
8	Shear capacity of bolt group connection to support	322.0
9	Shear and bearing capacity of cleats at support	295.7
10	Local capacity of supporting member	319.3

Critical design check: 2 - Strength of bolt group to cleat/beam web

Connection capacity = **90.5 kN** OK

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Beam: **Beam C** **Span: 3.5 m.**

		Load name	*Loading w1*	*Start x1*	*Loading w2*	*End x2*	*R1comp*	*R2comp*
U	D	o.w.	0.25	0		L	0.44	0.44
U	D	PITCHED ROOF	1.60*2.0	0		L	5.60	5.60
U	D	ROOF SPACE	0.55*2.0	0		L	1.93	1.93
U	D	BRICKWORK PARTITION	2.70*2.40	0		L	11.34	11.34
U	D	TIMBER STUD PARTITION	0.75*2.4	0		L	3.15	3.15
				Unfactored reactions (kN)		**Total:**	**22.45**	**22.45**
						Dead:	*22.45*	*22.45*
						Live:	*0.00*	*0.00*
		Total load: 44.90/62.87 kN *Unfactored/Factored*				**Factored reactions:**	**31.43**	**31.43**

Load types: U:UDL D: Dead; L: Live (positions in m. from R1)

Maximum B.M. (factored) = 27.5 kNm at 1.75 m. from R1

Maximum S.F. (factored) = 31.4 kN at R1

Live load deflection = 0.00×10^8/EI at R2 *(E in N/mm^2, I in cm^4)*

Total deflection = 25.1×10^8/EI at 1.75 m. from R1

Beam calculation to BS5950-1:2000 using S275 steel

SECTION SIZE : **203 x 102 x 23 UB S275 (compact)**

D=203.2 mm B=101.8 mm t=5.4 mm T=9.3 mm I_x=2,110 cm^4 r_y=2.36 cm S_x=234 cm^3

Shear capacity = 0.6 p_y.t.D = 0.6 x 275 x 5.4 x 203.2/1000 = 181 kN (>=31.4) OK

Maximum moment = 27.50 kNm at 1.75 m. from R1

Moment capacity, $M_c = p_y.S_x$ = 275 x 234/1000 = 64.35 kNm OK

Beam is laterally restrained at supports only: effective length = 1.0L

Effective length (L_E) = 3.50m
Slenderness, λ (L_E/r_y) = 3.50 x 100/2.36 = 148.3
Buckling parameter (u) = 0.888
Slenderness factor (v) = 0.749 (x = 22.5; λ/x = 6.59)
β_w = 1.000 (Class 1/2 compact)
Equivalent slenderness (λ_{LT}) = u.v.λ.$\sqrt{\beta_w}$ = 98.68
Bending strength, p_b = 127.2 N/mm^2

Maximum moment within segment, M_x = 27.50 kNm
Equivalent uniform moment factor, m_{LT} = 0.925 (M_2=20.6, M_3=27.5, M_4=20.6)
Equivalent uniform moment = 0.925 x 27.50 = 25.44 kNm
Buckling resistance moment, $M_b = p_b.S_x$ = 127.2 x 234/1000 = 29.77 kNm OK

Check unstiffened web capacity with load of 31.43 kN
C1 = 50.2 kN; C2 = 1.49 kN/mm; C4 = 160; K = min{0.5+(a_e/1.4d),1.0}; p_{yw} = 275N/mm^2
(for derivation of C factors see Steelwork Design Guide to BS5950-1:2000 6th ed.)
Bearing capacity, $P_w = C1+b_1C2$ (b_e taken as zero) Buckling capacity, $P_x = K\sqrt{(C4.P_w)}$
With b_1=0, unstiffened web buckling capacity, P_x = 44.8 kN: no minimum stiff bearing length required

LL deflection = 0.000 x 1e8/205,000 x 2110.000 = 0.0 mm OK
TL deflection = 25.07 x 1e8/205,000 x 2110 = 5.8 mm (L/604)

Bearing details

203x102x23 UB stiff bearing length, b_1 = t + 1.6r + 2T = 36.2 mm

Local design strength of masonry (factored) = 0.700 N/mm^2 (User-entered value)

R1: 500 x 100 mm bearing plate

Factored reaction = 22.45 x 1.4 + 0.00 x 1.6 = 31.43 kN

25 mm m.s. bearing plate, size 500 x 100 mm
Bearing plate projection beyond stiff bearing length = (500-36.2)/2 = 231.9mm
Factored stress under plate = 31.43 x 1000/500 x 100 = 0.63 N/mm^2
Required plate thickness = $\sqrt{(3x0.63x232x232/265)}$ = 19.6 mm: use 25mm
Factored bending stress in plate = 0.63x232x(232/2)/(25x25/6) = 162.3 N/mm^2 (p_y=265 N/mm^2)

R2 as R1

Encase beam to provide half-hour fire resistance as per specification. Weld 12mm *plate to top of beam to support cavity construction*