JCP STRUCTURAL AND CIVIL ENGINEERS

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Unit 7, Boscombe Centre, Mills Way,
Amesbury, Wiltshire, SP4 7SD

Structural Design Calculations

for

Extension Over First Floor

Site address
2 The Terrace,
Chimney Lane,
Honeystreet,
Wiltshire, SN9 5PU

September 2023
Ref: 16518/AT/SC01A

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Project Ref:	16518
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Project type: Structural Calculations	Date: September 23

Design codes used:

BS 5268: 2002 "The Structural Use of Timber"
BS 5950: 2000 "The Structural Use of Steel in Building"
BS 5628: 1992 "Code of Practice for use of Masonry"
BS 5977: 1983 "Lintels"
BS 6399: 1997 "Loadings for Buildings"

Notes:

These calculations only apply to the structural elements included in these documents; if any discrepancies are found on site, the Engineer is to be informed. All architectural and building design requirements are to be provided by others.

Dimensions in these calculations are for design purposes only, having been scaled from copies of drawings. The building contractor is to obtain detailed dimensions from site measurements and is not to rely on those provided herein for fabrication purposes or procurement of materials.

The contractor is responsible for ensuring the stability of the structure at all times and that the works are carried out in strict compliance with all relevant Codes of Practice, Building Regulations and good building practice. All temporary support works required during the course of construction are the responsibility of the contractor.

Throughout the works the contractor / client is to be responsible for ensuring that the requirements of the Construction, Design and Management Regulations are complied with. Before any demolition works are undertaken, an R&D asbestos survey is recommended.

The Engineer believes that there are no foreseeable unusual risks that may arise during construction, maintenance, or use that a competent contractor could not foresee; however, due attention is to be given to ensuring a safe method of working and risk assessment is planned.

All structural steelwork and components are to be manufactured in accordance with the requirements of execution class EXC2 to BS EN 1090-2.

Architectural drawings:

Chris Hyde Architectural drawings numbered 1709

Structural drawings:

16518-101-P2 - Structural General Arrangement

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General Loading Data

Pitched roof load

Rafters	=	0.15	kN/m²
Roof covering	=	0.60	kN/m²
Battens, felt, insulation, etc	=	0.18	kN/m²
Plasterboard ceiling & skim coat	=	0.20	kN/m²
Total pitched roof dead load	=	1.13	kN/m²
Roof pitch	=	35	°
Dead load on plan	=	1.38	kN/m²
Roof imposed load	=	0.50	kN/m²
Total roof load	=	1.88	kN/m²

Ceiling load

Joists	=	0.15	kN/m²
Plasterboard ceiling & skim coat	=	0.20	kN/m²
Total ceiling dead load	=	0.35	kN/m²
Ceiling imposed load	=	0.25	kN/m²
Total ceiling load	=	0.60	kN/m²

Timber Floor load

Joists	=	0.18	kN/m²
Boards	=	0.18	kN/m²
Plasterboard ceiling & skim coat	=	0.20	kN/m²
Total floor dead load	=	0.56	kN/m²
Floor imposed load	=	1.50	kN/m²
Total floor load	=	2.06	kN/m²

Cavity wall load

Brickwork outer leaf	=	2.20	kN/m²
Blockwork inner leaf	=	2.00	kN/m²
Plasterboard & skim coat	=	0.20	kN/m²
Total cavity wall load	=	4.40	kN/m²

Internal wall load - timber

Timber studwork	=	0.15	kN/m²
Plasterboard & skim coat	=	0.40	kN/m²
Total wall load	=	0.55	kN/m²

Floor Joists

Joist details

Joist breadth	b = **50** mm
Joist depth	h = **200** mm
Joist spacing	s = **400** mm
Timber strength class	**C24**
Service class of timber	**1**

Span details

Number of spans	N_{span} = **1**
Length of bearing	L_b = **100** mm
Effective length of span	L_{s1} = **3300** mm

Section properties

Second moment of area	$I = b \times h^3 / 12$ = **33333333** mm^4
Section modulus	$Z = b \times h^2 / 6$ = **333333** mm^3

Loading details

Joist self weight	$F_{swt} = b \times h \times \rho_{char} \times g_{acc}$ = **0.03** kN/m
Dead load	F_{d_udl} = **0.56** kN/m^2
Imposed UDL(Long term)	F_{i_udl} = **1.50** kN/m^2
Imposed point load (Medium term)	F_{i_pt} = **1.40** kN

Modification factors

Service class for bending parallel to grain	K_{2m} = **1.00**
Service class for compression	K_{2c} = **1.00**
Service class for shear parallel to grain	K_{2s} = **1.00**
Service class for modulus of elasticity	K_{2e} = **1.00**
Section depth factor	K_7 = **1.05**
Load sharing factor	K_8 = **1.10**

Consider long term loads

Load duration factor	K_3 = **1.00**
Maximum bending moment	M = **1.168** kNm
Maximum shear force	V = **1.416** kN
Maximum support reaction	R = **1.416** kN
Maximum deflection	δ = **3.889** mm

Check bending stress

Bending stress	σ_m = **7.500** N/mm^2
Permissible bending stress	$\sigma_{m_adm} = \sigma_m \times K_{2m} \times K_3 \times K_7 \times K_8$ = **8.626** N/mm^2
Applied bending stress	$\sigma_{m_max} = M / Z$ = **3.505** N/mm^2

PASS - Applied bending stress within permissible limits

Check shear stress

Shear stress	τ = **0.710** N/mm^2
Permissible shear stress	$\tau_{adm} = \tau \times K_{2s} \times K_3 \times K_8$ = **0.781** N/mm^2
Applied shear stress	$\tau_{max} = 3 \times V / (2 \times b \times h)$ = **0.212** N/mm^2

PASS - Applied shear stress within permissible limits

Check bearing stress

Compression perpendicular to grain (no wane)	σ_{cp1} = **2.400** N/mm^2
Permissible bearing stress	$\sigma_{c_adm} = \sigma_{cp1} \times K_{2c} \times K_3 \times K_8$ = **2.640** N/mm^2
Applied bearing stress	$\sigma_{c_max} = R / (b \times L_b)$ = **0.283** N/mm^2

PASS - Applied bearing stress within permissible limits

Check deflection

Permissible deflection	$\delta_{adm} = \min(L_{s1} \times 0.003, 14\ mm) =$ **9.900** mm
Bending deflection (based on E_{mean})	$\delta_{bending} =$ **3.682** mm
Shear deflection	$\delta_{shear} =$ **0.208** mm
Total deflection	$\delta = \delta_{bending} + \delta_{shear} =$ **3.889** mm

PASS - Actual deflection within permissible limits

Consider medium term loads

Load duration factor	$K_3 =$ **1.25**
Maximum bending moment	M = **1.507** kNm
Maximum shear force	V = **1.826** kN
Maximum support reaction	R = **1.826** kN
Maximum deflection	$\delta =$ **4.287** mm

Check bending stress

Bending stress	$\sigma_m =$ **7.500** N/mm^2
Permissible bending stress	$\sigma_{m_adm} = \sigma_m \times K_{2m} \times K_3 \times K_7 \times K_8 =$ **10.783** N/mm^2
Applied bending stress	$\sigma_{m_max} = M / Z =$ **4.520** N/mm^2

PASS - Applied bending stress within permissible limits

Check shear stress

Shear stress	$\tau =$ **0.710** N/mm^2
Permissible shear stress	$\tau_{adm} = \tau \times K_{2s} \times K_3 \times K_8 =$ **0.976** N/mm^2
Applied shear stress	$\tau_{max} = 3 \times V / (2 \times b \times h) =$ **0.274** N/mm^2

PASS - Applied shear stress within permissible limits

Check bearing stress

Compression perpendicular to grain (no wane)	$\sigma_{cp1} =$ **2.400** N/mm^2
Permissible bearing stress	$\sigma_{c_adm} = \sigma_{cp1} \times K_{2c} \times K_3 \times K_8 =$ **3.300** N/mm^2
Applied bearing stress	$\sigma_{c_max} = R / (b \times L_b) =$ **0.365** N/mm^2

PASS - Applied bearing stress within permissible limits

Check deflection

Permissible deflection	$\delta_{adm} = \min(L_{s1} \times 0.003, 14\ mm) =$ **9.900** mm
Bending deflection (based on E_{mean})	$\delta_{bending} =$ **4.020** mm
Shear deflection	$\delta_{shear} =$ **0.268** mm
Total deflection	$\delta = \delta_{bending} + \delta_{shear} =$ **4.287** mm

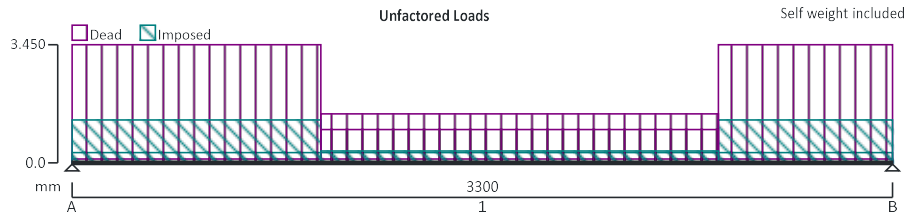
PASS - Actual deflection within permissible limits

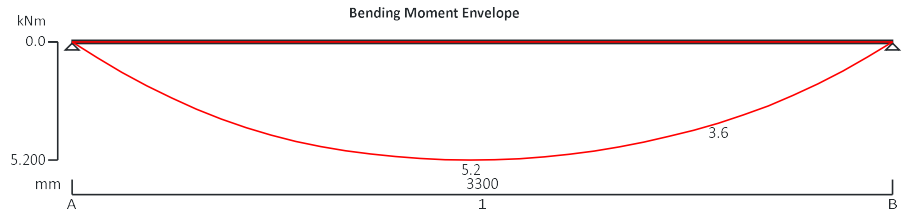
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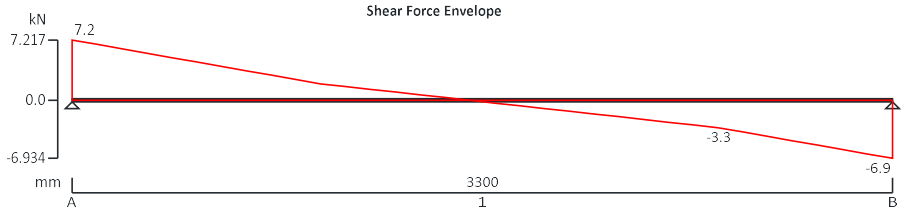
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Beam B1 & B2

Dead udl from	floor	=	0.56	x	0.20	=	0.11	kN/m
Imposed udl from	floor	=	1.50	x	0.20	=	0.30	kN/m
Dead partial udl from	dormer walls	=	0.55	x	2.60	=	1.43	kN/m
Dead partial udl from	pitched roof	=	1.38	x	0.70	=	0.97	kN/m
Imposed partial udl from	pitched roof	=	0.50	x	0.70	=	0.35	kN/m
Dead partial udl from	pitched roof	=	1.38	x	2.50	=	3.45	kN/m
Imposed partial udl from	pitched roof	=	0.50	x	2.50	=	1.25	kN/m







Analysis results

Maximum moment	M_{max} = **5.200** kNm
	M_{min} = **0.000** kNm
Design moment	M = max(abs(M_{max}),abs(M_{min})) = **5.200** kNm
Maximum shear	F_{max} = **7.217** kN
	F_{min} = **-6.934** kN
Design shear	F = max(abs(F_{max}),abs(F_{min})) = **7.217** kN
Total load on beam	W_{tot} = **14.151** kN

Reactions at support A	R_{A_max} = **7.217** kN
	R_{A_min} = **7.217** kN
Unfactored dead load reaction at support A	R_{A_Dead} = **5.314** kN
Unfactored imposed load reaction at support A	$R_{A_Imposed}$ = **1.903** kN
Reactions at support B	R_{B_max} = **6.934** kN
	R_{B_min} = **6.934** kN
Unfactored dead load reaction at support B	R_{B_Dead} = **5.162** kN
Unfactored imposed load reaction at support B	$R_{B_Imposed}$ = **1.772** kN
Timber section details	
Breadth of sections	b = **50** mm
Depth of sections	h = **200** mm
Number of sections in member	N = **3**
Overall breadth of member	$b_b = N \times b$ = **150** mm
Timber strength class	**C24**
Member details	
Service class of timber	**1**
Load duration	**Long term**
Length of span	L_{s1} = **3300** mm
Length of bearing	L_b = **100** mm
Section properties	
Cross sectional area of member	$A = N \times b \times h$ = **30000** mm^2
Section modulus	$Z_x = N \times b \times h^2 / 6$ = **1000000** mm^3
	$Z_y = h \times (N \times b)^2 / 6$ = **750000** mm^3
Second moment of area	$I_x = N \times b \times h^3 / 12$ = **100000000** mm^4
	$I_y = h \times (N \times b)^3 / 12$ = **56250000** mm^4
Radius of gyration	$i_x = \sqrt{(I_x / A)}$ = **57.7** mm
	$i_y = \sqrt{(I_y / A)}$ = **43.3** mm
Modification factors	
Duration of loading - Table 17	K_3 = **1.00**
Bearing stress - Table 18	K_4 = **1.00**
Total depth of member - cl.2.10.6	$K_7 = (300\ mm / h)^{0.11}$ = **1.05**
Load sharing - cl.2.9	K_8 = **1.00**
Lateral support - cl.2.10.8	
Ends held in position	
Permissible depth-to-breadth ratio - Table 19	**3.00**
Actual depth-to-breadth ratio	$h / (N \times b)$ = **1.33**
	PASS - Lateral support is adequate
Compression perpendicular to grain	
Permissible bearing stress (no wane)	$\sigma_{c_adm} = \sigma_{cp1} \times K_3 \times K_4 \times K_8$ = **2.400** N/mm^2
Applied bearing stress	$\sigma_{c_a} = R_{A_max} / (N \times b \times L_b)$ = **0.481** N/mm^2
	$\sigma_{c_a} / \sigma_{c_adm}$ = **0.200**
	PASS - Applied compressive stress is less than permissible compressive stress at bearing
Bending parallel to grain	
Permissible bending stress	$\sigma_{m_adm} = \sigma_m \times K_3 \times K_7 \times K_8$ = **7.842** N/mm^2
Applied bending stress	$\sigma_{m_a} = M / Z_x$ = **5.200** N/mm^2
	$\sigma_{m_a} / \sigma_{m_adm}$ = **0.663**
	PASS - Applied bending stress is less than permissible bending stress
Shear parallel to grain	
Permissible shear stress	$\tau_{adm} = \tau \times K_3 \times K_8$ = **0.710** N/mm^2

Applied shear stress

$\tau_a = 3 \times F / (2 \times A) =$ **0.361** N/mm²

$\tau_a / \tau_{adm} =$ **0.508**

PASS - Applied shear stress is less than permissible shear stress

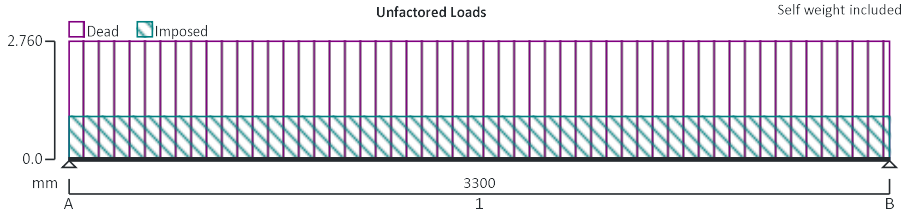
Deflection

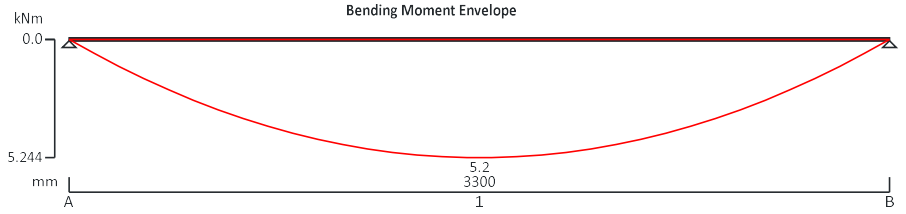
Modulus of elasticity for deflection	$E = E_{min} =$ **7200** N/mm²
Permissible deflection	$\delta_{adm} = \min(0.551 \text{ in}, 0.003 \times L_{s1}) =$ **9.900** mm
Bending deflection	$\delta_{b_s1} =$ **8.346** mm
Shear deflection	$\delta_{v_s1} =$ **0.462** mm
Total deflection	$\delta_a = \delta_{b_s1} + \delta_{v_s1} =$ **8.808** mm
	$\delta_a / \delta_{adm} =$ **0.890**

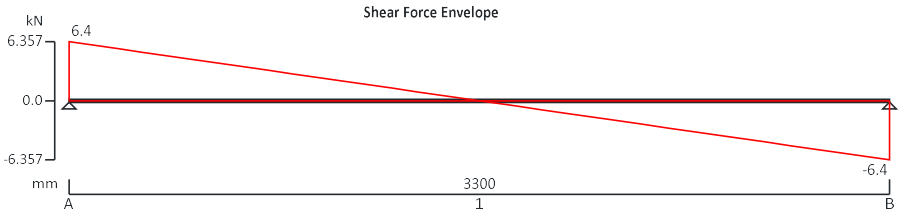
PASS - Total deflection is less than permissible deflection

Beam B3

Dead udl from	pitched roof	=	1.38	x	2.00	=	2.76	kN/m
Imposed udl from	pitched roof	=	0.50	x	2.00	=	1.00	kN/m







Analysis results

Maximum moment	M_{max} = **5.244** kNm
	M_{min} = **0.000** kNm
Design moment	M = max(abs(M_{max}),abs(M_{min})) = **5.244** kNm
Maximum shear	F_{max} = **6.357** kN
	F_{min} = **-6.357** kN
Design shear	F = max(abs(F_{max}),abs(F_{min})) = **6.357** kN
Total load on beam	W_{tot} = **12.714** kN
Reactions at support A	R_{A_max} = **6.357** kN
	R_{A_min} = **6.357** kN
Unfactored dead load reaction at support A	R_{A_Dead} = **4.707** kN
Unfactored imposed load reaction at support A	$R_{A_Imposed}$ = **1.650** kN
Reactions at support B	R_{B_max} = **6.357** kN
	R_{B_min} = **6.357** kN
Unfactored dead load reaction at support B	R_{B_Dead} = **4.707** kN
Unfactored imposed load reaction at support B	$R_{B_Imposed}$ = **1.650** kN

Timber section details

Breadth of sections	b = **50** mm
Depth of sections	h = **225** mm
Number of sections in member	N = **2**
Overall breadth of member	$b_b = N \times b$ = **100** mm
Timber strength class	**C24**

Member details

Service class of timber	**1**
Load duration	**Medium term**
Length of span	L_{s1} = **3300** mm
Length of bearing	L_b = **100** mm

Section properties

Cross sectional area of member	$A = N \times b \times h$ = **22500** mm^2
Section modulus	$Z_x = N \times b \times h^2 / 6$ = **843750** mm^3
	$Z_y = h \times (N \times b)^2 / 6$ = **375000** mm^3
Second moment of area	$I_x = N \times b \times h^3 / 12$ = **94921875** mm^4
	$I_y = h \times (N \times b)^3 / 12$ = **18750000** mm^4
Radius of gyration	$i_x = \sqrt{(I_x / A)}$ = **65.0** mm
	$i_y = \sqrt{(I_y / A)}$ = **28.9** mm

Modification factors

Duration of loading - Table 17	K_3 = **1.25**
Bearing stress - Table 18	K_4 = **1.00**
Total depth of member - cl.2.10.6	$K_7 = (300 \text{ mm} / h)^{0.11}$ = **1.03**
Load sharing - cl.2.9	K_8 = **1.00**

Lateral support - cl.2.10.8

Ends held in position	
Permissible depth-to-breadth ratio - Table 19	**3.00**
Actual depth-to-breadth ratio	$h / (N \times b)$ = **2.25**

PASS - Lateral support is adequate

Compression perpendicular to grain

Permissible bearing stress (no wane)	$\sigma_{c_adm} = \sigma_{cp1} \times K_3 \times K_4 \times K_8$ = **3.000** N/mm^2
Applied bearing stress	$\sigma_{c_a} = R_{A_max} / (N \times b \times L_b)$ = **0.636** N/mm^2
	$\sigma_{c_a} / \sigma_{c_adm}$ = **0.212**

PASS - Applied compressive stress is less than permissible compressive stress at bearing

Bending parallel to grain

Permissible bending stress	$\sigma_{m_adm} = \sigma_m \times K_3 \times K_7 \times K_8$ = **9.676** N/mm^2
Applied bending stress	$\sigma_{m_a} = M / Z_x$ = **6.216** N/mm^2
	$\sigma_{m_a} / \sigma_{m_adm}$ = **0.642**

PASS - Applied bending stress is less than permissible bending stress

Shear parallel to grain

Permissible shear stress	$\tau_{adm} = \tau \times K_3 \times K_8$ = **0.888** N/mm^2
Applied shear stress	$\tau_a = 3 \times F / (2 \times A)$ = **0.424** N/mm^2
	τ_a / τ_{adm} = **0.478**

PASS - Applied shear stress is less than permissible shear stress

Deflection

Modulus of elasticity for deflection	$E = E_{min}$ = **7200** N/mm^2
Permissible deflection	$\delta_{adm} = \min(0.551 \text{ in}, 0.003 \times L_{s1})$ = **9.900** mm
Bending deflection	δ_{b_s1} = **8.705** mm
Shear deflection	δ_{v_s1} = **0.622** mm

Total deflection

$\delta_a = \delta_{b_s1} + \delta_{v_s1}$ = **9.326** mm

δ_a / δ_{adm} = **0.942**

PASS - Total deflection is less than permissible deflection

Rafters

Rafter details

Breadth of timber sections	b = **50** mm
Depth of timber sections	h = **150** mm
Rafter spacing	s = **400** mm
Rafter slope	α = **35.0** deg
Clear span of rafter on horizontal	L_{clh} = **2000** mm
Clear span of rafter on slope	$L_{cl} = L_{clh} / \cos(\alpha)$ = **2442** mm
Rafter span	**Single span**
Timber strength class	**C24**

Section properties

Cross sectional area of rafter	$A = b \times h$ = **7500** mm^2
Section modulus	$Z = b \times h^2 / 6$ = **187500** mm^3
Second moment of area	$I = b \times h^3 / 12$ = **14062500** mm^4
Radius of gyration	$r = \sqrt{(I / A)}$ = **43.3** mm

Loading details

Rafter self weight	$F_j = b \times h \times \rho_{char} \times g_{acc}$ = **0.03** kN/m
Dead load on slope	F_d = **1.00** kN/m^2
Imposed load on plan	$F_u = [(60\ deg - \alpha) / 30\ deg] \times 0.6$ kN/m^2 = **0.50** kN/m^2
Imposed point load	F_p = **0.90** kN

Modification factors

Section depth factor	$K_7 = (300\ mm / h)^{0.11}$ = **1.08**
Load sharing factor	K_8 = **1.10**

Consider long term load condition

Load duration factor	K_3 = **1.00**
Total UDL perpendicular to rafter	$F = F_d \times \cos(\alpha) \times s + F_j \times \cos(\alpha)$ = **0.349** kN/m
Notional bearing length	$L_b = F \times L_{cl} / [2 \times (b \times \sigma_{cp1} \times K_8 - F)]$ = **3** mm
Effective span	$L_{eff} = L_{cl} + L_b$ = **2445** mm

Check bending stress

Bending stress parallel to grain	σ_m = **7.500** N/mm^2
Permissible bending stress	$\sigma_{m_adm} = \sigma_m \times K_3 \times K_7 \times K_8$ = **8.904** N/mm^2
Applied bending stress	$\sigma_{m_max} = F \times L_{eff}^2 / (8 \times Z)$ = **1.390** N/mm^2

PASS - Applied bending stress within permissible limits

Check compressive stress parallel to grain

Compression stress parallel to grain	σ_c = **7.900** N/mm^2
Minimum modulus of elasticity	E_{min} = **7200** N/mm^2
Compression member factor	K_{12} = **0.69**
Permissible compressive stress	$\sigma_{c_adm} = \sigma_c \times K_3 \times K_8 \times K_{12}$ = **6.008** N/mm^2
Applied compressive stress	$\sigma_{c_max} = F \times L_{eff} \times (\cot(\alpha) + 3 \times \tan(\alpha)) / (2 \times A)$ = **0.201** N/mm^2

PASS - Applied compressive stress within permissible limits

Check combined bending and compressive stress parallel to grain

Euler stress	$\sigma_e = \pi^2 \times E_{min} / \lambda^2$ = **22.292** N/mm^2
Euler coefficient	$K_{eu} = 1 - (1.5 \times \sigma_{c_max} \times K_{12} / \sigma_e)$ = **0.991**
Combined axial compression and bending check	$\sigma_{m_max} / (\sigma_{m_adm} \times K_{eu}) + \sigma_{c_max} / \sigma_{c_adm}$ = **0.191 < 1**

PASS - Combined compressive and bending stresses are within permissible limits

Check shear stress

Shear stress parallel to grain	τ = **0.710** N/mm^2
Permissible shear stress	$\tau_{adm} = \tau \times K_3 \times K_8$ = **0.781** N/mm^2

Applied shear stress $\tau_{max} = 3 \times F \times L_{eff} / (4 \times A) =$ **0.085** N/mm²

PASS - Applied shear stress within permissible limits

Check deflection

Permissible deflection $\delta_{adm} = 0.003 \times L_{eff} =$ **7.334** mm

Bending deflection $\delta_b = 5 \times F \times L_{eff}^4 / (384 \times E_{mean} \times I) =$ **1.068** mm

Shear deflection $\delta_s = 12 \times F \times L_{eff}^2 / (5 \times E_{mean} \times A) =$ **0.062** mm

Total deflection $\delta_{max} = \delta_b + \delta_s =$ **1.130** mm

PASS - Total deflection within permissible limits

Consider medium term load condition

Load duration factor $K_3 =$ **1.25**

Total UDL perpendicular to rafter $F = [F_u \times \cos(\alpha)^2 + F_d \times \cos(\alpha)] \times s + F_j \times \cos(\alpha) =$ **0.483** kN/m

Notional bearing length $L_b = F \times L_{cl} / [2 \times (b \times \sigma_{cp1} \times K_8 - F)] =$ **4** mm

Effective span $L_{eff} = L_{cl} + L_b =$ **2446** mm

Check bending stress

Bending stress parallel to grain $\sigma_m =$ **7.500** N/mm²

Permissible bending stress $\sigma_{m_adm} = \sigma_m \times K_3 \times K_7 \times K_8 =$ **11.130** N/mm²

Applied bending stress $\sigma_{m_max} = F \times L_{eff}^2 / (8 \times Z) =$ **1.926** N/mm²

PASS - Applied bending stress within permissible limits

Check compressive stress parallel to grain

Compression stress parallel to grain $\sigma_c =$ **7.900** N/mm²

Minimum modulus of elasticity $E_{min} =$ **7200** N/mm²

Compression member factor $K_{12} =$ **0.66**

Permissible compressive stress $\sigma_{c_adm} = \sigma_c \times K_3 \times K_8 \times K_{12} =$ **7.213** N/mm²

Applied compressive stress $\sigma_{c_max} = F \times L_{eff} \times (\cot(\alpha) + 3 \times \tan(\alpha)) / (2 \times A) =$ **0.278** N/mm²

PASS - Applied compressive stress within permissible limits

Check combined bending and compressive stress parallel to grain

Euler stress $\sigma_e = \pi^2 \times E_{min} / \lambda^2 =$ **22.269** N/mm²

Euler coefficient $K_{eu} = 1 - (1.5 \times \sigma_{c_max} \times K_{12} / \sigma_e) =$ **0.988**

Combined axial compression and bending check $\sigma_{m_max} / (\sigma_{m_adm} \times K_{eu}) + \sigma_{c_max} / \sigma_{c_adm} =$ **0.214 < 1**

PASS - Combined compressive and bending stresses are within permissible limits

Check shear stress

Shear stress parallel to grain $\tau =$ **0.710** N/mm²

Permissible shear stress $\tau_{adm} = \tau \times K_3 \times K_8 =$ **0.976** N/mm²

Applied shear stress $\tau_{max} = 3 \times F \times L_{eff} / (4 \times A) =$ **0.118** N/mm²

PASS - Applied shear stress within permissible limits

Check deflection

Permissible deflection $\delta_{adm} = 0.003 \times L_{eff} =$ **7.338** mm

Bending deflection $\delta_b = 5 \times F \times L_{eff}^4 / (384 \times E_{mean} \times I) =$ **1.482** mm

Shear deflection $\delta_s = 12 \times F \times L_{eff}^2 / (5 \times E_{mean} \times A) =$ **0.086** mm

Total deflection $\delta_{max} = \delta_b + \delta_s =$ **1.568** mm

PASS - Total deflection within permissible limits

Consider short term load condition

Load duration factor $K_3 =$ **1.50**

Total UDL perpendicular to rafter $F = F_d \times \cos(\alpha) \times s + F_j \times \cos(\alpha) =$ **0.349** kN/m

Notional bearing length $L_b = [F \times L_{cl} + F_p \times \cos(\alpha)] / [2 \times (b \times \sigma_{cp1} \times K_8 - F)] =$ **6** mm

Effective span $L_{eff} = L_{cl} + L_b =$ **2448** mm

Check bending stress

Bending stress parallel to grain $\sigma_m =$ **7.500** N/mm²

Permissible bending stress	$\sigma_{m_adm} = \sigma_m \times K_3 \times K_7 \times K_8 =$ **13.355** N/mm²
Applied bending stress	$\sigma_{m_max} = F \times L_{eff}^2/(8 \times Z) + F_p \times \cos(\alpha) \times L_{eff}/(4 \times Z) =$ **3.799** N/mm²
	PASS - Applied bending stress within permissible limits

Check compressive stress parallel to grain

Compression stress parallel to grain	$\sigma_c =$ **7.900** N/mm²
Minimum modulus of elasticity	$E_{min} =$ **7200** N/mm²
Compression member factor	$K_{12} =$ **0.64**
Permissible compressive stress	$\sigma_{c_adm} = \sigma_c \times K_3 \times K_8 \times K_{12} =$ **8.281** N/mm²
Applied compressive stress	$\sigma_{c_max} = F \times L_{eff} \times (\cot(\alpha)+3 \times \tan(\alpha))/(2 \times A) + F_p \times \sin(\alpha)/A =$ **0.270** N/mm²
	PASS - Applied compressive stress within permissible limits

Check combined bending and compressive stress parallel to grain

Euler stress	$\sigma_e = \pi^2 \times E_{min} / \lambda^2 =$ **22.241** N/mm²
Euler coefficient	$K_{eu} = 1 - (1.5 \times \sigma_{c_max} \times K_{12} / \sigma_e) =$ **0.988**
Combined axial compression and bending check	$\sigma_{m_max} / (\sigma_{m_adm} \times K_{eu}) + \sigma_{c_max} / \sigma_{c_adm} =$ **0.320 < 1**
	PASS - Combined compressive and bending stresses are within permissible limits

Check shear stress

Shear stress parallel to grain	$\tau =$ **0.710** N/mm²
Permissible shear stress	$\tau_{adm} = \tau \times K_3 \times K_8 =$ **1.172** N/mm²
Applied shear stress	$\tau_{max} = 3 \times F \times L_{eff} / (4 \times A) + 3 \times F_p \times \cos(\alpha) / (2 \times A) =$ **0.233** N/mm²
	PASS - Applied shear stress within permissible limits

Check deflection

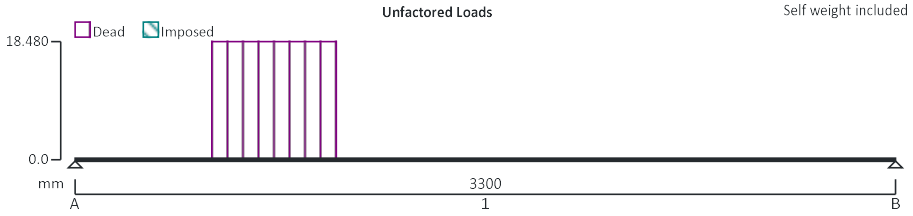
Permissible deflection	$\delta_{adm} = 0.003 \times L_{eff} =$ **7.343** mm
Bending deflection	$\delta_b = L_{eff}^3 \times (5 \times F \times L_{eff} / 384 + F_p \times \cos(\alpha)/ 48) / (E_{mean} \times I) =$ **2.556** mm
Shear deflection	$\delta_s = 12 \times L_{eff} \times (F \times L_{eff} + 2 \times F_p \times \cos(\alpha))/(5 \times E_{mean} \times A) =$ **0.169** mm
Total deflection	$\delta_{max} = \delta_b + \delta_s =$ **2.725** mm
	PASS - Total deflection within permissible limits

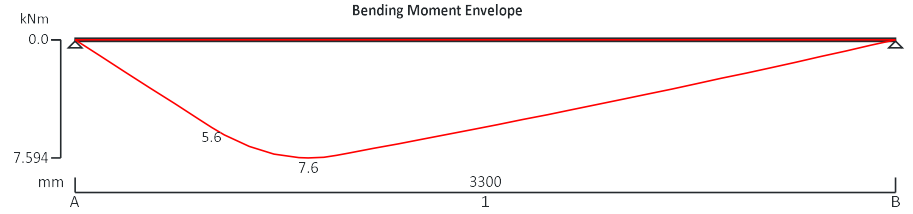
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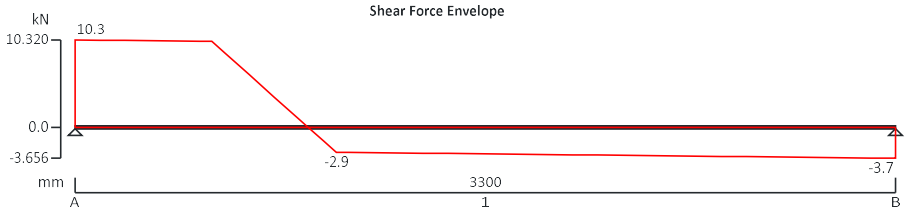
Project Ref:	16518
Page No:	14
Site Address: 2 The Terrace	Engineer: AT
Project type: Structural Calculations	Date: September 23

Beam B4

Dead udl from chimney = 4.40 x 4.20 = 18.48 kN/m







Support conditions

Support A	Vertically restrained Rotationally free
Support B	Vertically restrained Rotationally free

Analysis results

Maximum moment	M_{max} = **7.6** kNm
	M_{min} = **0** kNm
Maximum shear	V_{max} = **10.3** kN
	V_{min} = **-3.7** kN
Deflection	δ_{max} = **2** mm
	δ_{min} = **0** mm
Maximum reaction at support A	R_{A_max} = **10.3** kN
	R_{A_min} = **10.3** kN
Unfactored dead load reaction at support A	R_{A_Dead} = **7.4** kN
Maximum reaction at support B	R_{B_max} = **3.7** kN
	R_{B_min} = **3.7** kN
Unfactored dead load reaction at support B	R_{B_Dead} = **2.6** kN

Section details

Section type	**UC 152x152x23 (British Steel Section Range 2022 (BS4-1))**
Steel grade	**S355**

From table 9: Design strength p_y

Thickness of element	max(T, t) = **6.8** mm
Design strength	p_y = **355** N/mm^2
Modulus of elasticity	E = **205000** N/mm^2

Lateral restraint

Span 1 has lateral restraint at supports only

Effective length factors

Effective length factor in major axis	K_x = **1.00**
Effective length factor in minor axis	K_y = **1.00**
Effective length factor for lateral-torsional buckling	$K_{LT.A}$ = **1.40** + 2 × D
	$K_{LT.B}$ = **1.00**

Classification of cross sections - Section 3.5

$\varepsilon = \sqrt{[275\ N/mm^2 / p_y]}$ = **0.88**

Internal compression parts - Table 11

Depth of section	d = **123.6** mm
	d / t = 24.2 × ε <= 80 × ε
	Class 1 plastic

Outstand flanges - Table 11

Width of section	b = B / 2 = **76.1** mm
	b / T = 12.7 × ε <= 15 × ε
	Class 3 semi-compact
	Section is class 3 semi-compact

Shear capacity - Section 4.2.3

Design shear force	F_v = max(abs(V_{max}), abs(V_{min})) = **10.3** kN
	d / t < 70 × ε
	Web does not need to be checked for shear buckling
Shear area	A_v = t × D = **884** mm^2
Design shear resistance	P_v = 0.6 × p_y × A_v = **188.3** kN
	PASS - Design shear resistance exceeds design shear force

Moment capacity - Section 4.2.5

Design bending moment: M = max(abs(M_{s1_max}), abs(M_{s1_min})) = **7.6** kNm

Effective plastic modulus - Section 3.5.6

Limiting value for class 2 compact flange	β_{2f} = 10 × ε = **8.801**
Limiting value for class 3 semi-compact flange	β_{3f} = 15 × ε = **13.202**
Limiting value for class 2 compact web	β_{2w} = 100 × ε = **88.014**
Limiting value for class 3 semi-compact web	β_{3w} = 120 × ε = **105.617**

Effective plastic modulus - cl.3.5.6.2

$S_{eff} = \min(Z_{xx} + (S_{xx} - Z_{xx}) \times \min([((\beta_{3w} / (d / t))^2 - 1) / ((\beta_{3w} / \beta_{2w})^2 - 1)], [(\beta_{3f} / (b / T) - 1) / (\beta_{3f} / \beta_{2f} - 1)]), S_{xx})$ = **170473** mm^3

Moment capacity low shear - cl.4.2.5.2: $M_c = \min(p_y \times S_{eff}, 1.2 \times p_y \times Z_{xx})$ = **60.5** kNm

Effective length for lateral-torsional buckling - Section 4.3.5

Effective length for lateral torsional buckling	L_E = ((1.4 + 1.2) × L_{s1} + 2 × D) / 2 = **4442** mm
Slenderness ratio	λ = L_E / r_{yy} = **120.133**

Equivalent slenderness - Section 4.3.6.7

Buckling parameter	u = **0.840**
Torsional index	x = **20.701**

Slenderness factor $v = 1 / [1 + 0.05 \times (\lambda / x)^2]^{0.25} = \mathbf{0.781}$

Ratio - cl.4.3.6.9 $\beta_W = S_{eff} / S_{xx} = \mathbf{0.937}$

Equivalent slenderness - cl.4.3.6.7 $\lambda_{LT} = u \times v \times \lambda \times \sqrt{[\beta_W]} = \mathbf{76.266}$

Limiting slenderness - Annex B.2.2 $\lambda_{L0} = 0.4 \times (\pi^2 \times E / p_y)^{0.5} = \mathbf{30.198}$

$\lambda_{LT} > \lambda_{L0}$ - Allowance should be made for lateral-torsional buckling

Bending strength - Section 4.3.6.5

Robertson constant $\alpha_{LT} = \mathbf{7.0}$

Perry factor $\eta_{LT} = \max(\alpha_{LT} \times (\lambda_{LT} - \lambda_{L0}) / 1000, 0) = \mathbf{0.322}$

Euler stress $p_E = \pi^2 \times E / \lambda_{LT}^2 = \mathbf{347.8}$ N/mm²

$\phi_{LT} = (p_y + (\eta_{LT} + 1) \times p_E) / 2 = \mathbf{407.5}$ N/mm²

Bending strength - Annex B.2.1 $p_b = p_E \times p_y / (\phi_{LT} + (\phi_{LT}^2 - p_E \times p_y)^{0.5}) = \mathbf{201.2}$ N/mm²

Equivalent uniform moment factor - Section 4.3.6.6

Equivalent uniform moment factor for LTB $m_{LT} = \mathbf{1.000}$

Buckling resistance moment - Section 4.3.6.4

Buckling resistance moment $M_b = p_b \times S_{eff} = \mathbf{34.3}$ kNm

$M_b / m_{LT} = \mathbf{34.3}$ kNm

PASS - Buckling resistance moment exceeds design bending moment

Check vertical deflection - Section 2.5.2

Consider deflection due to dead and imposed loads

Limiting deflection $\delta_{lim} = L_{s1} / 250 = \mathbf{13.2}$ mm

Maximum deflection span 1 $\delta = \max(\text{abs}(\delta_{max}), \text{abs}(\delta_{min})) = \mathbf{1.957}$ mm

PASS - Maximum deflection does not exceed deflection limit