2nd September 2021
Job No: 9353MWA160

Barn at The Post Office
Newtown
Newbury
Berkshire
RG20 9AP

<u>Report on Structural Aspects of the Feasibility of Conversion of a Single Storey Barn</u>

Author: M.W.Mitchell
Director BSc CEng MICE

Structural Solutions Management Ltd
Dairy Studios, 102 Lincoln Street, Bristol BS5 0BJ tel: 0117 924 5014
Email: admin@structuralsolutions.co.uk Website: www.structuralsolutions.co.uk

Barn at The Post Office, Newtown, Newbury, Berkshire RG20 9AP

<u>Report on the Structural Aspects of the feasibility of conversion of a single storey barn at The Post Office, Newtown, Newbury</u>

Purpose of the Report

Structural Solutions was commissioned to carry out an investigation into the feasibility of converting a single storey barn at The Post Office in Newtown south of Newbury into a residential property. This report considers the current condition of the structure and the likely work required as part of the conversion. It is not intended to be a full structural evaluation of the building.

Introduction

The building is rectangular in plan constructed with 'dwarf' concrete block walls to the external perimeter supporting timber posts at approximately 3 metres centres forming the outer structure of structural timber 'frames'. There are also two rows of internal posts within these frames supporting principal rafters and a 'collar' member. Spanning between the frames are timber purlins at relatively close spacing (approximately 600mm c/c's) supporting a lightweight profiled metal deck roof sheet. External walls above the 'dwarf' blockwork wall are of timber frame construction supporting vertical timber cladding. There are a number of windows in the external walls that have been covered with corrugated metal sheets providing both a weatherproof and security measures. The floor appears to be concrete in parts and gravel in others.

Investigation

Our investigation is based on a visual walk over only and no testing of the materials has been carried out. However, the Client has photos of the early stages of construction which indicate that foundations were constructed below the external blockwork walls and a structural analysis carried out on the existing structural timber frames using loads appropriate to conversion into residential use.

The barn is currently used as a store and is relatively water tight as during our inspection it was raining constantly. The structural timber support frames of the barn consist of 100mm x 100mm timber posts supporting 175mm deep principal rafters, collar and internal struts. All members are bolted together at joint locations but the rafters appears to be in one length from eaves to ridge. Spanning between the frames are 50mm x 100mm timbers acting as purlins supporting the profiled metal sheet roof covering. The blockwork of the walls is in good condition and are of solid construction. From what could be seen, there are no significant cracks in the blockwork despite the length of the building at approximately 15 metres. The main structural timber is exposed and could be visually inspected. There appears to be very little decay.

Discussion

We understand from the Client that the proposed conversion work will maintain the basic plan of the building including retention of the existing roof profiles.

Generally, the structure can be incorporated into a conversion of all of the barn without any structural alterations. Analysis of the existing timber frame structure (see Appendix B) show that it is capable of supporting loads from a residential building without modification. The external concrete blockwork appears to be in relatively good condition and likely to only require application of 'surface' insulation and finishes. The timber wall and profile metal roof cladding will require upgrading to add insulation and finishes internally appropriate to a residential property but these elements are not considered structural and the external profile of the building will not change. Based on our inspection, areas of the existing concrete floor may need to be replaced to introduction of a damp proof membrane, insulation and floor finishes.

Conclusion

As stated above, this report is not intended to be a full and detailed structural survey. Its purpose is to establish in structural terms whether the conversion into a usable property is feasible without significant modification or demolition. In brief, demolition or significant removal of the fabric of the building is not necessary as the existing structure, with some remedial work, could be incorporated into the proposed conversion without major modification.

Appendix A – Photos of Existing Barn

External View of the ‘front’ of the Barn

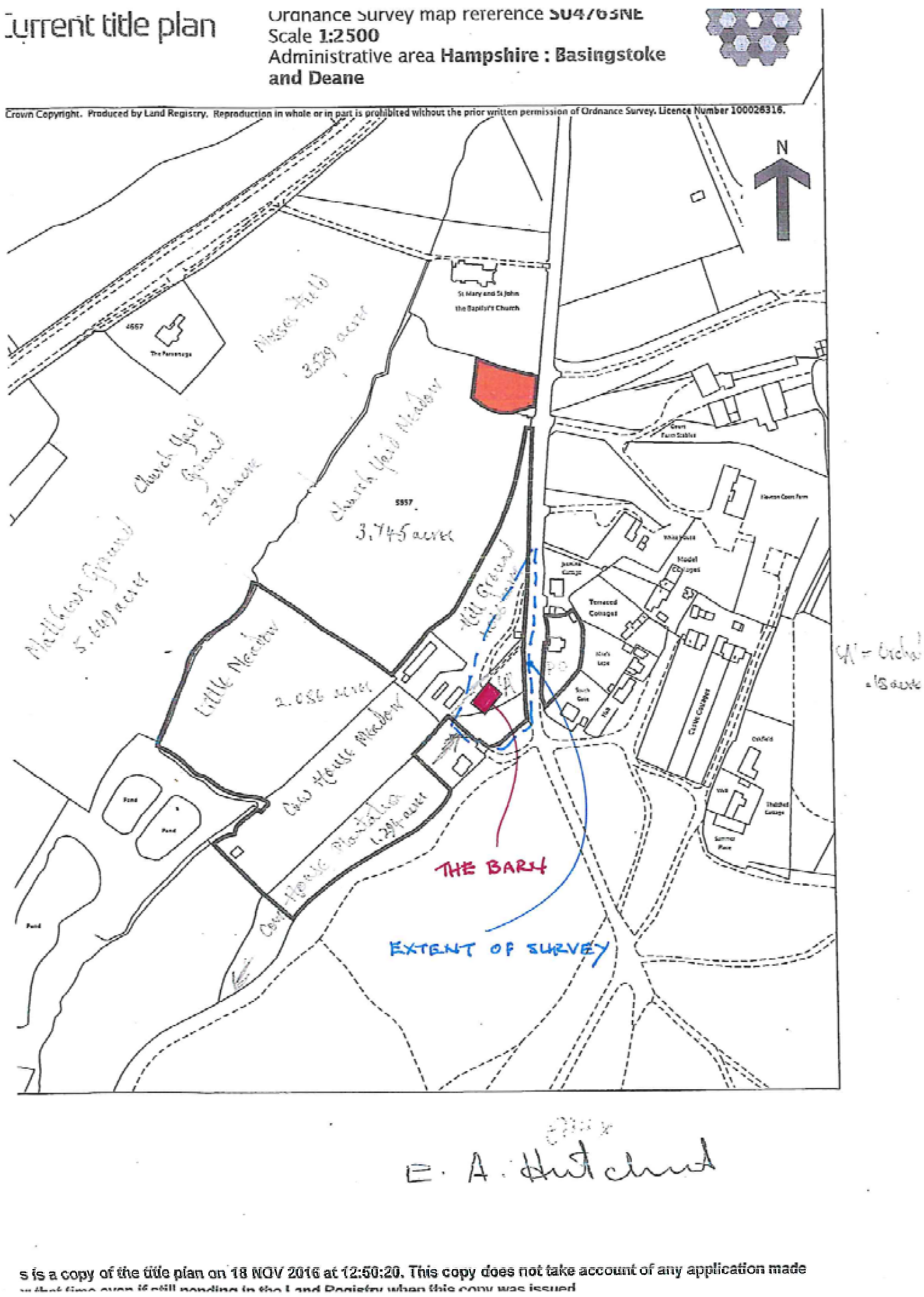
External view of the ‘front’ of the Barn

Internal view of Barn showing part of structural timber support frame

Internal view of Barn showing part of structural timber support frame

Internal view of Barn showing part of purlins spanning between frames

Appendix B – Site Location Plan



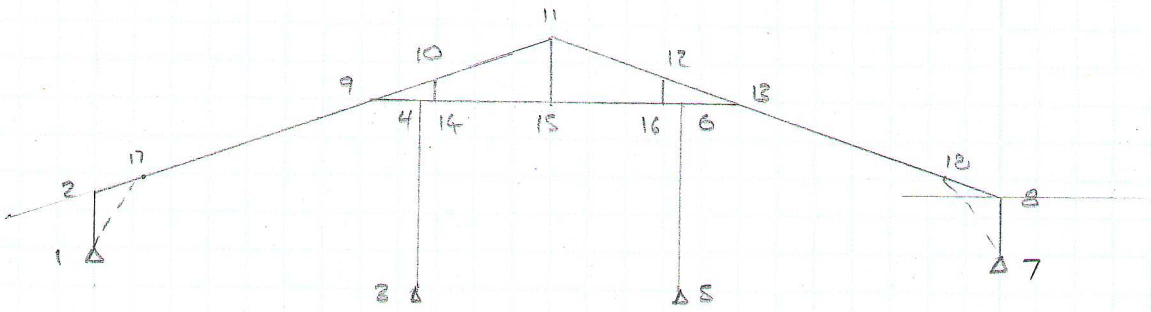
STRUCTURAL SOLUTIONS

Appendix C – Existing Structural Frame Analysis

Project	Sheet no./rev.
BARN AT THE POST OFFICE, NEWTOWN, NEWBURY	MWA160
EXISTING FRAME ANALYSIS	By/Date MM 3/8/21

CONSIDER EXISTING FRAME

SPACING OF FRAME
3000



NODES.	X	Y
1	0	0.675
2	0	1.346
3	4.250	0
4	4.250	2.500
5	7.650	0
6	7.650	2.500
7	11.900	0.675
8	11.900	1.346
9	3.550	2.50
10	4.750	2.890
11	5.950	3.280
12	7.150	2.890
13	8.350	2.50
14	4.750	2.50
15	5.950	2.50
16	7.150	2.50
17	0.477	1.502
18	11.423	1.502

MEMBERS

POSTS	100 x 100	SW
PR.	2/25 x 175	SW
COLLAR	50 x 175	SW
STRUTS	50 x 175	SW

LOADING – UDL ON PR

DEAD. 0.25 kN/m² x 3.0 = 0.75 kN/m

LIVE 0.60 kN/m² x cos 18° x 3.0 = 1.71 kN/m

TIMBER 2D ANALYSIS & DESIGN (EN1995)

TIMBER MEMBER ANALYSIS & DESIGN (EN1995-1-1:2004)

In accordance with EN1995-1-1:2004 + A2:2014 incorporating corrigendum June 2006 and the UK national annex

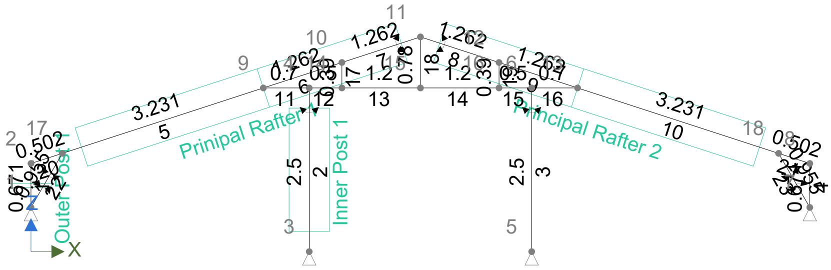
Tedds calculation version 2.2.10

ANALYSIS

Tedds calculation version 1.0.36

Geometry

Geometry (m) - C24 (EC5)



Materials

Name	Density (kg/m³)	Youngs Modulus kN/mm²	Shear Modulus kN/mm²	Thermal Coefficient °C^{-1}
C24 (EC5)	420	11	0.69	0

Sections

Name	Area	Moment of inertia		Shear area parallel to	
		Major	Minor	Minor	Major
	(cm²)	(cm⁴)	(cm⁴)	(cm²)	(cm²)
100x100	100	833.3	833.3	83.3	83.3
2/25x175	87.5	2233.1	182.3	72.9	72.9
50x175	87.5	2233.1	182.3	72.9	72.9

Nodes

Node	Co-ordinates		Freedom			Coordinate system		Spring		
	X	Z	X	Z	Rot.	Name	Angle	X	Z	Rot.
	(m)	(m)					(°)	(kN/m)	(kN/m)	kNm/°
1	0	0.675	Fixed	Fixed	Free		0	0	0	0
2	0	1.346	Free	Free	Free		0	0	0	0
3	4.25	0	Fixed	Fixed	Free		0	0	0	0
4	4.25	2.5	Free	Free	Free		0	0	0	0
5	7.65	0	Fixed	Fixed	Free		0	0	0	0
6	7.65	2.5	Free	Free	Free		0	0	0	0
7	11.9	0.675	Fixed	Fixed	Free		0	0	0	0
8	11.9	1.346	Free	Free	Free		0	0	0	0
9	3.55	2.5	Free	Free	Free		0	0	0	0
10	4.75	2.89	Free	Free	Free		0	0	0	0
11	5.95	3.28	Free	Free	Free		0	0	0	0
12	7.15	2.89	Free	Free	Free		0	0	0	0
13	8.35	2.5	Free	Free	Free		0	0	0	0
14	4.75	2.5	Free	Free	Free		0	0	0	0
15	5.95	2.5	Free	Free	Free		0	0	0	0
16	7.15	2.5	Free	Free	Free		0	0	0	0
17	0.477	1.502	Free	Free	Free		0	0	0	0
18	11.423	1.502	Free	Free	Free		0	0	0	0

Elements

Element	Length	Nodes		Section	Material	Releases			Rotated
	(m)	Start	End			Start moment	End moment	Axial	
1	0.671	1	2	100x100	C24 (EC5)	Fixed	Fixed	Fixed	
2	2.5	3	4	100x100	C24 (EC5)	Fixed	Free	Fixed	
3	2.5	5	6	100x100	C24 (EC5)	Fixed	Free	Fixed	
4	0.671	7	8	100x100	C24 (EC5)	Fixed	Fixed	Fixed	

Element	Length	Nodes		Section	Material	Releases			Rotated
	(m)	Start	End			Start moment	End moment	Axial	
5	3.231	17	9	2/25x175	C24 (EC5)	Fixed	Fixed	Fixed	
6	1.262	9	10	2/25x175	C24 (EC5)	Fixed	Fixed	Fixed	
7	1.262	10	11	2/25x175	C24 (EC5)	Fixed	Free	Fixed	
8	1.262	11	12	2/25x175	C24 (EC5)	Free	Fixed	Fixed	
9	1.262	12	13	2/25x175	C24 (EC5)	Fixed	Fixed	Fixed	
10	3.231	13	18	2/25x175	C24 (EC5)	Fixed	Fixed	Fixed	
11	0.7	9	4	50x175	C24 (EC5)	Free	Fixed	Fixed	
12	0.5	4	14	50x175	C24 (EC5)	Fixed	Fixed	Fixed	
13	1.2	14	15	50x175	C24 (EC5)	Fixed	Fixed	Fixed	
14	1.2	15	16	50x175	C24 (EC5)	Fixed	Fixed	Fixed	
15	0.5	16	6	50x175	C24 (EC5)	Fixed	Fixed	Fixed	
16	0.7	6	13	50x175	C24 (EC5)	Fixed	Free	Fixed	
17	0.39	14	10	50x175	C24 (EC5)	Free	Free	Fixed	
18	0.78	15	11	50x175	C24 (EC5)	Free	Fixed	Fixed	
19	0.39	16	12	50x175	C24 (EC5)	Free	Free	Fixed	
20	0.502	2	17	2/25x175	C24 (EC5)	Fixed	Fixed	Fixed	
21	0.502	18	8	2/25x175	C24 (EC5)	Fixed	Fixed	Fixed	
22	0.955	1	17	100x100	C24 (EC5)	Free	Free	Fixed	
23	0.955	18	7	100x100	C24 (EC5)	Free	Free	Fixed	

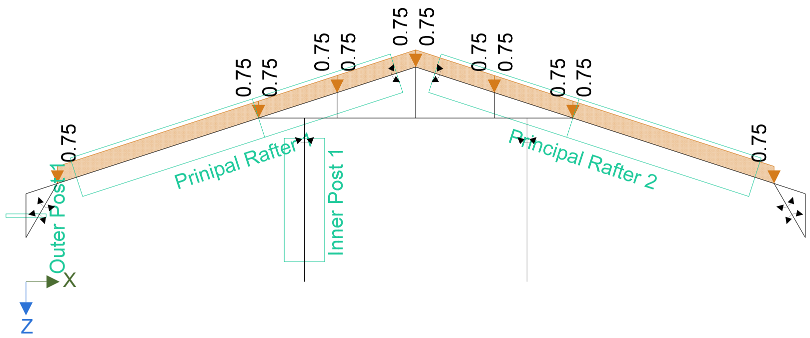
Members

Name	Elements	
	Start	End
Prinipal Rafter 1	5	7
Principal Rafter 2	8	10
Outer Post 1	1	1
Inner Post 1	2	2

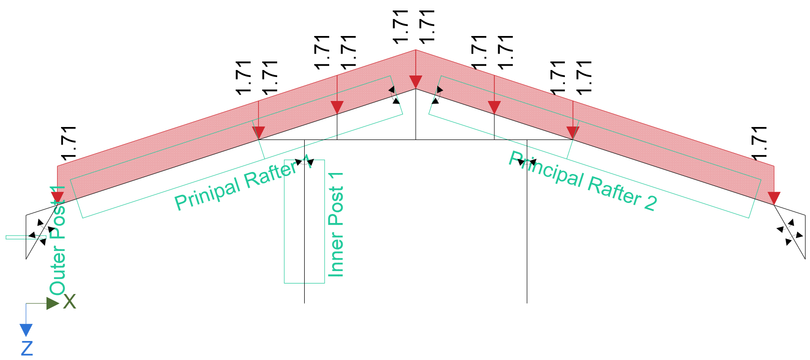
Loading

Self weight included

Permanent - Loading (kN/m)



Imposed - Loading (kN/m)



Load combination factors

Load combination	Self Weight	Permanent	Imposed

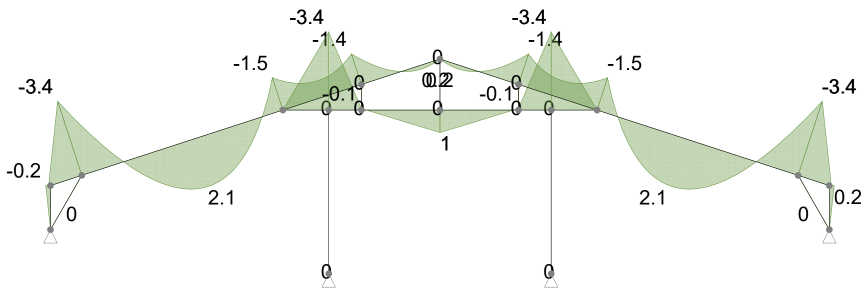
Member Loads

Member	Load case	Load Type	Orientation	Description
Prinipal Rafter 1	Permanent	UDL	GlobalZ	0.75 kN/m
Principal Rafter 2	Permanent	UDL	GlobalZ	0.75 kN/m
Prinipal Rafter 1	Imposed	UDL	GlobalZ	1.71 kN/m
Principal Rafter 2	Imposed	UDL	GlobalZ	1.71 kN/m

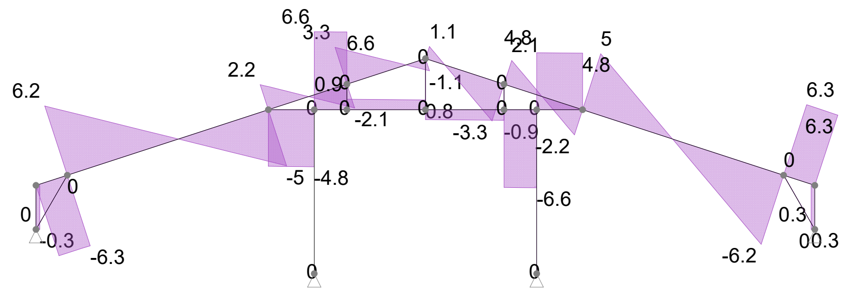
Results

Forces

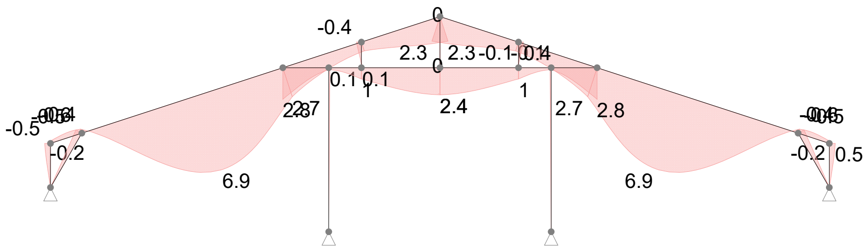
Strength combinations - Moment envelope (kNm)



Strength combinations - Shear envelope (kN)



Service combinations - Deflection envelope (mm)



Prinipal Rafter 1 - Span 1

Partial factor for material properties and resistances

Partial factor for material properties - Table 2.3 γ_M = **1.300**

Member details

Load duration - cl.2.3.1.2	Short-term
Service class - cl.2.3.1.3	1

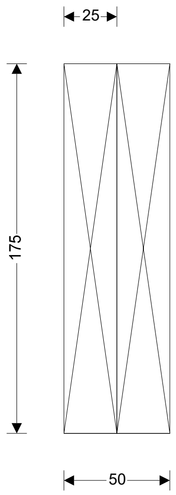
Timber section details

Number of timber sections in member N = **2**

Breadth of sections b = **25** mm

Depth of sections h = **175** mm

Timber strength class - EN 338:2016 Table 1 **C24**



2/25x175 timber sections

Cross-sectional area, A, 8750 mm^2

Section modulus, W_y, 255208.3 mm^3

Section modulus, W_z, 36458 mm^3

Second moment of area, I_y, 22330729 mm^4

Second moment of area, I_z, 455729 mm^4

Radius of gyration, i_y, 50.5 mm

Radius of gyration, i_z, 7.2 mm

Timber strength class C24

Characteristic bending strength, $f_{m.k}$, 24 N/mm^2

Characteristic shear strength, $f_{v.k}$, 4 N/mm^2

Characteristic compression strength parallel to grain, $f_{c.0.k}$, 21 N/mm^2

Characteristic compression strength perpendicular to grain, $f_{c.90.k}$, 2.5 N/mm^2

Characteristic tension strength parallel to grain, $f_{t.0.k}$, 14.5 N/mm^2

Mean modulus of elasticity, $E_{0.mean}$, 11000 N/mm^2

Fifth percentile modulus of elasticity, $E_{0.05}$, 7400 N/mm^2

Shear modulus of elasticity, G_{mean}, 690 N/mm^2

Characteristic density, ρ_k, 350 kg/m^3

Mean density, ρ_{mean}, 420 kg/m^3

Span details

Bearing length L_b = **100** mm

Prinipal Rafter 1 span 1 results summary	**Unit**	**Capacity**	**Maximum**	**Utilisation**	**Result**
Compressive stress	N/mm^2	16.0	1.4	0.087	PASS
Bending stress	N/mm^2	18.3	13.1	0.719	PASS
Shear stress	N/mm^2	3.0	1.6	0.517	PASS
Bending and axial force				0.727	PASS
Column stability check				0.842	PASS

Consider Combination 1 - 1.35G + 1.5Q + 1.5RQ (Strength)

Modification factors

Duration of load and moisture content - Table 3.1 k_{mod} = **0.9**

Deformation factor - Table 3.2 k_{def} = **0.6**

Bending stress re-distribution factor - cl.6.1.6(2) k_m = **0.7**

Crack factor for shear resistance - cl.6.1.7(2) k_{cr} = **0.67**

System strength factor - cl.6.6 k_{sys} = **1.1**

Check compression parallel to the grain - cl.6.1.4

Design axial compression P_d = **12.109** kN

Design compressive stress $\sigma_{c,0,d} = P_d / A =$ **1.384** N/mm^2

Design compressive strength $f_{c,0,d} = k_{mod} \times k_{sys} \times f_{c.0.k} / \gamma_M =$ **15.992** N/mm^2

$\sigma_{c,0,d} / f_{c,0,d} =$ **0.087**

PASS - Design parallel compression strength exceeds design parallel compression stress

Check design at start of span

Check shear force - Section 6.1.7

Design shear force $F_{y,d} =$ **6.157** kN

Design shear stress - exp.6.60 $\tau_{y,d} = 1.5 \times F_{y,d} / (k_{cr} \times N \times b \times h) =$ **1.575** N/mm^2

Design shear strength $f_{v,y,d} = k_{mod} \times k_{sys} \times f_{v.k} / \gamma_M =$ **3.046** N/mm^2

$\tau_{y,d} / f_{v,y,d} =$ **0.517**

PASS - Design shear strength exceeds design shear stress

Check bending moment - Section 6.1.6

Design bending moment $M_{y,d} =$ **3.356** kNm

Design bending stress $\sigma_{m,y,d} = M_{y,d} / W_y =$ **13.149** N/mm^2

Design bending strength $f_{m,y,d} = k_{mod} \times k_{sys} \times f_{m.k} / \gamma_M =$ **18.277** N/mm^2

$\sigma_{m,y,d} / f_{m,y,d} =$ **0.719**

PASS - Design bending strength exceeds design bending stress

Check combined bending and axial tension - Section 6.2.3

Combined loading checks - exp.6.19 & 6.20 $(\sigma_{c,0,d} / f_{c,0,d})^2 + \sigma_{m,y,d} / f_{m,y,d} =$ **0.727**

$(\sigma_{c,0,d} / f_{c,0,d})^2 + k_m \times \sigma_{m,y,d} / f_{m,y,d} =$ **0.511**

PASS - Combined bending and axial compression utilisation is acceptable

Check columns subjected to either compression or combined compression and bending - cl.6.3.2

Effective length for y-axis bending $L_{e,y} = 0.9 \times 3231$ mm = **2908** mm

Slenderness ratio $\lambda_y = L_{e,y} / i_y =$ **57.561**

Relative slenderness ratio - exp. 6.21 $\lambda_{rel,y} = \lambda_y / \pi \times \sqrt{(f_{c.0.k} / E_{0.05})} =$ **0.976**

Effective length for z-axis bending $L_{e,z} =$ **0** mm

Slenderness ratio $\lambda_z = L_{e,z} / i_z =$ **0**

Relative slenderness ratio - exp. 6.22 $\lambda_{rel,z} = \lambda_z / \pi \times \sqrt{(f_{c.0.k} / E_{0.05})} =$ **0**

$\lambda_{rel,y}$ > 0.3 column stability check is required

Straightness factor $\beta_c =$ **0.2**

Instability factors - exp.6.25, 6.26, 6.27 & 6.28 $k_y = 0.5 \times (1 + \beta_c \times (\lambda_{rel,y} - 0.3) + \lambda_{rel,y}^2) =$ **1.044**

$k_z = 0.5 \times (1 + \beta_c \times (\lambda_{rel,z} - 0.3) + \lambda_{rel,z}^2) =$ **0.470**

$k_{c,y} = 1 / (k_y + \sqrt{(k_y^2 - \lambda_{rel,y}^2)}) =$ **0.707**

$k_{c,z} = 1 / (k_z + \sqrt{(k_z^2 - \lambda_{rel,z}^2)}) =$ **1.064**

Column stability checks - exp.6.23 & 6.24 $\sigma_{c,0,d} / (k_{c,y} \times f_{c,0,d}) + \sigma_{m,y,d} / f_{m,y,d} =$ **0.842**

$\sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d}) + k_m \times \sigma_{m,y,d} / f_{m,y,d} =$ **0.585**

PASS - Column stability is acceptable

Prinipal Rafter 1 - Span 2

Partial factor for material properties and resistances

Partial factor for material properties - Table 2.3 γ_M = **1.300**

Member details

Load duration - cl.2.3.1.2 Short-term

Service class - cl.2.3.1.3 1

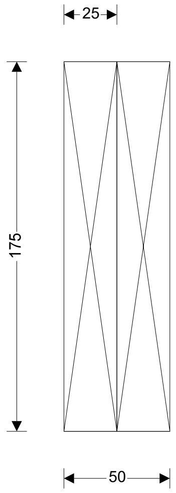
Timber section details

Number of timber sections in member N = **2**

Breadth of sections b = **25** mm

Depth of sections h = **175** mm

Timber strength class - EN 338:2016 Table 1 **C24**



2/25x175 timber sections
Cross-sectional area, A, 8750 mm^2
Section modulus, W_y, 255208.3 mm^3
Section modulus, W_z, 36458 mm^3
Second moment of area, I_y, 22330729 mm^4
Second moment of area, I_z, 455729 mm^4
Radius of gyration, i_y, 50.5 mm
Radius of gyration, i_z, 7.2 mm
Timber strength class C24
Characteristic bending strength, $f_{m.k}$, 24 N/mm^2
Characteristic shear strength, $f_{v.k}$, 4 N/mm^2
Characteristic compression strength parallel to grain, $f_{c.0.k}$, 21 N/mm^2
Characteristic compression strength perpendicular to grain, $f_{c.90.k}$, 2.5 N/mm^2
Characteristic tension strength parallel to grain, $f_{t.0.k}$, 14.5 N/mm^2
Mean modulus of elasticity, $E_{0.mean}$, 11000 N/mm^2
Fifth percentile modulus of elasticity, $E_{0.05}$, 7400 N/mm^2
Shear modulus of elasticity, G_{mean}, 690 N/mm^2
Characteristic density, ρ_k, 350 kg/m^3
Mean density, ρ_{mean}, 420 kg/m^3

Span details

Bearing length L_b = **100** mm

Prinipal Rafter 1 span 2 results summary	**Unit**	**Capacity**	**Maximum**	**Utilisation**	**Result**
Compressive stress	N/mm^2	16.0	0.2	0.015	PASS
Bending stress	N/mm^2	18.3	5.7	0.314	PASS
Shear stress	N/mm^2	3.0	0.8	0.275	PASS
Bending and axial force				0.314	PASS
Column stability check				0.329	PASS
Beam stability check				0.110	PASS

Consider Combination 1 - 1.35G + 1.5Q + 1.5RQ (Strength)

Modification factors

Duration of load and moisture content - Table 3.1 k_{mod} = **0.9**

Deformation factor - Table 3.2 k_{def} = **0.6**

Bending stress re-distribution factor - cl.6.1.6(2) k_m = **0.7**

Crack factor for shear resistance - cl.6.1.7(2) k_{cr} = **0.67**

System strength factor - cl.6.6 k_{sys} = **1.1**

Check compression parallel to the grain - cl.6.1.4

Design axial compression P_d = **1.753** kN

Design compressive stress $\sigma_{c,0,d} = P_d / A$ = **0.200** N/mm^2

Design compressive strength $f_{c,0,d} = k_{mod} \times k_{sys} \times f_{c.0.k} / \gamma_M$ = **15.992** N/mm^2

$\sigma_{c,0,d} / f_{c,0,d}$ = **0.013**

PASS - Design parallel compression strength exceeds design parallel compression stress

Check design at start of span

Check shear force - Section 6.1.7

Design shear force $F_{y,d}$ = **2.236** kN

Design shear stress - exp.6.60 $\tau_{y,d} = 1.5 \times F_{y,d} / (k_{cr} \times N \times b \times h)$ = **0.572** N/mm^2

Design shear strength $f_{v,y,d} = k_{mod} \times k_{sys} \times f_{v.k} / \gamma_M$ = **3.046** N/mm^2

$\tau_{y,d} / f_{v,y,d}$ = **0.188**

PASS - Design shear strength exceeds design shear stress

Check bending moment - Section 6.1.6

Design bending moment $M_{y,d}$ = **1.463** kNm

Design bending stress $\sigma_{m,y,d} = M_{y,d} / W_y$ = **5.734** N/mm^2

Design bending strength $f_{m,y,d} = k_{mod} \times k_{sys} \times f_{m.k} / \gamma_M$ = **18.277** N/mm^2

$\sigma_{m,y,d} / f_{m,y,d}$ = **0.314**

PASS - Design bending strength exceeds design bending stress

Check combined bending and axial tension - Section 6.2.3

Combined loading checks - exp.6.19 & 6.20 $(\sigma_{c,0,d} / f_{c,0,d})^2 + \sigma_{m,y,d} / f_{m,y,d}$ = **0.314**

$(\sigma_{c,0,d} / f_{c,0,d})^2 + k_m \times \sigma_{m,y,d} / f_{m,y,d}$ = **0.220**

PASS - Combined bending and axial compression utilisation is acceptable

Check columns subjected to either compression or combined compression and bending - cl.6.3.2

Effective length for y-axis bending $L_{e,y} = 0.9 \times 2524$ mm = **2272** mm

Slenderness ratio $\lambda_y = L_{e,y} / i_y$ = **44.966**

Relative slenderness ratio - exp. 6.21 $\lambda_{rel,y} = \lambda_y / \pi \times \sqrt{(f_{c.0.k} / E_{0.05})}$ = **0.762**

Effective length for z-axis bending $L_{e,z}$ = **0** mm

Slenderness ratio $\lambda_z = L_{e,z} / i_z$ = **0**

Relative slenderness ratio - exp. 6.22 — $\lambda_{rel,z} = \lambda_z / \pi \times \sqrt{(f_{c.0.k} / E_{0.05})} = \mathbf{0}$

$\lambda_{rel,y}$ > 0.3 column stability check is required

Straightness factor — $\beta_c = \mathbf{0.2}$

Instability factors - exp.6.25, 6.26, 6.27 & 6.28 — $k_y = 0.5 \times (1 + \beta_c \times (\lambda_{rel,y} - 0.3) + \lambda_{rel,y}^2) = \mathbf{0.837}$

$k_z = 0.5 \times (1 + \beta_c \times (\lambda_{rel,z} - 0.3) + \lambda_{rel,z}^2) = \mathbf{0.470}$

$k_{c,y} = 1 / (k_y + \sqrt{(k_y^2 - \lambda_{rel,y}^2)}) = \mathbf{0.846}$

$k_{c,z} = 1 / (k_z + \sqrt{(k_z^2 - \lambda_{rel,z}^2)}) = \mathbf{1.064}$

Column stability checks - exp.6.23 & 6.24 — $\sigma_{c,0,d} / (k_{c,y} \times f_{c,0,d}) + \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.329}$

$\sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d}) + k_m \times \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.231}$

PASS - Column stability is acceptable

Check beams subjected to either bending or combined bending and compression - cl.6.3.3

Lateral buckling factor - exp.6.34 — $k_{crit} = \mathbf{1.000}$

Beam stability check - exp.6.35 — $(\sigma_{m,y,d} / (k_{crit} \times f_{m,y,d}))^2 + \sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d}) = \mathbf{0.11}$

PASS - Beam stability is acceptable

<u>Check design 1262 mm along span</u>

Check shear force - Section 6.1.7

Design shear force — $F_{y,d} = \mathbf{3.275}$ kN

Design shear stress - exp.6.60 — $\tau_{y,d} = 1.5 \times F_{y,d} / (k_{cr} \times N \times b \times h) = \mathbf{0.838}$ N/mm^2

Design shear strength — $f_{v,y,d} = k_{mod} \times k_{sys} \times f_{v.k} / \gamma_M = \mathbf{3.046}$ N/mm^2

$\tau_{y,d} / f_{v,y,d} = \mathbf{0.275}$

PASS - Design shear strength exceeds design shear stress

Check bending moment - Section 6.1.6

Design bending moment — $M_{y,d} = \mathbf{1.387}$ kNm

Design bending stress — $\sigma_{m,y,d} = M_{y,d} / W_y = \mathbf{5.434}$ N/mm^2

Design bending strength — $f_{m,y,d} = k_{mod} \times k_{sys} \times f_{m.k} / \gamma_M = \mathbf{18.277}$ N/mm^2

$\sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.297}$

PASS - Design bending strength exceeds design bending stress

Check combined bending and axial tension - Section 6.2.3

Combined loading checks - exp.6.19 & 6.20 — $(\sigma_{c,0,d} / f_{c,0,d})^2 + \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.297}$

$(\sigma_{c,0,d} / f_{c,0,d})^2 + k_m \times \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.208}$

PASS - Combined bending and axial compression utilisation is acceptable

Check columns subjected to either compression or combined compression and bending - cl.6.3.2

Effective length for y-axis bending — $L_{e,y} = 0.9 \times 2524$ mm $= \mathbf{2272}$ mm

Slenderness ratio — $\lambda_y = L_{e,y} / i_y = \mathbf{44.966}$

Relative slenderness ratio - exp. 6.21 — $\lambda_{rel,y} = \lambda_y / \pi \times \sqrt{(f_{c.0.k} / E_{0.05})} = \mathbf{0.762}$

Effective length for z-axis bending — $L_{e,z} = \mathbf{0}$ mm

Slenderness ratio — $\lambda_z = L_{e,z} / i_z = \mathbf{0}$

Relative slenderness ratio - exp. 6.22 — $\lambda_{rel,z} = \lambda_z / \pi \times \sqrt{(f_{c.0.k} / E_{0.05})}$ = **0**

$\lambda_{rel,y}$ > 0.3 column stability check is required

Straightness factor — β_c = **0.2**

Instability factors - exp.6.25, 6.26, 6.27 & 6.28 — $k_y = 0.5 \times (1 + \beta_c \times (\lambda_{rel,y} - 0.3) + \lambda_{rel,y}^2)$ = **0.837**

$k_z = 0.5 \times (1 + \beta_c \times (\lambda_{rel,z} - 0.3) + \lambda_{rel,z}^2)$ = **0.470**

$k_{c,y} = 1 / (k_y + \sqrt{(k_y^2 - \lambda_{rel,y}^2)})$ = **0.846**

$k_{c,z} = 1 / (k_z + \sqrt{(k_z^2 - \lambda_{rel,z}^2)})$ = **1.064**

Column stability checks - exp.6.23 & 6.24 — $\sigma_{c,0,d} / (k_{c,y} \times f_{c,0,d}) + \sigma_{m,y,d} / f_{m,y,d}$ = **0.312**

$\sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d}) + k_m \times \sigma_{m,y,d} / f_{m,y,d}$ = **0.220**

PASS - Column stability is acceptable

Check beams subjected to either bending or combined bending and compression - cl.6.3.3

Lateral buckling factor - exp.6.34 — k_{crit} = **1.000**

Beam stability check - exp.6.35 — $(\sigma_{m,y,d} / (k_{crit} \times f_{m,y,d}))^2 + \sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d})$ = **0.1**

PASS - Beam stability is acceptable

<u>Outer Post 1 - Span 1</u>

Partial factor for material properties and resistances

Partial factor for material properties - Table 2.3 — γ_M = **1.300**

Member details

Load duration - cl.2.3.1.2 — Short-term

Service class - cl.2.3.1.3 — 1

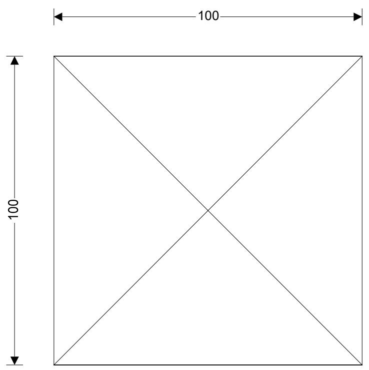
Timber section details

Number of timber sections in member — N = **1**

Breadth of sections — b = **100** mm

Depth of sections — h = **100** mm

Timber strength class - EN 338:2016 Table 1 — **C24**



100x100 timber section
Cross-sectional area, A, 10000 mm^2
Section modulus, W_y, 166666.7 mm^3
Section modulus, W_z, 166667 mm^3
Second moment of area, I_y, 8333333 mm^4
Second moment of area, I_z, 8333333 mm^4
Radius of gyration, i_y, 28.9 mm
Radius of gyration, i_z, 28.9 mm
Timber strength class C24
Characteristic bending strength, $f_{m.k}$, 24 N/mm^2
Characteristic shear strength, $f_{v.k}$, 4 N/mm^2
Characteristic compression strength parallel to grain, $f_{c.0.k}$, 21 N/mm^2
Characteristic compression strength perpendicular to grain, $f_{c.90.k}$, 2.5 N/mm^2
Characteristic tension strength parallel to grain, $f_{t.0.k}$, 14.5 N/mm^2
Mean modulus of elasticity, $E_{0.mean}$, 11000 N/mm^2
Fifth percentile modulus of elasticity, $E_{0.05}$, 7400 N/mm^2
Shear modulus of elasticity, G_{mean}, 690 N/mm^2
Characteristic density, ρ_k, 350 kg/m^3
Mean density, ρ_{mean}, 420 kg/m^3

Span details

Bearing length — L_b = **100** mm

Outer Post 1 results summary	Unit	Capacity	Maximum	Utilisation	Result
Tensile stress	N/mm^2	10.9	0.3	0.031	PASS
Bearing stress	N/mm^2	2.6	0.7	0.285	PASS
Bending stress	N/mm^2	18.0	1.3	0.070	PASS
Shear stress	N/mm^2	2.8	0.1	0.025	PASS
Bending and axial force				0.100	PASS

Consider Combination 1 - 1.35G + 1.5Q + 1.5RQ (Strength)

Modification factors

Duration of load and moisture content - Table 3.1 k_{mod} = **0.9**

Deformation factor - Table 3.2 k_{def} = **0.6**

Depth factor for bending - Major axis - exp.3.1 $k_{h,m,y} = \min((150 \text{ mm} / h)^{0.2}, 1.3)$ = **1.084**

Depth factor for tension - exp.3.1 $k_{h,t} = \min((150 \text{ mm} / \max(b, h))^{0.2}, 1.3)$ = **1.084**

Bending stress re-distribution factor - cl.6.1.6(2) k_m = **0.7**

Crack factor for shear resistance - cl.6.1.7(2) k_{cr} = **0.67**

Load configuration factor - cl.6.1.5(4) $k_{c,90}$ = **1.5**

Check tension parallel to the grain - Section 6.1.2

Axial tension P_d = **6.444** kN

Design tensile stress $\sigma_{t,0,d} = P_d / (b \times \min(h_{ef\_e1}, h_{ef\_e2}))$ = **0.330** N/mm^2

Design tensile strength $f_{t,0,d} = k_{h,t} \times k_{mod} \times f_{t.0.k} / \gamma_M$ = **10.886** N/mm^2

$\sigma_{t,0,d} / f_{t,0,d}$ = **0.030**

PASS - Design tensile strength exceeds design tensile stress

Check design at start of span

Check compression perpendicular to the grain - cl.6.1.5

Design perpendicular compression - major axis $F_{c,y,90,d}$ = **9.615** kN

Effective contact length $L_{b,ef} = L_b + \min(671 \text{ mm} / 2, L_b, 30 \text{ mm})$ = **130** mm

Design perpendicular compressive stress - exp.6.4 $\sigma_{c,y,90,d} = F_{c,y,90,d} / (b \times L_{b,ef})$ = **0.740** N/mm^2

Design perpendicular compressive strength $f_{c,y,90,d} = k_{mod} \times f_{c.90.k} / \gamma_M$ = **1.731** N/mm^2

$\sigma_{c,y,90,d} / (k_{c,90} \times f_{c,y,90,d})$ = **0.285**

PASS - Design perpendicular compression strength exceeds design perpendicular compression stress

Check shear force - Section 6.1.7

Design shear force $F_{y,d}$ = **0.312** kN

Design shear stress - exp.6.60 $\tau_{y,d} = 1.5 \times F_{y,d} / (k_{cr} \times b \times h)$ = **0.070** N/mm^2

Design shear strength $f_{v,y,d} = k_{mod} \times f_{v.k} / \gamma_M = \mathbf{2.769}$ N/mm^2

$\tau_{y,d} / f_{v,y,d} = \mathbf{0.025}$

PASS - Design shear strength exceeds design shear stress

Check design at end of span

Check shear force - Section 6.1.7

Design shear force $F_{y,d} = \mathbf{0.312}$ kN

Design shear stress - exp.6.60 $\tau_{y,d} = 1.5 \times F_{y,d} / (k_{cr} \times b \times h) = \mathbf{0.070}$ N/mm^2

Design shear strength $f_{v,y,d} = k_{mod} \times f_{v.k} / \gamma_M = \mathbf{2.769}$ N/mm^2

$\tau_{y,d} / f_{v,y,d} = \mathbf{0.025}$

PASS - Design shear strength exceeds design shear stress

Check bending moment - Section 6.1.6

Design bending moment $M_{y,d} = \mathbf{0.209}$ kNm

Design bending stress $\sigma_{m,y,d} = M_{y,d} / W_y = \mathbf{1.257}$ N/mm^2

Design bending strength $f_{m,y,d} = k_{h,m,y} \times k_{mod} \times f_{m.k} / \gamma_M = \mathbf{18.019}$ N/mm^2

$\sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.07}$

PASS - Design bending strength exceeds design bending stress

Check combined bending and axial tension - Section 6.2.3

Combined loading checks - exp.6.17 & 6.18 $\sigma_{t,0,d} / f_{t,0,d} + \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.100}$

$\sigma_{t,0,d} / f_{t,0,d} + k_m \times \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.079}$

PASS - Combined bending and axial tension utilisation is acceptable

Inner Post 1 - Span 1

Partial factor for material properties and resistances

Partial factor for material properties - Table 2.3 $\gamma_M = \mathbf{1.300}$

Member details

Load duration - cl.2.3.1.2 Short-term

Service class - cl.2.3.1.3 1

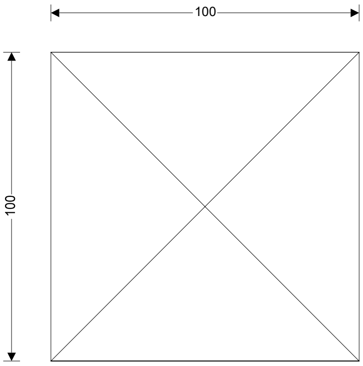
Timber section details

Number of timber sections in member N = **1**

Breadth of sections b = **100** mm

Depth of sections h = **100** mm

Timber strength class - EN 338:2016 Table 1 **C24**



100x100 timber section
Cross-sectional area, A, 10000 mm^2
Section modulus, W_y, 166666.7 mm^3
Section modulus, W_z, 166667 mm^3
Second moment of area, I_y, 8333333 mm^4
Second moment of area, I_z, 8333333 mm^4
Radius of gyration, i_y, 28.9 mm
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Timber strength class C24
Characteristic bending strength, $f_{m.k}$, 24 N/mm^2
Characteristic shear strength, $f_{v.k}$, 4 N/mm^2
Characteristic compression strength parallel to grain, $f_{c.0.k}$, 21 N/mm^2
Characteristic compression strength perpendicular to grain, $f_{c.90.k}$, 2.5 N/mm^2
Characteristic tension strength parallel to grain, $f_{t.0.k}$, 14.5 N/mm^2
Mean modulus of elasticity, $E_{0.mean}$, 11000 N/mm^2
Fifth percentile modulus of elasticity, $E_{0.05}$, 7400 N/mm^2
Shear modulus of elasticity, G_{mean}, 690 N/mm^2
Characteristic density, ρ_k, 350 kg/m^3
Mean density, ρ_{mean}, 420 kg/m^3

Span details

Bearing length L_b = **100** mm

Inner Post 1 results summary	Unit	Capacity	Maximum	Utilisation	Result
Compressive stress	N/mm^2	14.5	1.2	0.080	PASS
Column stability check				0.170	PASS

<u>Consider Combination 1 - 1.35G + 1.5Q + 1.5RQ (Strength)</u>

Modification factors

Duration of load and moisture content - Table 3.1 k_{mod} = **0.9**

Deformation factor - Table 3.2 k_{def} = **0.6**

Check compression parallel to the grain - cl.6.1.4

Design axial compression P_d = **11.564** kN

Design compressive stress $\sigma_{c,0,d} = P_d / A$ = **1.156** N/mm^2

Design compressive strength $f_{c,0,d} = k_{mod} \times f_{c.0.k} / \gamma_M$ = **14.538** N/mm^2

$\sigma_{c,0,d} / f_{c,0,d}$ = **0.080**

PASS - Design parallel compression strength exceeds design parallel compression stress

Check columns subjected to either compression or combined compression and bending - cl.6.3.2

Effective length for y-axis bending $L_{e,y} = 0.9 \times 2500$ mm = **2250** mm

Slenderness ratio $\lambda_y = L_{e,y} / i_y$ = **77.942**

Relative slenderness ratio - exp. 6.21 $\lambda_{rel,y} = \lambda_y / \pi \times \sqrt{(f_{c.0.k} / E_{0.05})}$ = **1.322**

Effective length for z-axis bending $L_{e,z}$ = **0** mm

Slenderness ratio $\lambda_z = L_{e,z} / i_z$ = **0**

Relative slenderness ratio - exp. 6.22 $\lambda_{rel,z} = \lambda_z / \pi \times \sqrt{(f_{c.0.k} / E_{0.05})}$ = **0**

$\lambda_{rel,y}$ > 0.3 column stability check is required

Straightness factor β_c = **0.2**

Instability factors - exp.6.25, 6.26, 6.27 & 6.28 $k_y = 0.5 \times (1 + \beta_c \times (\lambda_{rel,y} - 0.3) + \lambda_{rel,y}^2)$ = **1.476**

$k_z = 0.5 \times (1 + \beta_c \times (\lambda_{rel,z} - 0.3) + \lambda_{rel,z}^2)$ = **0.470**

$k_{c,y} = 1 / (k_y + \sqrt{(k_y^2 - \lambda_{rel,y}^2)})$ = **0.469**

$k_{c,z} = 1 / (k_z + \sqrt{(k_z^2 - \lambda_{rel,z}^2)})$ = **1.064**

Column stability checks - exp.6.23 & 6.24 $\sigma_{c,0,d} / (k_{c,y} \times f_{c,0,d})$ = **0.170**

$\sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d})$ = **0.075**

PASS - Column stability is acceptable

Check columns subjected to either compression or combined compression and bending - cl.6.3.2

Effective length for y-axis bending $L_{e,y} = 0.9 \times 2500$ mm = **2250** mm

Slenderness ratio $\lambda_y = L_{e,y} / i_y$ = **77.942**

Relative slenderness ratio - exp. 6.21 $\lambda_{rel,y} = \lambda_y / \pi \times \sqrt{(f_{c.0.k} / E_{0.05})}$ = **1.322**

Effective length for z-axis bending $L_{e,z}$ = **0** mm

Slenderness ratio $\lambda_z = L_{e,z} / i_z$ = **0**

Relative slenderness ratio - exp. 6.22 $\lambda_{rel,z} = \lambda_z / \pi \times \sqrt{(f_{c.0.k} / E_{0.05})}$ = **0**

$\lambda_{rel,y}$ > 0.3 column stability check is required

Straightness factor β_c = **0.2**

Instability factors - exp.6.25, 6.26, 6.27 & 6.28 $k_y = 0.5 \times (1 + \beta_c \times (\lambda_{rel,y} - 0.3) + \lambda_{rel,y}^2)$ = **1.476**

$k_z = 0.5 \times (1 + \beta_c \times (\lambda_{rel,z} - 0.3) + \lambda_{rel,z}^2)$ = **0.470**

$k_{c,y} = 1 / (k_y + \sqrt{(k_y^2 - \lambda_{rel,y}^2)})$ = **0.469**

$k_{c,z} = 1 / (k_z + \sqrt{(k_z^2 - \lambda_{rel,z}^2)})$ = **1.064**

Column stability checks - exp.6.23 & 6.24 $\sigma_{c,0,d} / (k_{c,y} \times f_{c,0,d})$ = **0.170**

$\sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d})$ = **0.075**

PASS - Column stability is acceptable