

# Superstructure and Substructure Design Calculation Report

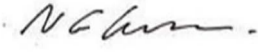
Clough Bank B

Manchester Airport Group

Project number: 60719865

May 2024

Quality information

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Revision History

| Revision | Revision date | Details          | Authorized | Name | Position |
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| P01      | May 2024      | Issue for Tender |            |      |          |

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# 1. Introduction

## 1.1 Report Overview

The proposed bat mitigation structure is to be constructed to provide a facility for bats located on site and protect the bat population from damaging activities and to reduce or remove the impacts of development. This calculation report describes the structural philosophy behind the design and provides calculations in the appendix.

## 1.2 Superstructure Overview

The proposed structure is rectangular on plan, measuring 4.5m x 5m supporting a single floor attic space. Floor to floor height is 5m, with a pitched duopitched roof reaching an overall structure height of 7.5m. The attic space is fitted with open dormers on the eastern and western sides of the roof to allow access and egress for bats. The superstructure is proposed to be constructed from timber.

The roof is finished with battens and slate tiles, spanning between rafters. The rafters are spaced at 600mm centres with staggered noggins at 600mm centres to provide diaphragm action to the roof. Rafters span between purlins, which span between 4 no. king post trusses. The trusses span between downstand beams on the eastern and western perimeter of the structure. An additional downstand beam is provided at midspan of the floor which spans between columns at the perimeter, and the two internal trusses bottom chord. The floor is formed from joists spanning between the downstand beams at 450mm centres. Staggered noggins are to be provided at 900mm centres to provide diaphragm action of the floor. The joists support timber floor boarding which is to be pre-treated.

8 no. timber posts support the floor located at each corner of the structure, and at centre spans along the perimeter. A mid height restraint beam is provided at the perimeter, and haunched connections are designed at mid height and full height of the posts to provide stability to the structure. This is favoured over cross bracing to avoid unwanted climbing of the structure. A partial fixity of 10% has been allowed for in the base connections of the columns via a 4 bolt connection.

It was found that the self-weight of the structure is sufficient to prevent any uplift imposed on the dormer.

Stability of the structure is provided via moment connections and diaphragm action in both the longitudinal and transverse directions. Moment connections is achieved by haunches at mid height and the underside of the floor to horizontal members spanning between columns. It is imperative that the haunches are installed as the columns and beams are erected and before roof construction. The overall stability and load take down analysis has been completed via hand calculations which can be found in the appendix and confirmed using a SCIA model. Sway of the structure has been assessed within the SCIA model.

All connections are to be designed by The Contractor to the Ultimate Limit State (ULS) loads stated in Table 1.

**Table 1 - Connections forces (ULS):**

| Element            | Axial Force (kN) | Shear Force (kN) |
|--------------------|------------------|------------------|
| Raftes             | 5                | 5                |
| Purlins            | 5                | 5                |
| Truss Chords       | 5                | 10               |
| Truss Diagonals    | 25               | 5                |
| Downstand Beams    | 5                | 5                |
| Haunches           | 15               | 5                |
| Mid-level tie beam | 15               | 5                |
| Column Baseplate   | +45/-10          | 5                |

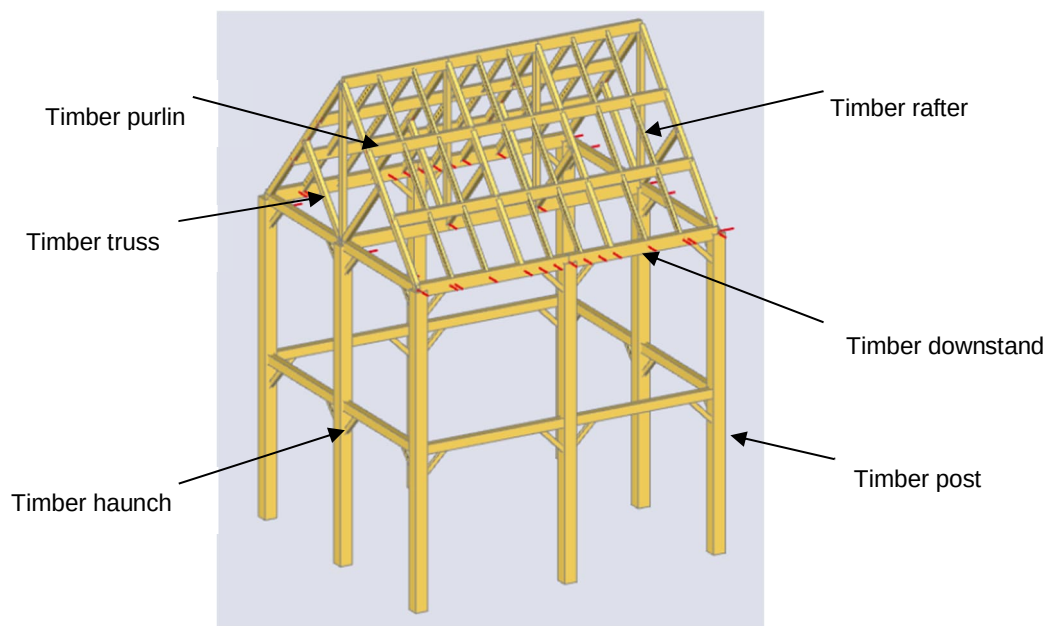


**Figure 1 - Superstructure proposal.**

### 1.3 Substructure Overview

There is currently no information available on the ground conditions at the proposed site. However, as the proposed loads from the superstructure are a low order of magnitude as seen in Figure 2 to Figure 4, shallow foundations are proposed. A conservative bearing pressure of  $50\text{kN/m}^2$  has been assumed and a  $1000\text{mm} \times 1000\text{mm}$  pad foundation is proposed under each timber post, with a  $600\text{mm} \times 600\text{mm}$  upstand to form the connection. The top of foundation is to sit  $150\text{mm}$  above ground level, and the timber posts are to be connected with a steel shoe bolted to the concrete upstand. The steel shoe is to provide an additional offset to the ground level, increasing durability of the timber superstructure. The bolted connection to concrete is required to provide a 10% fixity in the connection to reduce sway of the structure. The Contractor is to dig out to a firm strata and inform AECOM Structures of ground conditions for inspection.

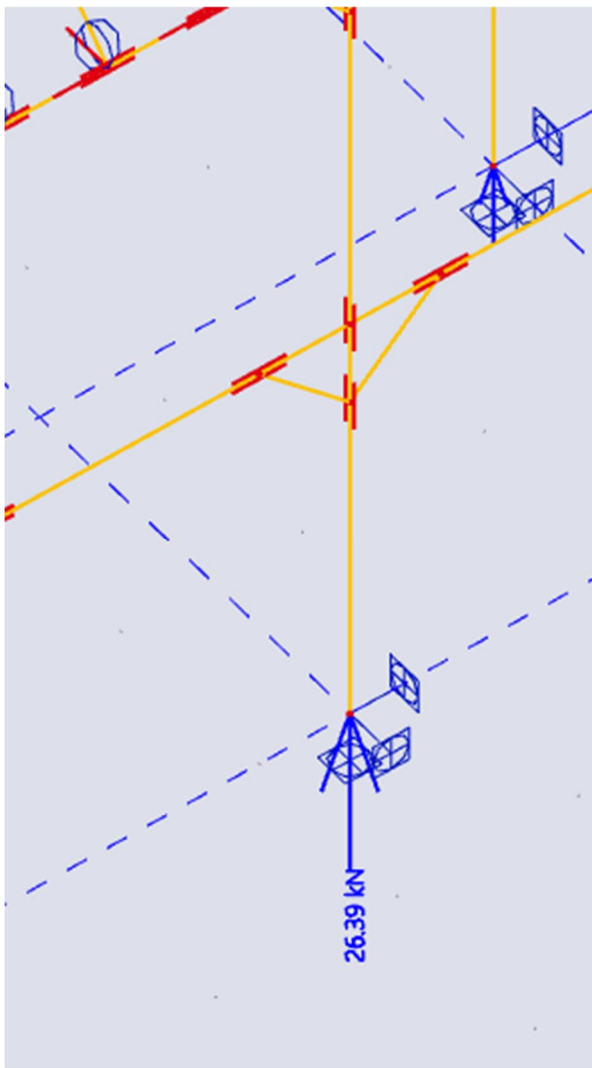


Figure 2 - Vertical reaction (SLS)

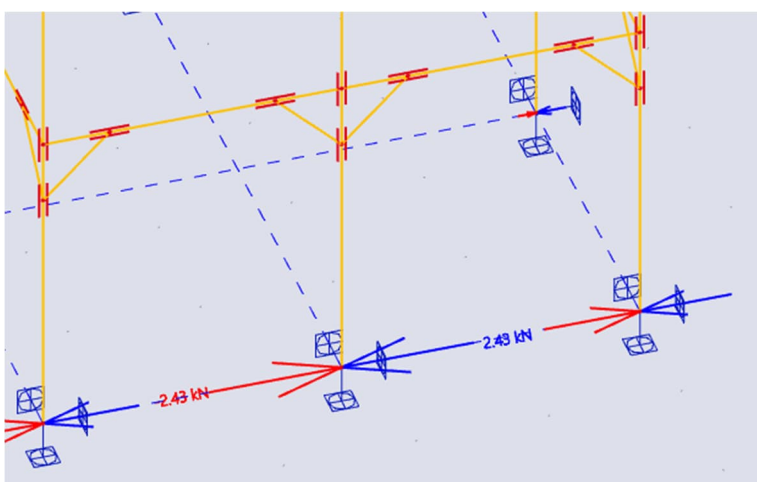


Figure 3 - Shear reaction (SLS)

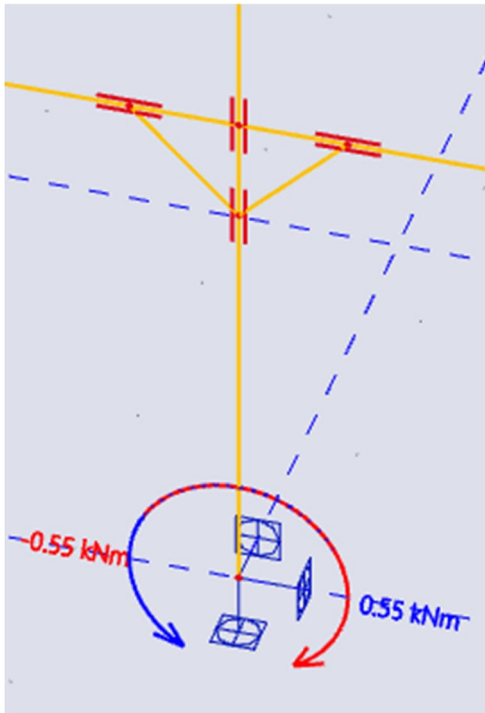


Figure 4 - Moment reaction (SLS)

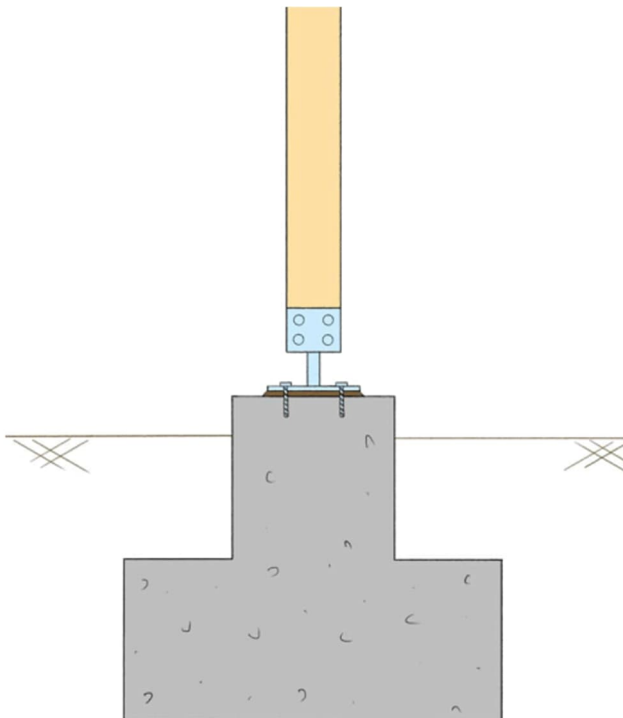


Figure 5 - Substructure proposal.

## 2. Material Specification

All timber elements are to be Grade C24 to BS EN 338

All timber elements are to be service class 3 to BS EN 1995-1-1

All timber elements are to be pre-treated including any end cuts.

All timber elements are to be vacuum low pressure treated.

All concrete elements shall be specified in accordance with BS8500 Pt 1 and Pt 2. Concrete is to be Grade C32/40 with a DC-2 mix. Exposure classes shall be selected taking into consideration locations, use, and exposure to other materials or elements such as chemicals in the ground or de-icing salts.

### 3. Design Loading and Limits

#### 3.1 Design Loading

Table 2 - Imposed Loads

| Category                 | Load (kN/m <sup>2</sup> ) |
|--------------------------|---------------------------|
| Live load to attic floor | 1.0                       |
| Access to roof           | 0.6                       |
| Peak wind pressure       | 0.8                       |

Table 3 - Dead Loads

| Category                | Load (kN/m <sup>2</sup> ) |
|-------------------------|---------------------------|
| Battens and slate tiles | 0.66                      |
| Ceiling                 | 0.25                      |
| Timber flooring         | 0.15                      |
| Timber floor structure  | 0.6                       |

#### 3.2 Design Serviceability Limits

**Typical Horizontal deflection limits:**

- Overall Building sway = height /250

**Typical Vertical deflection limits:**

- Net final deflection limit = span/250
- Variable load deflection limit = span/360 (NA to EC3 Table NA.3)

**Typical Foundation Settlement and Movements:**

- Vertical settlement of spread bases limited to 25mm
- Differential settlement of adjacent supports = 10mm or 1:500 whichever is more onerous

## 4. Structural design

As seen in the calculations in the appendix, the loading on structural members are a low order of magnitude and as such members are sized considering constructability and sway requirements. Notched connections are considered in sizing elements to ensure the effective section is suitable for the applied loads, as well as providing sections of typical sizes for procurement. The sway of the structure dictates the column and haunch sizes, as well as the required 10% fixity of the base connection, with a permissible deflection of 20mm. As seen in Figure 6, the overall sway of the structure is circa 17mm.

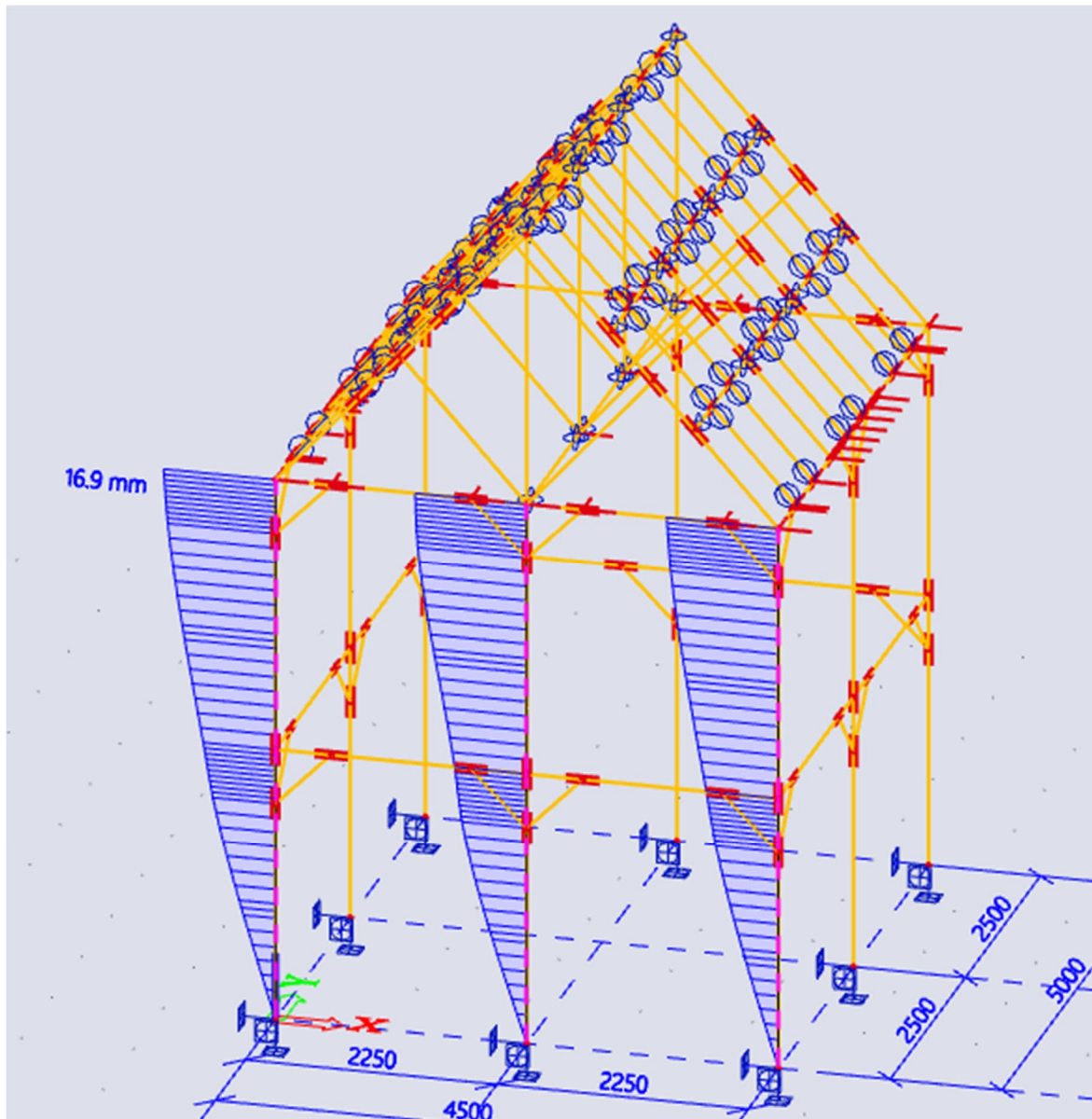


Figure 6 - Horizontal sway of structure.

## Appendix A – Structural Calculations

Project: **MAG Bat House**

Job No: **60719865**

Section: **Structural Sizes for costing**

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Sheet No: **1 of 13**

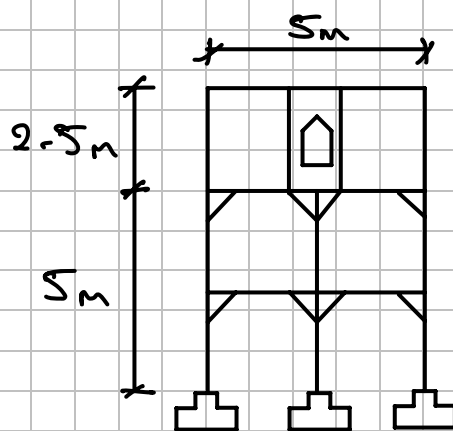
Ref: Calculations

### Introduction:

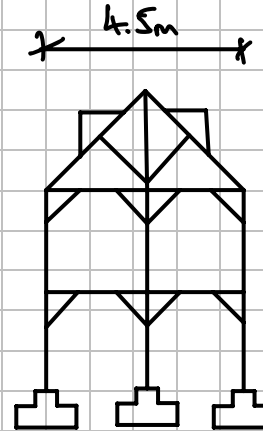
Calculations in accordance to BS EN 1995 + UK NA for initial sizing of bat house located at Manchester Airport.

### Geometry:

Front Elevation



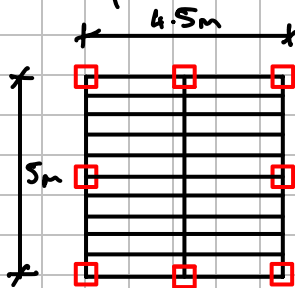
Side Elevation



Dormer

Open

Loft Level Plan



### Design Philosophy:

- Timber moment frame, with haunched connections.
- 8 No. Timber posts, double height supporting timber loft space.
- Mid-height column restraint beams.
- Timber beams supporting joists @ 450mm c/c to support floor.

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- Staggered Noggins @ 900 c/c to joists to provide diaphragm action.
- 4 No. Queens Truss supporting roof.
- Roof Purlins span between trusses
- Rafters @ 600 c/c span between purlins.
- central floor beam to be supported by trusses.

### Loading:

Assumed DL to loft floor =  $1.0 \text{ kN/m}^2$   
" LL to loft floor =  $1.0 \text{ kN/m}^2$   
Peak wind pressure =  $0.8 \text{ kN/m}^2$   
Assumed U to Roof Access =  $0.6 \text{ kN/m}^2$

### Timber Specification:

Service class 3 to BS EN 1995-1-1 Table NA.2  
Timber Grade C24 to BS EN 338  
Timber to be vacuum low pressure treated. Pre-treated timber.  
All cut ends to be pre-treated.

### Material Strength:

Tension parallel to grain =  $4.5 \text{ GPa}$

Bending parallel to grain =  $24 \text{ N/mm}^2$

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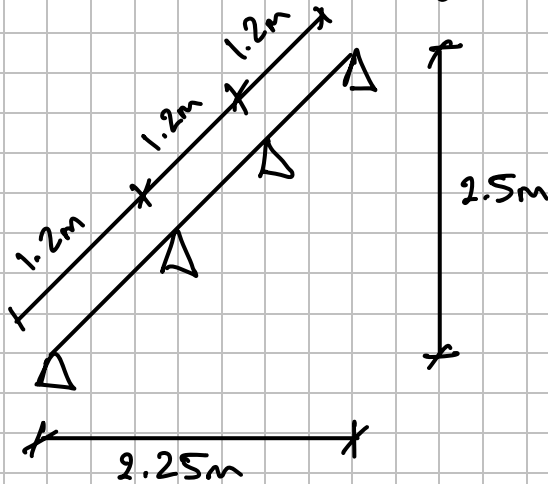
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Calculations

Roof rafter design:



$$\begin{aligned} \text{Roof Dead load on rafters} &= 0.6 \text{ kN/m}^2 \\ \text{Wind pressure} &= 0.8 \text{ kN/m}^2 \end{aligned}$$

Combination

$$1.35 C_k + 1.5 Q_k$$

$$\begin{aligned} \text{total load} &= 1.35 \times 0.6 + 1.5 \times 0.8 \\ &= 0.81 + 1.2 \\ &= 2.01 \text{ kN/m}^2 \end{aligned}$$

Rafters @ 600 c/c

$$\therefore 2.01 \times 0.6 = 1.21 \text{ kN/m}$$

$$\begin{aligned} \text{Max hogging moment} &= \frac{wl^2}{12} = \frac{1.21 \times 1.2^2}{12} \\ &= 0.15 \text{ kNm} \end{aligned}$$

$$\text{Max Shear} = wl = 1.5 \text{ kN}$$

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Calculations

Minimal force to rafter so size for connection.

Rafter 47 x 100 mm deep

$$\text{Deflection check} \rightarrow \delta = \frac{5wl^4}{384EI}$$

$$I = \frac{47 \times 100^3}{12} = 3.92 \times 10^6, \quad E = 10800 \text{ N/mm}^2 \text{ for C24 Timber.}$$

$$\delta = \frac{5 \times 1.56 \times 1200^4}{384 \times 10800 \times 3.92 \times 10^6} = 1 \text{ mm}$$

$$\delta_{\text{creep}} = 1 \times 0.8 = 0.8 \text{ mm}$$

$$\delta_{\text{final}} = \underline{1.8 \text{ mm}}$$

Bending Stress:

Design Capacity of C24 timber,

$$f_{m,y,d} = \frac{k_{\text{mod}} \cdot k_h \cdot f_{mk}}{\gamma_m}$$

$$= \frac{0.8 \times 1.05 \times 24}{1.3} = 15.5 \text{ N/mm}^2$$

$$\text{Section modulus} = \frac{47 \times 100^3}{6} = 7.8 \times 10^6$$

$$\text{Applied stress} = \frac{0.15 \times 10^6}{7.8 \times 10^6} = 0.02 \text{ N/mm}^2$$

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Calculations

Roof Truss design:depth of members,  $h = \frac{L}{40}$  (Scheme Sizing)

$$\text{ie. } \frac{4500}{40} = 112.5 \text{ mm}$$

provide 100 x 150mm deep Truss to bottom chordAdditional check:

Point load at centre of bottom chord:

$$DL = 1 \text{ kN/m}^2$$

$$LL = 1 \text{ kN/m}^2$$

$$\frac{4.5}{2} \times 1.75 = 3.9 \text{ m}^2$$

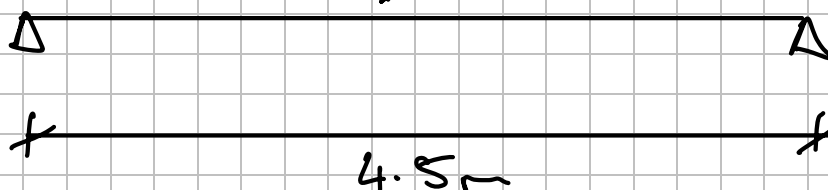
$$1 \times 3.9 = 3.9 \text{ kN/m}$$

length of beam supporting joists = 1.75m

$$\text{Point load} = \frac{3.9 \times 1.75}{2} = 3.4 \text{ kN}$$

Bottom chord:

$$\downarrow P = 3.4 \text{ kN}$$



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Calculations

$$V_d = \frac{1.35 \times 3.4 + 1.5 \times 3.4}{2} = 4.8 \text{ kN}$$

$$M_d = \frac{[1.35 \times 3.4 + 1.5 \times 3.4] \times 4.5}{4} = 11 \text{ kNm}$$

Tie force:

peak wind pressure =  $0.8 \text{ kN/m}^2$ 

Cpe factor = 1.2

 $\therefore$  Suction force =  $0.8 \times 1.2 = 0.96 \text{ kN/m}^2$ 

$$3.6 \times 1.75 \times 1 \times 1.5 = 9.5 \text{ kN}$$

$$\frac{9.5}{2} = 4.25 \text{ kN tie force through chord.}$$

$$\text{Tensile stress} = \frac{4.25}{0.1 \times 0.15} = 2.8 \times 10^{-4} \text{ GPa}$$

Forces are minimal  $\therefore$  size for connection

Diagonal members:

provide 75mm x 100mmRoof truss design for specialist designer.  
See Tedd's calculation.

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Calculations

Loft floor Design:

Timber joists to span 2.25m

From TRADA span tables, floor joists to be  
47 x 145mm @ 450mm c/c.

Joists to support hard wearing ply topping.

Total dead load = 1.0 kN/m<sup>2</sup>

Provide staggered Noggins @ 900 c/c to provide diaphragm action.

Dead load =  $1 \times 1.35 \times 0.45 = 0.61 \text{ kN/m}$ Live load =  $1 \times 1.5 \times 0.45 = 0.68 \text{ kN/m}$ 

Total factored UDL = 1.3 kN/m

Max Moment =  $\frac{1.3 \times 2.25^2}{8} = 0.82 \text{ kNm}$ 

Deflection:

 $I_{yy} = \frac{47 \times 145^3}{12} = 11.9 \times 10^6 \text{ mm}^4$  $\delta = \frac{5wL^4}{384EI} = \frac{5 \times 0.9 \times 2250^4}{384 \times 10800 \times 11.9 \times 10^6}$   
 $= 2.3 \text{ mm}$

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$$S_{creep} = 0.8 f = 1.9 \text{ mm}$$

$$f_{final} = 4.2 \text{ mm}$$

$$f_{allowable} = \frac{2250}{250} = 9 \text{ mm} \therefore \text{Ok.}$$

Bending Stress check:

$$\text{Section modulus} = \frac{47 \times 145^3}{6} = 23.8 \times 10^6 \text{ mm}^3$$

$$\begin{aligned} \text{Applied Stress} &= \frac{0.82 \times 10^6}{23.8 \times 10^6} \\ &= 0.03 \text{ N/mm}^2 < 15.5 \therefore \text{Ok.} \end{aligned}$$

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Timber beams to support joists:

$$DL = LL = 1.0 \text{ kN/m}^2$$

$$\text{Assume UDL} = 1 \times \frac{2.25}{2} = 1.125 \text{ kN/m}$$

$$\text{Factored load} = 1.35 \times 1.125 + 1.5 \times 1.125 = 3.2 \text{ kN/m}$$

$$\text{Max hogging moment} = \frac{3.2 \times 2.5^2}{12} = 1.7 \text{ kNm}$$

$$\text{Max shear load} = 3.2 \times 2.5 = 8 \text{ kN}$$

$$\text{Bearing to column} = 200 \text{ mm} \times 200 \text{ mm}$$

$$\text{Bearing stress} = 0.2 \text{ GPa}$$

Size for connection

Provide 100 x 150 mm beam

Deflection check

$$\delta = \frac{5wl^4}{384EI} = \frac{5 \times 2.25 \times 2500^4}{384 \times 10800 \times \frac{100 \times 150^4}{12}} = 0.03 \text{ mm}$$

$$\delta_{\text{creep}} = 0.8 \delta = 0.02 \text{ mm}, \quad \delta_{\text{final}} = 0.05 \text{ mm}$$

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Calculations

Bending Stress check

$$\text{Section modulus} = \frac{100 \times 150^3}{12} = 56.25 \times 10^6 \text{ mm}^3$$

$$\text{Applied Stress} = \frac{1.7 \times 10^6}{56.25 \times 10^6} = 0.03 \text{ N/mm}^2$$

$$0.03 < 15.5 \therefore \text{ok}$$

Column Size design:

ULS axial load from SCIA model  
= 38 kN

10% partial fixity provided at base connection.

Lateral restraint provided at midpoint.

$$\text{Effective length} = 0.9 \times \frac{5}{2} = 2.25 \text{ m}$$

$$\text{width} \times \text{length} = 200 \text{ mm} \times 200 \text{ mm}$$

$$\text{Cross sectional area} = 40 \times 10^3 \text{ mm}^2$$

$$I_{yy} = \frac{200^4}{12} = 133 \times 10^6 \text{ mm}^4$$

$$\text{Section Modulus} = \frac{200^3}{6} = 1.33 \times 10^6$$

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$$\text{Radius of gyration} = \sqrt{\frac{133 \times 10^4}{40 \times 10^3}} = 57.6 \text{ mm}$$

$$\text{Slenderness ratio} = \frac{2250}{57.6} = 39.1$$

$$\begin{aligned} \text{Applied bending moment} &= 37 \times 0.1 \\ &= 3.7 \text{ kNm} \end{aligned}$$

$$\text{moment from supporting beam} = 1.7 \text{ kNm}$$

$$\text{Total moment at top} = 5.4 \text{ kNm}$$

$$\text{Applied bending stress} = \frac{5.4 \times 10^6}{1.33 \times 10^6} = 4.1 \text{ N/mm}^2$$

$$\text{Design strength of post} = \frac{0.7 \times 24}{1.3} = 12.9 \text{ N/mm}^2$$

Axial compression check:

$$\sigma_c = \frac{37 \times 10^3}{40 \times 10^3} = 0.93 \text{ N/mm}^2$$

member size ok. Size driven by

Sway of frame + connection.

Provide 200 x 200 mm column

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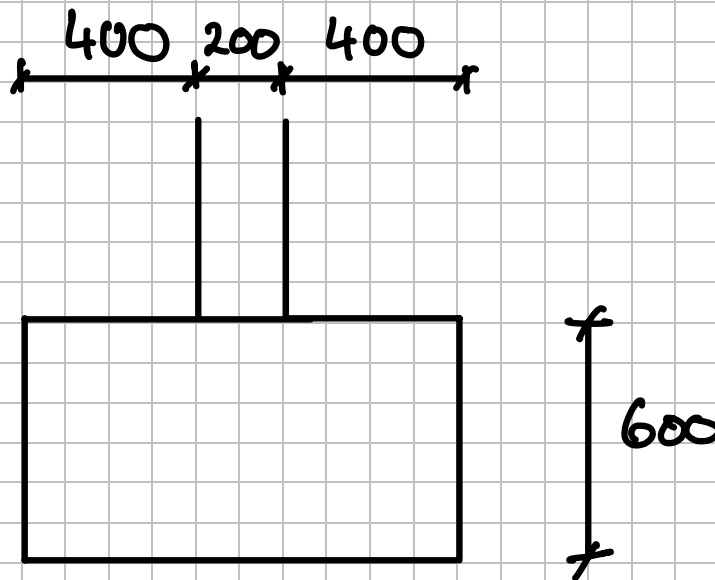
Calculations

Pad Foundation design:

column Axial load (SLS) = 27 kN

" Shear load (SLS) = 2.5 kN

" Moment load (SLS) = 0.6 kNm

Assumed bearing pressure 50 kN/m<sup>2</sup>Bearing Stress

Is the resultant force lie within the middle third?

$$e = \frac{0.6}{27} = 0.022 \text{ m} < \frac{1000}{6} = 167 \text{ mm}$$

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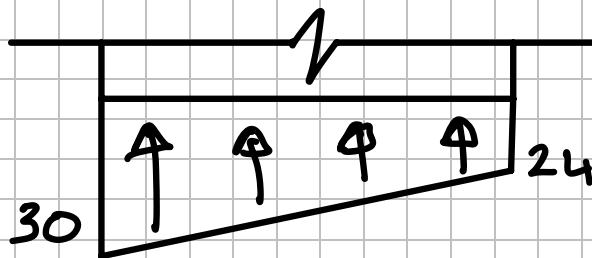
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Calculations

Bearing stress:

$$p = \frac{27}{1 \times 1} \left( 1 \pm \frac{6 \times 0.02}{1} \right) = 30 \text{ kN/m}^2 \text{ to } 24 \text{ kN/m}^2$$



$$30 \text{ kN/m}^2 < 50 \text{ kN/m}^2 \therefore \text{ok.}$$

Sliding check:

$$\gamma_{\text{soil}} = 18 \text{ kN/m}^3$$

$$\text{passive pressure} = \frac{1 \times 18}{2} = 9 \text{ kN}$$

$$\text{Applied shear} = 2.5 \text{ kN} < 9 \text{ kN} \therefore \text{ok.}$$

## TIMBER ATTIC TRUSS

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

Tedds calculation version 2.2.20

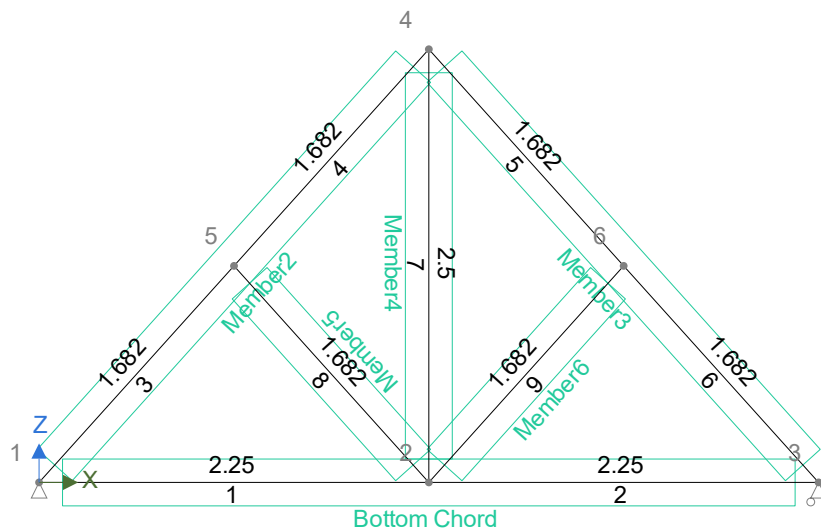
User note: Attic trusses at 400 mm centres

## ANALYSIS

Tedds calculation version 1.0.38

## Geometry

Geometry (m) - C24 (EC5)



## Materials

| Name      | Density<br>(kg/m <sup>3</sup> ) | Youngs Modulus<br>kN/mm <sup>2</sup> | Shear Modulus<br>kN/mm <sup>2</sup> | Thermal Coefficient<br>°C <sup>-1</sup> |
|-----------|---------------------------------|--------------------------------------|-------------------------------------|-----------------------------------------|
| C24 (EC5) | 420                             | 11                                   | 0.69                                | 0                                       |

## Sections

| Name    | Area<br>(cm <sup>2</sup> ) | Moment of inertia<br>Major<br>(cm <sup>4</sup> ) | Minor<br>(cm <sup>4</sup> ) | Shear area parallel to<br>Minor<br>(cm <sup>2</sup> ) | Major<br>(cm <sup>2</sup> ) |
|---------|----------------------------|--------------------------------------------------|-----------------------------|-------------------------------------------------------|-----------------------------|
| 75x100  | 75                         | 625                                              | 351.6                       | 62.5                                                  | 62.5                        |
| 100x150 | 150                        | 2812.5                                           | 1250                        | 125                                                   | 125                         |

## Nodes

| Node | Co-ordinates |          | Freedom |       |      | Coordinate system |              | Spring      |             |               |
|------|--------------|----------|---------|-------|------|-------------------|--------------|-------------|-------------|---------------|
|      | X<br>(m)     | Z<br>(m) | X       | Z     | Rot. | Name              | Angle<br>(°) | X<br>(kN/m) | Z<br>(kN/m) | Rot.<br>kNm/° |
| 1    | 0            | 0        | Fixed   | Fixed | Free |                   | 0            | 0           | 0           | 0             |
| 2    | 2.25         | 0        | Free    | Free  | Free |                   | 0            | 0           | 0           | 0             |
| 3    | 4.5          | 0        | Free    | Fixed | Free |                   | 0            | 0           | 0           | 0             |
| 4    | 2.25         | 2.5      | Free    | Free  | Free |                   | 0            | 0           | 0           | 0             |
| 5    | 1.125        | 1.25     | Free    | Free  | Free |                   | 0            | 0           | 0           | 0             |
| 6    | 3.375        | 1.25     | Free    | Free  | Free |                   | 0            | 0           | 0           | 0             |

|                                                                                 |               |            |              |             |                         |  |
|---------------------------------------------------------------------------------|---------------|------------|--------------|-------------|-------------------------|--|
|  | Project       |            |              |             | Job no.                 |  |
|                                                                                 | MAG Bat House |            |              |             | 60719865                |  |
|                                                                                 | Calcs for     |            |              |             | Start page no./Revision |  |
| Attic Queen Truss                                                               |               |            |              | 2           |                         |  |
| Calcs by                                                                        | Calcs date    | Checked by | Checked date | Approved by | Approved date           |  |
| WH                                                                              | 23/05/2024    | NK         | 24/05/2024   |             |                         |  |

Elements

| Element | Length<br>(m) | Nodes |     | Section | Material  | Releases        |               |       | Rotated |
|---------|---------------|-------|-----|---------|-----------|-----------------|---------------|-------|---------|
|         |               | Start | End |         |           | Start<br>moment | End<br>moment | Axial |         |
| 1       | 2.25          | 1     | 2   | 100x150 | C24 (EC5) | Fixed           | Fixed         | Fixed |         |
| 2       | 2.25          | 2     | 3   | 100x150 | C24 (EC5) | Fixed           | Fixed         | Fixed |         |
| 3       | 1.682         | 1     | 5   | 75x100  | C24 (EC5) | Fixed           | Fixed         | Fixed |         |
| 4       | 1.682         | 5     | 4   | 75x100  | C24 (EC5) | Fixed           | Fixed         | Fixed |         |
| 5       | 1.682         | 4     | 6   | 75x100  | C24 (EC5) | Fixed           | Fixed         | Fixed |         |
| 6       | 1.682         | 6     | 3   | 75x100  | C24 (EC5) | Fixed           | Fixed         | Fixed |         |
| 7       | 2.5           | 4     | 2   | 75x100  | C24 (EC5) | Fixed           | Fixed         | Fixed |         |
| 8       | 1.682         | 2     | 5   | 75x100  | C24 (EC5) | Fixed           | Fixed         | Fixed |         |
| 9       | 1.682         | 2     | 6   | 75x100  | C24 (EC5) | Fixed           | Fixed         | Fixed |         |

Members

| Name         | Elements |     |
|--------------|----------|-----|
|              | Start    | End |
| Bottom Chord | 1        | 2   |
| Member2      | 3        | 4   |
| Member3      | 5        | 6   |
| Member4      | 7        | 7   |
| Member5      | 8        | 8   |
| Member6      | 9        | 9   |

Loading

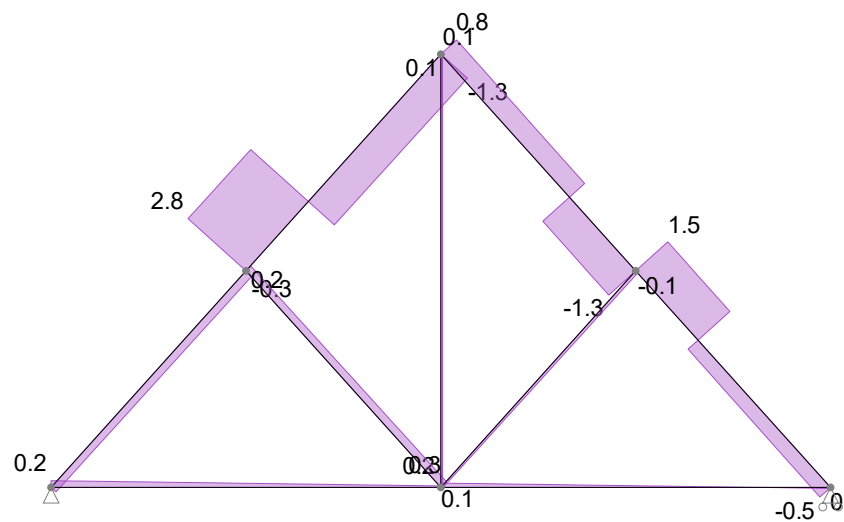
Self weight included

Load combination factors

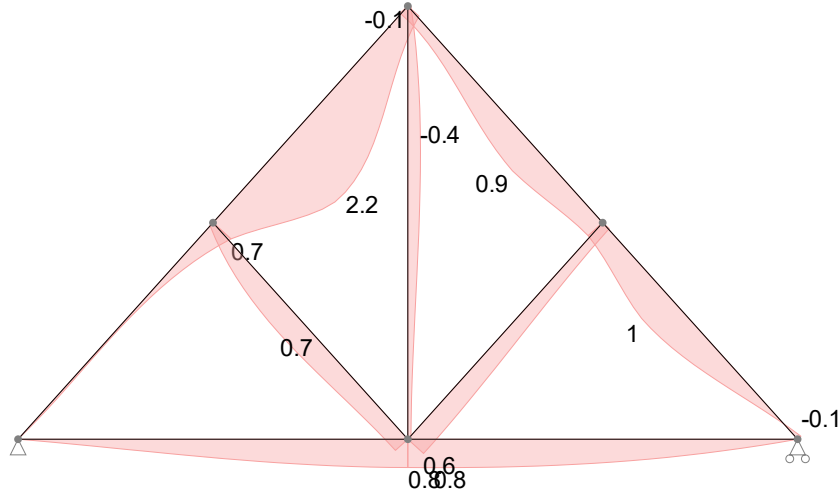
| Load combination                | Self Weight | Permanent | Imposed | Factored<br>Point load<br>from purlin |
|---------------------------------|-------------|-----------|---------|---------------------------------------|
| 1.35G + 1.5Q + 1.5RQ (Strength) | 1.35        | 1.35      | 1.50    | 1.00                                  |
| 1.0G + 1.0Q + 1.0RQ (Service)   | 1.00        | 1.00      | 1.00    | 0.75                                  |

Member Loads

| Member       | Load case                       | Load Type  | Orientation | Description             |
|--------------|---------------------------------|------------|-------------|-------------------------|
| Bottom Chord | Permanent                       | Point load | GlobalZ     | 2.5 kN at 2.25 m        |
| Bottom Chord | Permanent                       | UDL        | GlobalZ     | 0 kN/m at 0 m to 2.25 m |
| Bottom Chord | Imposed                         | Point load | GlobalZ     | 2.5 kN at 2.25 m        |
| Member2      | Factored Point load from purlin | Point load | GlobalZ     | 3 kN at 2.22 m          |
| Member2      | Factored Point load from purlin | Point load | GlobalZ     | 3 kN at 2.22 m          |
| Member3      | Factored Point load from purlin | Point load | GlobalZ     | 3 kN at 1.11 m          |
| Member3      | Factored Point load from purlin | Point load | GlobalZ     | 3 kN at 2.22 m          |



### Service combinations - Deflection envelope (mm)



### Bottom Chord - Span 1

#### Partial factor for material properties and resistances

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

#### Member details

Load duration - cl.2.3.1.2

Medium-term

Service class - cl.2.3.1.3

1

#### Timber section details

Number of timber sections in member

N = 1

Breadth of sections

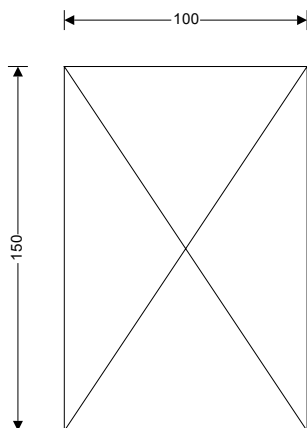
b = 100 mm

Depth of sections

h = 150 mm

Timber strength class - EN 338:2016 Table 1

C24



#### 100x150 timber section

Cross-sectional area, A, 15000 mm<sup>2</sup>

Section modulus, W<sub>y</sub>, 375000 mm<sup>3</sup>

Section modulus, W<sub>z</sub>, 250000 mm<sup>3</sup>

Second moment of area, I<sub>y</sub>, 28125000 mm<sup>4</sup>

Second moment of area, I<sub>z</sub>, 12500000 mm<sup>4</sup>

Radius of gyration, i<sub>y</sub>, 43.3 mm

Radius of gyration, i<sub>z</sub>, 28.9 mm

#### Timber strength class C24

Characteristic bending strength, f<sub>m,k</sub>, 24 N/mm<sup>2</sup>

Characteristic shear strength, f<sub>v,k</sub>, 4 N/mm<sup>2</sup>

Characteristic compression strength parallel to grain, f<sub>c,0,k</sub>, 21 N/mm<sup>2</sup>

Characteristic compression strength perpendicular to grain, f<sub>c,90,k</sub>, 2.5 N/mm<sup>2</sup>

Characteristic tension strength parallel to grain, f<sub>t,0,k</sub>, 14.5 N/mm<sup>2</sup>

Mean modulus of elasticity, E<sub>0,mean</sub>, 11000 N/mm<sup>2</sup>

Fifth percentile modulus of elasticity, E<sub>0,05</sub>, 7400 N/mm<sup>2</sup>

Shear modulus of elasticity, G<sub>mean</sub>, 690 N/mm<sup>2</sup>

Characteristic density, ρ<sub>k</sub>, 350 kg/m<sup>3</sup>

Mean density, ρ<sub>mean</sub>, 420 kg/m<sup>3</sup>

### Span details

Bearing length

L<sub>b</sub> = 100 mm

|                   |            |            |              |                         |               |
|-------------------|------------|------------|--------------|-------------------------|---------------|
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| MAG Bat House     |            |            |              | 60719865                |               |
| Calcs for         |            |            |              | Start page no./Revision |               |
| Attic Queen Truss |            |            |              | 5                       |               |
| Calcs by          | Calcs date | Checked by | Checked date | Approved by             | Approved date |
| WH                | 23/05/2024 | NK         | 24/05/2024   |                         |               |

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

#### Modification factors

|                                                     |                 |
|-----------------------------------------------------|-----------------|
| Duration of load and moisture content - Table 3.1   | $k_{mod} = 0.8$ |
| Deformation factor - Table 3.2                      | $k_{def} = 0.6$ |
| Depth factor for tension - exp.3.1                  | $k_{h,t} = 1$   |
| 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 tension parallel to the grain - Section 6.1.2

|                         |                                                                                                        |
|-------------------------|--------------------------------------------------------------------------------------------------------|
| Axial tension           | $P_d = 8.694 \text{ kN}$                                                                               |
| Design tensile stress   | $\sigma_{t,0,d} = P_d / (b \times \min(h_{ef,e1}, h_{ef,e2})) = 0.446 \text{ N/mm}^2$                  |
| Design tensile strength | $f_{t,0,d} = k_{h,t} \times k_{mod} \times k_{sys} \times f_{t,0,k} / \gamma_M = 9.815 \text{ N/mm}^2$ |
|                         | $\sigma_{t,0,d} / f_{t,0,d} = 0.045$                                                                   |

**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     | $F_{c,y,90,d} = 9.548 \text{ kN}$                                                           |
| Effective contact length                          | $L_{b,ef} = L_b + \min(L_b, 30 \text{ mm}) = 130 \text{ mm}$                                |
| Design perpendicular compressive stress - exp.6.4 | $\sigma_{c,y,90,d} = F_{c,y,90,d} / (b \times L_{b,ef}) = 0.734 \text{ N/mm}^2$             |
| Design perpendicular compressive strength         | $f_{c,y,90,d} = k_{mod} \times k_{sys} \times f_{c,90,k} / \gamma_M = 1.692 \text{ N/mm}^2$ |
|                                                   | $\sigma_{c,y,90,d} / (k_{c,90} \times f_{c,y,90,d}) = 0.434$                                |

**PASS - Design perpendicular compression strength exceeds design perpendicular compression stress**

#### Check shear force - Section 6.1.7

|                                |                                                                                       |
|--------------------------------|---------------------------------------------------------------------------------------|
| Design shear force             | $F_{y,d} = 0.241 \text{ kN}$                                                          |
| Design shear stress - exp.6.60 | $\tau_{y,d} = 1.5 \times F_{y,d} / (k_{cr} \times b \times h) = 0.036 \text{ N/mm}^2$ |
| Design shear strength          | $f_{v,y,d} = k_{mod} \times k_{sys} \times f_{v,k} / \gamma_M = 2.708 \text{ N/mm}^2$ |
|                                | $\tau_{y,d} / f_{v,y,d} = 0.013$                                                      |

**PASS - Design shear strength exceeds design shear stress**

#### Check bending moment - Section 6.1.6

|                         |                                                                                        |
|-------------------------|----------------------------------------------------------------------------------------|
| Design bending moment   | $M_{y,d} = 0.132 \text{ kNm}$                                                          |
| Design bending stress   | $\sigma_{m,y,d} = M_{y,d} / W_y = 0.351 \text{ N/mm}^2$                                |
| Design bending strength | $f_{m,y,d} = k_{mod} \times k_{sys} \times f_{m,k} / \gamma_M = 16.246 \text{ N/mm}^2$ |
|                         | $\sigma_{m,y,d} / f_{m,y,d} = 0.022$                                                   |

**PASS - Design bending strength exceeds design bending stress**

#### Check combined bending and axial compression - Section 6.2.4

|                                           |                                                                              |
|-------------------------------------------|------------------------------------------------------------------------------|
| Combined loading checks - exp.6.17 & 6.18 | $\sigma_{t,0,d} / f_{t,0,d} + \sigma_{m,y,d} / f_{m,y,d} = 0.067$            |
|                                           | $\sigma_{t,0,d} / f_{t,0,d} + k_m \times \sigma_{m,y,d} / f_{m,y,d} = 0.061$ |

**PASS - Combined bending and axial tension utilisation 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.6.33    | $\sigma_{m,y,d} / (k_{crit} \times f_{m,y,d}) = 0.022$ |

**PASS - Beam stability is acceptable**

|                   |            |            |              |                         |               |
|-------------------|------------|------------|--------------|-------------------------|---------------|
| Project           |            |            |              | Job no.                 |               |
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| Calcs by          | Calcs date | Checked by | Checked date | Approved by             | Approved date |
| WH                | 23/05/2024 | NK         | 24/05/2024   |                         |               |

### Check design 4099 mm along span

#### **Check bending moment - Section 6.1.6**

Design bending moment

$$M_{y,d} = 0.202 \text{ kNm}$$

Design bending stress

$$\sigma_{m,y,d} = M_{y,d} / W_y = 0.54 \text{ N/mm}^2$$

Design bending strength

$$f_{m,y,d} = k_{mod} \times k_{sys} \times f_{m,k} / \gamma_M = 16.246 \text{ N/mm}^2$$

$$\sigma_{m,y,d} / f_{m,y,d} = 0.033$$

**PASS - Design bending strength exceeds design bending stress**

#### **Check combined bending and axial compression - Section 6.2.4**

Combined loading checks - exp.6.17 & 6.18

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

$$\sigma_{t,0,d} / f_{t,0,d} + k_m \times \sigma_{m,y,d} / f_{m,y,d} = 0.069$$

**PASS - Combined bending and axial tension utilisation 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.6.33

$$\sigma_{m,y,d} / (k_{crit} \times f_{m,y,d}) = 0.033$$

**PASS - Beam stability is acceptable**

### Consider Combination 2 - 1.0G + 1.0Q + 1.0RQ (Service)

### Check design 2403 mm along span

#### **Check y-y axis deflection - Section 7.2**

Instantaneous deflection

$$\delta_y = 0.8 \text{ mm}$$

Allowable deflection

$$\delta_{y,Allowable} = \text{Min}(L_{m1,s1} / 250, 14 \text{ mm}) = 14 \text{ mm}$$

$$\delta_y / \delta_{y,Allowable} = 0.057$$

**PASS - Allowable deflection exceeds instantaneous deflection**

### Member2 - Span 1

#### **Partial factor for material properties and resistances**

Partial factor for material properties - Table 2.3

$$\gamma_M = 1.300$$

#### **Member details**

Load duration - cl.2.3.1.2

Medium-term

Service class - cl.2.3.1.3

1

#### **Timber section details**

Number of timber sections in member

$$N = 1$$

Breadth of sections

$$b = 75 \text{ mm}$$

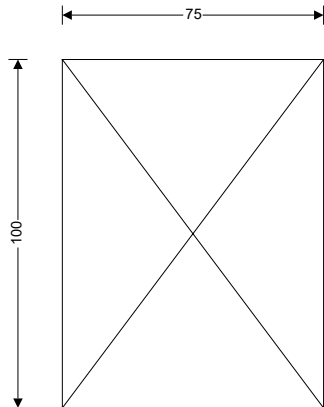
Depth of sections

$$h = 100 \text{ mm}$$

Timber strength class - EN 338:2016 Table 1

$$C24$$

|                   |            |            |              |                         |               |
|-------------------|------------|------------|--------------|-------------------------|---------------|
| Project           |            |            |              | Job no.                 |               |
| MAG Bat House     |            |            |              | 60719865                |               |
| Calcs for         |            |            |              | Start page no./Revision |               |
| Attic Queen Truss |            |            |              | 7                       |               |
| Calcs by          | Calcs date | Checked by | Checked date | Approved by             | Approved date |
| WH                | 23/05/2024 | NK         | 24/05/2024   |                         |               |



#### 75x100 timber section

Cross-sectional area,  $A$ , 7500 mm<sup>2</sup>

Section modulus,  $W_y$ , 125000 mm<sup>3</sup>

Section modulus,  $W_z$ , 93750 mm<sup>3</sup>

Second moment of area,  $I_y$ , 6250000 mm<sup>4</sup>

Second moment of area,  $I_z$ , 3515625 mm<sup>4</sup>

Radius of gyration,  $i_y$ , 28.9 mm

Radius of gyration,  $i_z$ , 21.7 mm

#### Timber strength class C24

Characteristic bending strength,  $f_{m,k}$ , 24 N/mm<sup>2</sup>

Characteristic shear strength,  $f_{v,k}$ , 4 N/mm<sup>2</sup>

Characteristic compression strength parallel to grain,  $f_{c,0,k}$ , 21 N/mm<sup>2</sup>

Characteristic compression strength perpendicular to grain,  $f_{c,90,k}$ , 2.5 N/mm<sup>2</sup>

Characteristic tension strength parallel to grain,  $f_{t,0,k}$ , 14.5 N/mm<sup>2</sup>

Mean modulus of elasticity,  $E_{0,mean}$ , 11000 N/mm<sup>2</sup>

Fifth percentile modulus of elasticity,  $E_{0,05}$ , 7400 N/mm<sup>2</sup>

Shear modulus of elasticity,  $G_{mean}$ , 690 N/mm<sup>2</sup>

Characteristic density,  $\rho_k$ , 350 kg/m<sup>3</sup>

Mean density,  $\rho_{mean}$ , 420 kg/m<sup>3</sup>

### Span details

Bearing length

$L_b = 100$  mm

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

#### Modification factors

Duration of load and moisture content - Table 3.1

$k_{mod} = 0.8$

Deformation factor - Table 3.2

$k_{def} = 0.6$

Depth factor for bending - Major axis - exp.3.1

$k_{h,m,y} = \min((150 \text{ mm} / h)^{0.2}, 1.3) = 1.084$

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)

$k_{c,90} = 1.5$

System strength factor - cl.6.6

$k_{sys} = 1.1$

#### Check compression parallel to the grain - cl.6.1.4

Design axial compression

$P_d = 13.247$  kN

Design compressive stress

$\sigma_{c,0,d} = P_d / A = 1.766$  N/mm<sup>2</sup>

Design compressive strength

$f_{c,0,d} = k_{mod} \times k_{sys} \times f_{c,0,k} / \gamma_M = 14.215$  N/mm<sup>2</sup>

$\sigma_{c,0,d} / f_{c,0,d} = 0.124$

**PASS - Design parallel compression strength exceeds design parallel compression stress**

#### Check design 1682 mm along span

#### Check compression perpendicular to the grain - cl.6.1.5

Design perpendicular compression - major axis

$F_{c,y,90,d} = 6.387$  kN

Effective contact length

$L_{b,ef} = L_b + \min(2220 \text{ mm} / 2, L_b, 30 \text{ mm}) = 130$  mm

Design perpendicular compressive stress - exp.6.4

$\sigma_{c,y,90,d} = F_{c,y,90,d} / (b \times L_{b,ef}) = 0.655$  N/mm<sup>2</sup>

Design perpendicular compressive strength

$f_{c,y,90,d} = k_{mod} \times k_{sys} \times f_{c,90,k} / \gamma_M = 1.692$  N/mm<sup>2</sup>

$\sigma_{c,y,90,d} / (k_{c,90} \times f_{c,y,90,d}) = 0.258$

**PASS - Design perpendicular compression strength exceeds design perpendicular compression stress**

#### Check shear force - Section 6.1.7

Design shear force

$F_{y,d} = 2.782$  kN

Design shear stress - exp.6.60

$\tau_{y,d} = 1.5 \times F_{y,d} / (k_{cr} \times b \times h) = 0.830$  N/mm<sup>2</sup>

Design shear strength

$f_{v,y,d} = k_{mod} \times k_{sys} \times f_{v,k} / \gamma_M = 2.708$  N/mm<sup>2</sup>

$\tau_{y,d} / f_{v,y,d} = 0.307$

**PASS - Design shear strength exceeds design shear stress**

|                   |            |            |              |                         |               |
|-------------------|------------|------------|--------------|-------------------------|---------------|
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| Attic Queen Truss |            |            |              | 8                       |               |
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| WH                | 23/05/2024 | NK         | 24/05/2024   |                         |               |

#### Check bending moment - Section 6.1.6

Design bending moment

$$M_{y,d} = 0.623 \text{ kNm}$$

Design bending stress

$$\sigma_{m,y,d} = M_{y,d} / W_y = 4.986 \text{ N/mm}^2$$

Design bending strength

$$f_{m,y,d} = k_{h,m,y} \times k_{mod} \times k_{sys} \times f_{m,k} / \gamma_M = 17.618 \text{ N/mm}^2$$

$$\sigma_{m,y,d} / f_{m,y,d} = 0.283$$

**PASS - Design bending strength exceeds design bending stress**

#### Check combined bending and axial compression - Section 6.2.4

Combined loading checks - exp.6.19 & 6.20

$$(\sigma_{c,0,d} / f_{c,0,d})^2 + \sigma_{m,y,d} / f_{m,y,d} = 0.298$$

$$(\sigma_{c,0,d} / f_{c,0,d})^2 + k_m \times \sigma_{m,y,d} / f_{m,y,d} = 0.214$$

**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

$$L_{e,y} = 0.9 \times 3363 \text{ mm} = 3027 \text{ mm}$$

Slenderness ratio

$$\lambda_{y} = L_{e,y} / i_y = 104.848$$

Relative slenderness ratio - exp. 6.21

$$\lambda_{rel,y} = \lambda_y / \pi \times \sqrt{(f_{c,0,k} / E_{0.05})} = 1.778$$

Effective length for z-axis bending

$$L_{e,z} = 0 \text{ mm}$$

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

$$k_y = 0.5 \times (1 + \beta_c \times (\lambda_{rel,y} - 0.3) + \lambda_{rel,y}^2) = 2.228$$

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

$$k_{c,y} = 1 / (k_y + \sqrt{(k_y^2 - \lambda_{rel,y}^2)}) = 0.280$$

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

Column stability checks - exp.6.23 & 6.24

$$\sigma_{c,0,d} / (k_{c,y} \times f_{c,0,d}) + \sigma_{m,y,d} / f_{m,y,d} = 0.727$$

$$\sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d}) + k_m \times \sigma_{m,y,d} / f_{m,y,d} = 0.315$$

**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

$$(\sigma_{m,y,d} / (K_{crit} \times f_{m,y,d}))^2 + \sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d}) = 0.197$$

**PASS - Beam stability is acceptable**

#### Check design 2220 mm along span

##### Check shear force - Section 6.1.7

Design shear force

$$F_{y,d} = 2.767 \text{ kN}$$

Design shear stress - exp.6.60

$$\tau_{y,d} = 1.5 \times F_{y,d} / (k_{cr} \times b \times h) = 0.826 \text{ N/mm}^2$$

Design shear strength

$$f_{v,y,d} = k_{mod} \times k_{sys} \times f_{v,k} / \gamma_M = 2.708 \text{ N/mm}^2$$

$$\tau_{y,d} / f_{v,y,d} = 0.305$$

**PASS - Design shear strength exceeds design shear stress**

#### Check bending moment - Section 6.1.6

Design bending moment

$$M_{y,d} = 0.87 \text{ kNm}$$

Design bending stress

$$\sigma_{m,y,d} = M_{y,d} / W_y = 6.957 \text{ N/mm}^2$$

Design bending strength

$$f_{m,y,d} = k_{h,m,y} \times k_{mod} \times k_{sys} \times f_{m,k} / \gamma_M = 17.618 \text{ N/mm}^2$$

$$\sigma_{m,y,d} / f_{m,y,d} = 0.395$$

**PASS - Design bending strength exceeds design bending stress**

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#### Check combined bending and axial compression - Section 6.2.4

Combined loading checks - exp.6.19 & 6.20  $(\sigma_{c,0,d} / f_{c,0,d})^2 + \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.410}$   
 $(\sigma_{c,0,d} / f_{c,0,d})^2 + k_m \times \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.292}$

**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  $L_{e,y} = 0.9 \times 3363 \text{ mm} = \mathbf{3027 \text{ mm}}$   
Slenderness ratio  $\lambda_y = L_{e,y} / i_y = \mathbf{104.848}$   
Relative slenderness ratio - exp. 6.21  $\lambda_{rel,y} = \lambda_y / \pi \times \sqrt{(f_{c,0,k} / E_{0.05})} = \mathbf{1.778}$   
Effective length for z-axis bending  $L_{e,z} = \mathbf{0 \text{ mm}}$   
Slenderness ratio  $\lambda_z = L_{e,z} / i_z = \mathbf{0}$   
Relative slenderness ratio - exp. 6.22  $\lambda_{rel,z} = \lambda_z / \pi \times \sqrt{(f_{c,0,k} / E_{0.05})} = \mathbf{0}$

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

Straightness factor  $\beta_c = \mathbf{0.2}$   
Instability factors - exp.6.25, 6.26, 6.27 & 6.28  $k_y = 0.5 \times (1 + \beta_c \times (\lambda_{rel,y} - 0.3) + \lambda_{rel,y}^2) = \mathbf{2.228}$   
 $k_z = 0.5 \times (1 + \beta_c \times (\lambda_{rel,z} - 0.3) + \lambda_{rel,z}^2) = \mathbf{0.470}$   
 $k_{c,y} = 1 / (k_y + \sqrt{(k_y^2 - \lambda_{rel,y}^2)}) = \mathbf{0.280}$   
 $k_{c,z} = 1 / (k_z + \sqrt{(k_z^2 - \lambda_{rel,z}^2)}) = \mathbf{1.064}$

Column stability checks - exp.6.23 & 6.24  $\sigma_{c,0,d} / (k_{c,y} \times f_{c,0,d}) + \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.839}$   
 $\sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d}) + k_m \times \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.393}$

**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  $(\sigma_{m,y,d} / (K_{crit} \times f_{m,y,d}))^2 + \sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d}) = \mathbf{0.273}$

**PASS - Beam stability is acceptable**

#### Consider Combination 2 - 1.0G + 1.0Q + 1.0RQ (Service)

##### Check design 2327 mm along span

##### Check y-y axis deflection - Section 7.2

Instantaneous deflection  $\delta_y = \mathbf{2.2 \text{ mm}}$   
Allowable deflection  $\delta_{y,Allowable} = \text{Min}(L_{m2\_s1} / 250, 14 \text{ mm}) = \mathbf{13.5 \text{ mm}}$   
 $\delta_y / \delta_{y,Allowable} = \mathbf{0.163}$

**PASS - Allowable deflection exceeds instantaneous deflection**

#### Member3 - Span 1

##### Partial factor for material properties and resistances

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

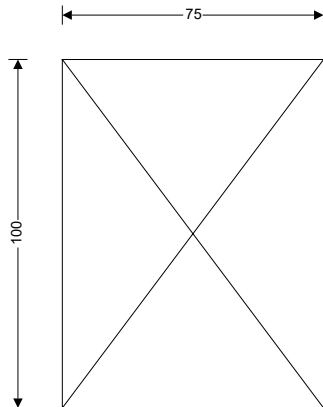
##### Member details

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

##### Timber section details

Number of timber sections in member  $N = \mathbf{1}$   
Breadth of sections  $b = \mathbf{75 \text{ mm}}$   
Depth of sections  $h = \mathbf{100 \text{ mm}}$   
Timber strength class - EN 338:2016 Table 1 **C24**

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#### 75x100 timber section

Cross-sectional area,  $A$ , 7500 mm<sup>2</sup>

Section modulus,  $W_y$ , 125000 mm<sup>3</sup>

Section modulus,  $W_z$ , 93750 mm<sup>3</sup>

Second moment of area,  $I_y$ , 6250000 mm<sup>4</sup>

Second moment of area,  $I_z$ , 3515625 mm<sup>4</sup>

Radius of gyration,  $i_y$ , 28.9 mm

Radius of gyration,  $i_z$ , 21.7 mm

#### Timber strength class C24

Characteristic bending strength,  $f_{m,k}$ , 24 N/mm<sup>2</sup>

Characteristic shear strength,  $f_{v,k}$ , 4 N/mm<sup>2</sup>

Characteristic compression strength parallel to grain,  $f_{c,0,k}$ , 21 N/mm<sup>2</sup>

Characteristic compression strength perpendicular to grain,  $f_{c,90,k}$ , 2.5 N/mm<sup>2</sup>

Characteristic tension strength parallel to grain,  $f_{t,0,k}$ , 14.5 N/mm<sup>2</sup>

Mean modulus of elasticity,  $E_{0,mean}$ , 11000 N/mm<sup>2</sup>

Fifth percentile modulus of elasticity,  $E_{0,05}$ , 7400 N/mm<sup>2</sup>

Shear modulus of elasticity,  $G_{mean}$ , 690 N/mm<sup>2</sup>

Characteristic density,  $\rho_k$ , 350 kg/m<sup>3</sup>

Mean density,  $\rho_{mean}$ , 420 kg/m<sup>3</sup>

### Span details

Bearing length

$L_b = 100$  mm

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

#### Modification factors

Duration of load and moisture content - Table 3.1

$k_{mod} = 0.8$

Deformation factor - Table 3.2

$k_{def} = 0.6$

Depth factor for bending - Major axis - exp.3.1

$k_{h,m,y} = \min((150 \text{ mm} / h)^{0.2}, 1.3) = 1.084$

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

$P_d = 9.221$  kN

Design compressive stress

$\sigma_{c,0,d} = P_d / A = 1.229$  N/mm<sup>2</sup>

Design compressive strength

$f_{c,0,d} = k_{mod} \times k_{sys} \times f_{c,0,k} / \gamma_M = 14.215$  N/mm<sup>2</sup>

$\sigma_{c,0,d} / f_{c,0,d} = 0.086$

**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

$F_{y,d} = 0.76$  kN

Design shear stress - exp.6.60

$\tau_{y,d} = 1.5 \times F_{y,d} / (k_{cr} \times b \times h) = 0.227$  N/mm<sup>2</sup>

Design shear strength

$f_{v,y,d} = k_{mod} \times k_{sys} \times f_{v,k} / \gamma_M = 2.708$  N/mm<sup>2</sup>

$\tau_{y,d} / f_{v,y,d} = 0.084$

**PASS - Design shear strength exceeds design shear stress**

#### Check bending moment - Section 6.1.6

Design bending moment

$M_{y,d} = 0.471$  kNm

Design bending stress

$\sigma_{m,y,d} = M_{y,d} / W_y = 3.766$  N/mm<sup>2</sup>

Design bending strength

$f_{m,y,d} = k_{h,m,y} \times k_{mod} \times k_{sys} \times f_{m,k} / \gamma_M = 17.618$  N/mm<sup>2</sup>

$\sigma_{m,y,d} / f_{m,y,d} = 0.214$

**PASS - Design bending strength exceeds design bending stress**

#### Check combined bending and axial compression - Section 6.2.4

Combined loading checks - exp.6.19 & 6.20

$(\sigma_{c,0,d} / f_{c,0,d})^2 + \sigma_{m,y,d} / f_{m,y,d} = 0.221$

|                                                                                  |               |            |              |             |                         |  |
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$$(\sigma_{c,0,d} / f_{c,0,d})^2 + k_m \times \sigma_{m,y,d} / f_{m,y,d} = 0.157$$

**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  $L_{e,y} = 0.9 \times 3363 \text{ mm} = 3027 \text{ mm}$

Slenderness ratio  $\lambda_y = L_{e,y} / i_y = 104.848$

Relative slenderness ratio - exp. 6.21  $\lambda_{rel,y} = \lambda_y / \pi \times \sqrt{(f_{c,0,k} / E_{0.05})} = 1.778$

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

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  $k_y = 0.5 \times (1 + \beta_c \times (\lambda_{rel,y} - 0.3) + \lambda_{rel,y}^2) = 2.228$

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

$$k_{c,y} = 1 / (k_y + \sqrt{(k_y^2 - \lambda_{rel,y}^2)}) = 0.280$$

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

Column stability checks - exp.6.23 & 6.24  $\sigma_{c,0,d} / (k_{c,y} \times f_{c,0,d}) + \sigma_{m,y,d} / f_{m,y,d} = 0.523$

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

**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  $k_{crit} = 1.000$

Beam stability check - exp.6.35  $(\sigma_{m,y,d} / (k_{crit} \times f_{m,y,d}))^2 + \sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d}) = 0.127$

**PASS - Beam stability is acceptable**

#### Check design 1682 mm along span

##### Check shear force - Section 6.1.7

Design shear force  $F_{y,d} = 1.543 \text{ kN}$

Design shear stress - exp.6.60  $\tau_{y,d} = 1.5 \times F_{y,d} / (k_{cr} \times b \times h) = 0.460 \text{ N/mm}^2$

Design shear strength  $f_{v,y,d} = k_{mod} \times k_{sys} \times f_{v,k} / \gamma_M = 2.708 \text{ N/mm}^2$

$$\tau_{y,d} / f_{v,y,d} = 0.170$$

**PASS - Design shear strength exceeds design shear stress**

##### Check bending moment - Section 6.1.6

Design bending moment  $M_{y,d} = 0.455 \text{ kNm}$

Design bending stress  $\sigma_{m,y,d} = M_{y,d} / W_y = 3.644 \text{ N/mm}^2$

Design bending strength  $f_{m,y,d} = k_{h,m,y} \times k_{mod} \times k_{sys} \times f_{m,k} / \gamma_M = 17.618 \text{ N/mm}^2$

$$\sigma_{m,y,d} / f_{m,y,d} = 0.207$$

**PASS - Design bending strength exceeds design bending stress**

#### Check combined bending and axial compression - Section 6.2.4

Combined loading checks - exp.6.19 & 6.20  $(\sigma_{c,0,d} / f_{c,0,d})^2 + \sigma_{m,y,d} / f_{m,y,d} = 0.214$

$$(\sigma_{c,0,d} / f_{c,0,d})^2 + k_m \times \sigma_{m,y,d} / f_{m,y,d} = 0.152$$

**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  $L_{e,y} = 0.9 \times 3363 \text{ mm} = 3027 \text{ mm}$

Slenderness ratio  $\lambda_y = L_{e,y} / i_y = 104.848$

Relative slenderness ratio - exp. 6.21  $\lambda_{rel,y} = \lambda_y / \pi \times \sqrt{(f_{c,0,k} / E_{0.05})} = 1.778$

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

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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  $k_y = 0.5 \times (1 + \beta_c \times (\lambda_{rel,y} - 0.3) + \lambda_{rel,y}^2) = 2.228$   
 $k_z = 0.5 \times (1 + \beta_c \times (\lambda_{rel,z} - 0.3) + \lambda_{rel,z}^2) = 0.470$   
 $k_{c,y} = 1 / (k_y + \sqrt{(k_y^2 - \lambda_{rel,y}^2)}) = 0.280$   
 $k_{c,z} = 1 / (k_z + \sqrt{(k_z^2 - \lambda_{rel,z}^2)}) = 1.064$

Column stability checks - exp.6.23 & 6.24  $\sigma_{c,0,d} / (k_{c,y} \times f_{c,0,d}) + \sigma_{m,y,d} / f_{m,y,d} = 0.516$   
 $\sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d}) + k_m \times \sigma_{m,y,d} / f_{m,y,d} = 0.226$

**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  $(\sigma_{m,y,d} / (K_{crit} \times f_{m,y,d}))^2 + \sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d}) = 0.124$

**PASS - Beam stability is acceptable**

**Check design 2220 mm along span**

**Check shear force - Section 6.1.7**

Design shear force  $F_{y,d} = 1.528$  kN  
Design shear stress - exp.6.60  $\tau_{y,d} = 1.5 \times F_{y,d} / (k_{cr} \times b \times h) = 0.456$  N/mm<sup>2</sup>  
Design shear strength  $f_{v,y,d} = k_{mod} \times k_{sys} \times f_{v,k} / \gamma_M = 2.708$  N/mm<sup>2</sup>  
 $\tau_{y,d} / f_{v,y,d} = 0.168$

**PASS - Design shear strength exceeds design shear stress**

**Check bending moment - Section 6.1.6**

Design bending moment  $M_{y,d} = 0.371$  kNm  
Design bending stress  $\sigma_{m,y,d} = M_{y,d} / W_y = 2.965$  N/mm<sup>2</sup>  
Design bending strength  $f_{m,y,d} = k_{h,m,y} \times k_{mod} \times k_{sys} \times f_{m,k} / \gamma_M = 17.618$  N/mm<sup>2</sup>  
 $\sigma_{m,y,d} / f_{m,y,d} = 0.168$

**PASS - Design bending strength exceeds design bending stress**

**Check combined bending and axial compression - Section 6.2.4**

Combined loading checks - exp.6.19 & 6.20  $(\sigma_{c,0,d} / f_{c,0,d})^2 + \sigma_{m,y,d} / f_{m,y,d} = 0.176$   
 $(\sigma_{c,0,d} / f_{c,0,d})^2 + k_m \times \sigma_{m,y,d} / f_{m,y,d} = 0.125$

**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  $L_{e,y} = 0.9 \times 3363$  mm = 3027 mm  
Slenderness ratio  $\lambda_y = L_{e,y} / i_y = 104.848$   
Relative slenderness ratio - exp. 6.21  $\lambda_{rel,y} = \lambda_y / \pi \times \sqrt{(f_{c,0,k} / E_{0.05})} = 1.778$   
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  $k_y = 0.5 \times (1 + \beta_c \times (\lambda_{rel,y} - 0.3) + \lambda_{rel,y}^2) = 2.228$   
 $k_z = 0.5 \times (1 + \beta_c \times (\lambda_{rel,z} - 0.3) + \lambda_{rel,z}^2) = 0.470$   
 $k_{c,y} = 1 / (k_y + \sqrt{(k_y^2 - \lambda_{rel,y}^2)}) = 0.280$

|                                                                                  |               |            |              |             |                         |  |
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Column stability checks - exp.6.23 & 6.24

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

$$\sigma_{c,0,d} / (K_{c,y} \times f_{c,0,d}) + \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.477}$$

$$\sigma_{c,0,d} / (K_{c,z} \times f_{c,0,d}) + K_m \times \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.199}$$

**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**

#### Check design at end of span

##### Check compression perpendicular to the grain - cl.6.1.5

Design perpendicular compression - major axis  $F_{c,y,90,d} = \mathbf{7.009}$  kN

Effective contact length  $L_{b,ef} = \min(1144 \text{ mm} / 2, L_b, 30 \text{ mm}) + L_b = \mathbf{130}$  mm

Design perpendicular compressive stress - exp.6.4  $\sigma_{c,y,90,d} = F_{c,y,90,d} / (b \times L_{b,ef}) = \mathbf{0.719}$  N/mm<sup>2</sup>

Design perpendicular compressive strength  $f_{c,y,90,d} = k_{mod} \times k_{sys} \times f_{c,90,k} / \gamma_M = \mathbf{1.692}$  N/mm<sup>2</sup>

$$\sigma_{c,y,90,d} / (k_{c,90} \times f_{c,y,90,d}) = \mathbf{0.283}$$

**PASS - Design perpendicular compression strength exceeds design perpendicular compression stress**

##### Check shear force - Section 6.1.7

Design shear force  $F_{y,d} = \mathbf{0.511}$  kN

Design shear stress - exp.6.60  $\tau_{y,d} = 1.5 \times F_{y,d} / (k_{cr} \times b \times h) = \mathbf{0.153}$  N/mm<sup>2</sup>

Design shear strength  $f_{v,y,d} = k_{mod} \times k_{sys} \times f_{v,k} / \gamma_M = \mathbf{2.708}$  N/mm<sup>2</sup>

$$\tau_{y,d} / f_{v,y,d} = \mathbf{0.056}$$

**PASS - Design shear strength exceeds design shear stress**

##### Check bending moment - Section 6.1.6

Design bending moment  $M_{y,d} = \mathbf{0.196}$  kNm

Design bending stress  $\sigma_{m,y,d} = M_{y,d} / W_y = \mathbf{1.566}$  N/mm<sup>2</sup>

Design bending strength  $f_{m,y,d} = k_{h,m,y} \times k_{mod} \times k_{sys} \times f_{m,k} / \gamma_M = \mathbf{17.618}$  N/mm<sup>2</sup>

$$\sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.089}$$

**PASS - Design bending strength exceeds design bending stress**

##### Check combined bending and axial compression - Section 6.2.4

Combined loading checks - exp.6.19 & 6.20  $(\sigma_{c,0,d} / f_{c,0,d})^2 + \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.096}$

$$(\sigma_{c,0,d} / f_{c,0,d})^2 + K_m \times \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.070}$$

**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  $L_{e,y} = 0.9 \times 3363 \text{ mm} = \mathbf{3027}$  mm

Slenderness ratio  $\lambda_y = L_{e,y} / i_y = \mathbf{104.848}$

Relative slenderness ratio - exp. 6.21  $\lambda_{rel,y} = \lambda_y / \pi \times \sqrt{(f_{c,0,k} / E_{0.05})} = \mathbf{1.778}$

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  $\lambda_{rel,z} = \lambda_z / \pi \times \sqrt{(f_{c,0,k} / E_{0.05})} = \mathbf{0}$

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

Straightness factor

$$\beta_c = \mathbf{0.2}$$

Instability factors - exp.6.25, 6.26, 6.27 & 6.28

$$K_y = 0.5 \times (1 + \beta_c \times (\lambda_{rel,y} - 0.3) + \lambda_{rel,y}^2) = \mathbf{2.228}$$

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

$$K_{c,y} = 1 / (K_y + \sqrt{(K_y^2 - \lambda_{rel,y}^2)}) = \mathbf{0.280}$$

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Column stability checks - exp.6.23 & 6.24

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

$$\sigma_{c,0,d} / (K_{c,y} \times f_{c,0,d}) + \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.398}$$

$$\sigma_{c,0,d} / (K_{c,z} \times f_{c,0,d}) + K_m \times \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.144}$$

**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

$$(\sigma_{m,y,d} / (K_{crit} \times f_{m,y,d}))^2 + \sigma_{c,0,d} / (K_{c,z} \times f_{c,0,d}) = \mathbf{0.089}$$

**PASS - Beam stability is acceptable**

**Consider Combination 2 - 1.0G + 1.0Q + 1.0RQ (Service)**

**Check design 2265 mm along span**

**Check y-y axis deflection - Section 7.2**

Instantaneous deflection

$$\delta_y = \mathbf{1 \text{ mm}}$$

Allowable deflection

$$\delta_{y,Allowable} = \text{Min}(L_{m3\_s1} / 125, 14 \text{ mm}) = \mathbf{14 \text{ mm}}$$

$$\delta_y / \delta_{y,Allowable} = \mathbf{0.071}$$

**PASS - Allowable deflection exceeds instantaneous deflection**

**Member4 - 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

Medium-term

Service class - cl.2.3.1.3

1

**Timber section details**

Number of timber sections in member

$$N = \mathbf{1}$$

Breadth of sections

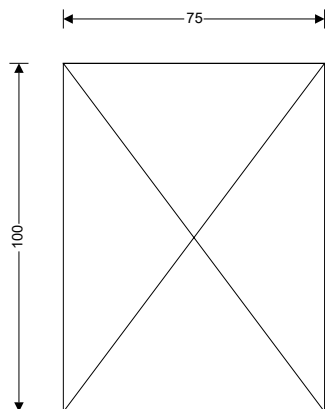
$$b = \mathbf{75 \text{ mm}}$$

Depth of sections

$$h = \mathbf{100 \text{ mm}}$$

Timber strength class - EN 338:2016 Table 1

**C24**



**75x100 timber section**

Cross-sectional area,  $A$ , 7500 mm<sup>2</sup>

Section modulus,  $W_y$ , 125000 mm<sup>3</sup>

Section modulus,  $W_z$ , 93750 mm<sup>3</sup>

Second moment of area,  $I_y$ , 6250000 mm<sup>4</sup>

Second moment of area,  $I_z$ , 3515625 mm<sup>4</sup>

Radius of gyration,  $i_y$ , 28.9 mm

Radius of gyration,  $i_z$ , 21.7 mm

**Timber strength class C24**

Characteristic bending strength,  $f_{m,k}$ , 24 N/mm<sup>2</sup>

Characteristic shear strength,  $f_{v,k}$ , 4 N/mm<sup>2</sup>

Characteristic compression strength parallel to grain,  $f_{t,0,k}$ , 21 N/mm<sup>2</sup>

Characteristic compression strength perpendicular to grain,  $f_{c,90,k}$ , 2.5 N/mm<sup>2</sup>

Characteristic tension strength parallel to grain,  $f_{t,0,k}$ , 14.5 N/mm<sup>2</sup>

Mean modulus of elasticity,  $E_{0,mean}$ , 11000 N/mm<sup>2</sup>

Fifth percentile modulus of elasticity,  $E_{0,05}$ , 7400 N/mm<sup>2</sup>

Shear modulus of elasticity,  $G_{mean}$ , 690 N/mm<sup>2</sup>

Characteristic density,  $\rho_k$ , 350 kg/m<sup>3</sup>

Mean density,  $\rho_{mean}$ , 420 kg/m<sup>3</sup>

**Span details**

Bearing length

$$L_b = \mathbf{100 \text{ mm}}$$

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

#### Modification factors

|                                                     |                                                                    |
|-----------------------------------------------------|--------------------------------------------------------------------|
| Duration of load and moisture content - Table 3.1   | $k_{mod} = 0.8$                                                    |
| 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)     | $k_{cr} = 0.67$                                                    |
| System strength factor - cl.6.6                     | $k_{sys} = 1.1$                                                    |

#### Check tension parallel to the grain - Section 6.1.2

|                                                                     |                                                                                                         |
|---------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| Axial tension                                                       | $P_d = 11.983 \text{ kN}$                                                                               |
| Design tensile stress                                               | $\sigma_{t,0,d} = P_d / (b \times \min(h_{ef,e1}, h_{ef,e2})) = 0.819 \text{ N/mm}^2$                   |
| Design tensile strength                                             | $f_{t,0,d} = k_{h,t} \times k_{mod} \times k_{sys} \times f_{t,0,k} / \gamma_M = 10.645 \text{ N/mm}^2$ |
|                                                                     | $\sigma_{t,0,d} / f_{t,0,d} = 0.077$                                                                    |
| <b>PASS - Design tensile strength exceeds design tensile stress</b> |                                                                                                         |

### Check design at start of span

#### Check shear force - Section 6.1.7

|                                                                 |                                                                                       |
|-----------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Design shear force                                              | $F_{y,d} = 0.061 \text{ kN}$                                                          |
| Design shear stress - exp.6.60                                  | $\tau_{y,d} = 1.5 \times F_{y,d} / (k_{cr} \times b \times h) = 0.018 \text{ N/mm}^2$ |
| Design shear strength                                           | $f_{v,y,d} = k_{mod} \times k_{sys} \times f_{v,k} / \gamma_M = 2.708 \text{ N/mm}^2$ |
|                                                                 | $\tau_{y,d} / f_{v,y,d} = 0.007$                                                      |
| <b>PASS - Design shear strength exceeds design shear stress</b> |                                                                                       |

#### Check bending moment - Section 6.1.6

|                                                                     |                                                                                                         |
|---------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| Design bending moment                                               | $M_{y,d} = 0.104 \text{ kNm}$                                                                           |
| Design bending stress                                               | $\sigma_{m,y,d} = M_{y,d} / W_y = 0.832 \text{ N/mm}^2$                                                 |
| Design bending strength                                             | $f_{m,y,d} = k_{h,m,y} \times k_{mod} \times k_{sys} \times f_{m,k} / \gamma_M = 17.618 \text{ N/mm}^2$ |
|                                                                     | $\sigma_{m,y,d} / f_{m,y,d} = 0.047$                                                                    |
| <b>PASS - Design bending strength exceeds design bending stress</b> |                                                                                                         |

#### Check combined bending and axial compression - Section 6.2.4

|                                                                            |                                                                              |
|----------------------------------------------------------------------------|------------------------------------------------------------------------------|
| Combined loading checks - exp.6.17 & 6.18                                  | $\sigma_{t,0,d} / f_{t,0,d} + \sigma_{m,y,d} / f_{m,y,d} = 0.124$            |
|                                                                            | $\sigma_{t,0,d} / f_{t,0,d} + k_m \times \sigma_{m,y,d} / f_{m,y,d} = 0.110$ |
| <b>PASS - Combined bending and axial tension utilisation is acceptable</b> |                                                                              |

#### 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.6.33            | $\sigma_{m,y,d} / (k_{crit} \times f_{m,y,d}) = 0.047$ |
| <b>PASS - Beam stability is acceptable</b> |                                                        |

### Consider Combination 2 - 1.0G + 1.0Q + 1.0RQ (Service)

#### Check design 847 mm along span

#### Check y-y axis deflection - Section 7.2

|                                                                     |                                                                                |
|---------------------------------------------------------------------|--------------------------------------------------------------------------------|
| Instantaneous deflection                                            | $\delta_y = 0.4 \text{ mm}$                                                    |
| Allowable deflection                                                | $\delta_{y,Allowable} = \min(L_{m4\_s1} / 250, 14 \text{ mm}) = 10 \text{ mm}$ |
|                                                                     | $\delta_y / \delta_{y,Allowable} = 0.036$                                      |
| <b>PASS - Allowable deflection exceeds instantaneous deflection</b> |                                                                                |

|                   |            |            |              |                         |               |
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## Member5 - Span 1

### Partial factor for material properties and resistances

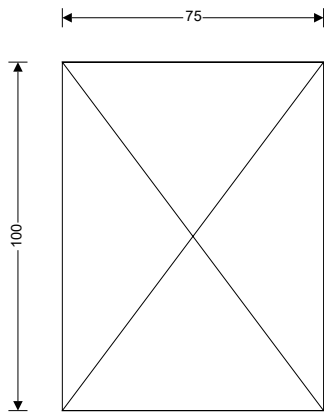
Partial factor for material properties - Table 2.3  $\gamma_M = 1.300$

### Member details

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

### Timber section details

Number of timber sections in member  $N = 1$   
Breadth of sections  $b = 75$  mm  
Depth of sections  $h = 100$  mm  
Timber strength class - EN 338:2016 Table 1 **C24**



#### 75x100 timber section

Cross-sectional area,  $A$ , 7500 mm<sup>2</sup>  
Section modulus,  $W_y$ , 125000 mm<sup>3</sup>  
Section modulus,  $W_z$ , 93750 mm<sup>3</sup>  
Second moment of area,  $I_y$ , 6250000 mm<sup>4</sup>  
Second moment of area,  $I_z$ , 3515625 mm<sup>4</sup>  
Radius of gyration,  $i_y$ , 28.9 mm  
Radius of gyration,  $i_z$ , 21.7 mm  
**Timber strength class C24**  
Characteristic bending strength,  $f_{m,k}$ , 24 N/mm<sup>2</sup>  
Characteristic shear strength,  $f_{v,k}$ , 4 N/mm<sup>2</sup>  
Characteristic compression strength parallel to grain,  $f_{c,0,k}$ , 21 N/mm<sup>2</sup>  
Characteristic compression strength perpendicular to grain,  $f_{c,90,k}$ , 2.5 N/mm<sup>2</sup>  
Characteristic tension strength parallel to grain,  $f_{t,0,k}$ , 14.5 N/mm<sup>2</sup>  
Mean modulus of elasticity,  $E_{0,mean}$ , 11000 N/mm<sup>2</sup>  
Fifth percentile modulus of elasticity,  $E_{0.05}$ , 7400 N/mm<sup>2</sup>  
Shear modulus of elasticity,  $G_{mean}$ , 690 N/mm<sup>2</sup>  
Characteristic density,  $\rho_k$ , 350 kg/m<sup>3</sup>  
Mean density,  $\rho_{mean}$ , 420 kg/m<sup>3</sup>

### Span details

Bearing length  $L_b = 100$  mm

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

#### Modification factors

Duration of load and moisture content - Table 3.1  $K_{mod} = 0.8$   
Deformation factor - Table 3.2  $K_{def} = 0.6$   
Depth factor for bending - Major axis - exp.3.1  $K_{h,m,y} = \min((150 \text{ mm} / h)^{0.2}, 1.3) = 1.084$   
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  $P_d = 3.16$  kN  
Design compressive stress  $\sigma_{c,0,d} = P_d / A = 0.421$  N/mm<sup>2</sup>  
Design compressive strength  $f_{c,0,d} = K_{mod} \times K_{sys} \times f_{c,0,k} / \gamma_M = 14.215$  N/mm<sup>2</sup>  
 $\sigma_{c,0,d} / f_{c,0,d} = 0.030$

**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  $F_{y,d} = 0.288$  kN

|                   |            |            |              |                         |               |
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Design shear stress - exp.6.60

$$\tau_{y,d} = 1.5 \times F_{y,d} / (k_{cr} \times b \times h) = \mathbf{0.086 \text{ N/mm}^2}$$

Design shear strength

$$f_{v,y,d} = k_{mod} \times k_{sys} \times f_{v,k} / \gamma_M = \mathbf{2.708 \text{ N/mm}^2}$$

$$\tau_{y,d} / f_{v,y,d} = \mathbf{0.032}$$

**PASS - Design shear strength exceeds design shear stress**

#### Check bending moment - Section 6.1.6

Design bending moment

$$M_{y,d} = \mathbf{0.127 \text{ kNm}}$$

Design bending stress

$$\sigma_{m,y,d} = M_{y,d} / W_y = \mathbf{1.02 \text{ N/mm}^2}$$

Design bending strength

$$f_{m,y,d} = k_{h,m,y} \times k_{mod} \times k_{sys} \times f_{m,k} / \gamma_M = \mathbf{17.618 \text{ N/mm}^2}$$

$$\sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.058}$$

**PASS - Design bending strength exceeds design bending stress**

#### Check combined bending and axial compression - Section 6.2.4

Combined loading checks - exp.6.19 & 6.20

$$(\sigma_{c,0,d} / f_{c,0,d})^2 + \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.059}$$

$$(\sigma_{c,0,d} / f_{c,0,d})^2 + k_m \times \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.041}$$

**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

$$L_{e,y} = 0.9 \times 1682 \text{ mm} = \mathbf{1514 \text{ mm}}$$

Slenderness ratio

$$\lambda_y = L_{e,y} / i_y = \mathbf{52.44}$$

Relative slenderness ratio - exp. 6.21

$$\lambda_{rel,y} = \lambda_y / \pi \times \sqrt{(f_{c,0,k} / E_{0.05})} = \mathbf{0.889}$$

Effective length for z-axis bending

$$L_{e,z} = \mathbf{0 \text{ mm}}$$

Slenderness ratio

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

Relative slenderness ratio - exp. 6.22

$$\lambda_{rel,z} = \lambda_z / \pi \times \sqrt{(f_{c,0,k} / E_{0.05})} = \mathbf{0}$$

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

Straightness factor

$$\beta_c = \mathbf{0.2}$$

Instability factors - exp.6.25, 6.26, 6.27 & 6.28

$$k_y = 0.5 \times (1 + \beta_c \times (\lambda_{rel,y} - 0.3) + \lambda_{rel,y}^2) = \mathbf{0.954}$$

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

$$k_{c,y} = 1 / (k_y + \sqrt{(k_y^2 - \lambda_{rel,y}^2)}) = \mathbf{0.769}$$

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

Column stability checks - exp.6.23 & 6.24

$$\sigma_{c,0,d} / (k_{c,y} \times f_{c,0,d}) + \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.096}$$

$$\sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d}) + k_m \times \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.068}$$

**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

$$(\sigma_{m,y,d} / (k_{crit} \times f_{m,y,d}))^2 + \sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d}) = \mathbf{0.031}$$

**PASS - Beam stability is acceptable**

#### Check design at end of span

##### Check shear force - Section 6.1.7

Design shear force

$$F_{y,d} = \mathbf{0.241 \text{ kN}}$$

Design shear stress - exp.6.60

$$\tau_{y,d} = 1.5 \times F_{y,d} / (k_{cr} \times b \times h) = \mathbf{0.072 \text{ N/mm}^2}$$

Design shear strength

$$f_{v,y,d} = k_{mod} \times k_{sys} \times f_{v,k} / \gamma_M = \mathbf{2.708 \text{ N/mm}^2}$$

$$\tau_{y,d} / f_{v,y,d} = \mathbf{0.027}$$

**PASS - Design shear strength exceeds design shear stress**

##### Check bending moment - Section 6.1.6

Design bending moment

$$M_{y,d} = \mathbf{0.317 \text{ kNm}}$$

Design bending stress

$$\sigma_{m,y,d} = M_{y,d} / W_y = \mathbf{2.537 \text{ N/mm}^2}$$

|                                                                                  |               |            |              |             |                         |  |
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| WH                                                                               | 23/05/2024    | NK         | 24/05/2024   |             |                         |  |

Design bending strength

$$f_{m,y,d} = k_{h,m,y} \times k_{mod} \times k_{sys} \times f_{m,k} / \gamma_M = 17.618 \text{ N/mm}^2$$

$$\sigma_{m,y,d} / f_{m,y,d} = 0.144$$

**PASS - Design bending strength exceeds design bending stress**

#### Check combined bending and axial compression - Section 6.2.4

Combined loading checks - exp.6.19 & 6.20

$$(\sigma_{c,0,d} / f_{c,0,d})^2 + \sigma_{m,y,d} / f_{m,y,d} = 0.145$$

$$(\sigma_{c,0,d} / f_{c,0,d})^2 + k_m \times \sigma_{m,y,d} / f_{m,y,d} = 0.102$$

**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

$$L_{e,y} = 0.9 \times 1682 \text{ mm} = 1514 \text{ mm}$$

Slenderness ratio

$$\lambda_{y} = L_{e,y} / i_y = 52.44$$

Relative slenderness ratio - exp. 6.21

$$\lambda_{rel,y} = \lambda_y / \pi \times \sqrt{(f_{c,0,k} / E_{0.05})} = 0.889$$

Effective length for z-axis bending

$$L_{e,z} = 0 \text{ mm}$$

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

$$k_y = 0.5 \times (1 + \beta_c \times (\lambda_{rel,y} - 0.3) + \lambda_{rel,y}^2) = 0.954$$

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

$$k_{c,y} = 1 / (k_y + \sqrt{(k_y^2 - \lambda_{rel,y}^2)}) = 0.769$$

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

Column stability checks - exp.6.23 & 6.24

$$\sigma_{c,0,d} / (k_{c,y} \times f_{c,0,d}) + \sigma_{m,y,d} / f_{m,y,d} = 0.183$$

$$\sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d}) + k_m \times \sigma_{m,y,d} / f_{m,y,d} = 0.129$$

**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

$$(\sigma_{m,y,d} / (k_{crit} \times f_{m,y,d}))^2 + \sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d}) = 0.049$$

**PASS - Beam stability is acceptable**

#### Consider Combination 2 - 1.0G + 1.0Q + 1.0RQ (Service)

##### Check design 944 mm along span

##### Check y-y axis deflection - Section 7.2

Instantaneous deflection

$$\delta_y = 0.7 \text{ mm}$$

Allowable deflection

$$\delta_{y,Allowable} = \text{Min}(L_{m5\_s1} / 250, 14 \text{ mm}) = 6.7 \text{ mm}$$

$$\delta_y / \delta_{y,Allowable} = 0.104$$

**PASS - Allowable deflection exceeds instantaneous deflection**

#### Member6 - Span 1

##### Partial factor for material properties and resistances

Partial factor for material properties - Table 2.3

$$\gamma_M = 1.300$$

##### Member details

Load duration - cl.2.3.1.2

Medium-term

Service class - cl.2.3.1.3

1

##### Timber section details

Number of timber sections in member

$$N = 1$$

Breadth of sections

$$b = 75 \text{ mm}$$

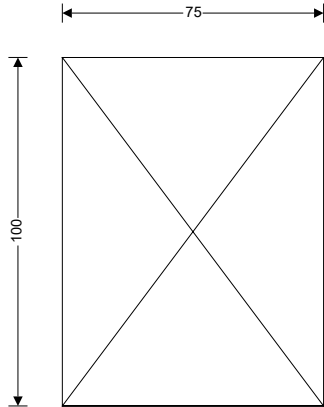
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Depth of sections

Timber strength class - EN 338:2016 Table 1

h = 100 mm

**C24**



**75x100 timber section**

Cross-sectional area, A, 7500 mm<sup>2</sup>

Section modulus, W<sub>y</sub>, 125000 mm<sup>3</sup>

Section modulus, W<sub>z</sub>, 93750 mm<sup>3</sup>

Second moment of area, I<sub>y</sub>, 6250000 mm<sup>4</sup>

Second moment of area, I<sub>z</sub>, 3515625 mm<sup>4</sup>

Radius of gyration, i<sub>y</sub>, 28.9 mm

Radius of gyration, i<sub>z</sub>, 21.7 mm

**Timber strength class C24**

Characteristic bending strength, f<sub>m,k</sub>, 24 N/mm<sup>2</sup>

Characteristic shear strength, f<sub>v,k</sub>, 4 N/mm<sup>2</sup>

Characteristic compression strength parallel to grain, f<sub>c,0,k</sub>, 21 N/mm<sup>2</sup>

Characteristic compression strength perpendicular to grain, f<sub>c,90,k</sub>, 2.5 N/mm<sup>2</sup>

Characteristic tension strength parallel to grain, f<sub>t,0,k</sub>, 14.5 N/mm<sup>2</sup>

Mean modulus of elasticity, E<sub>0,mean</sub>, 11000 N/mm<sup>2</sup>

Fifth percentile modulus of elasticity, E<sub>0,05</sub>, 7400 N/mm<sup>2</sup>

Shear modulus of elasticity, G<sub>mean</sub>, 690 N/mm<sup>2</sup>

Characteristic density, ρ<sub>k</sub>, 350 kg/m<sup>3</sup>

Mean density, ρ<sub>mean</sub>, 420 kg/m<sup>3</sup>

**Span details**

Bearing length

L<sub>b</sub> = 100 mm

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

**Modification factors**

Duration of load and moisture content - Table 3.1

k<sub>mod</sub> = 0.8

Deformation factor - Table 3.2

k<sub>def</sub> = 0.6

Depth factor for bending - Major axis - exp.3.1

k<sub>h,m,y</sub> = min((150 mm / h)<sup>0.2</sup>, 1.3) = 1.084

Bending stress re-distribution factor - cl.6.1.6(2)

k<sub>m</sub> = 0.7

Crack factor for shear resistance - cl.6.1.7(2)

k<sub>cr</sub> = 0.67

System strength factor - cl.6.6

k<sub>sys</sub> = 1.1

**Check compression parallel to the grain - cl.6.1.4**

Design axial compression

P<sub>d</sub> = 2.894 kN

Design compressive stress

σ<sub>c,0,d</sub> = P<sub>d</sub> / A = 0.386 N/mm<sup>2</sup>

Design compressive strength

f<sub>c,0,d</sub> = k<sub>mod</sub> × k<sub>sys</sub> × f<sub>c,0,k</sub> / γ<sub>M</sub> = 14.215 N/mm<sup>2</sup>

σ<sub>c,0,d</sub> / f<sub>c,0,d</sub> = 0.027

**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<sub>y,d</sub> = 0.058 kN

Design shear stress - exp.6.60

τ<sub>y,d</sub> = 1.5 × F<sub>y,d</sub> / (k<sub>cr</sub> × b × h) = 0.017 N/mm<sup>2</sup>

Design shear strength

f<sub>v,y,d</sub> = k<sub>mod</sub> × k<sub>sys</sub> × f<sub>v,k</sub> / γ<sub>M</sub> = 2.708 N/mm<sup>2</sup>

τ<sub>y,d</sub> / f<sub>v,y,d</sub> = 0.006

**PASS - Design shear strength exceeds design shear stress**

**Check bending moment - Section 6.1.6**

Design bending moment

M<sub>y,d</sub> = 0.062 kNm

Design bending stress

σ<sub>m,y,d</sub> = M<sub>y,d</sub> / W<sub>y</sub> = 0.5 N/mm<sup>2</sup>

Design bending strength

f<sub>m,y,d</sub> = k<sub>h,m,y</sub> × k<sub>mod</sub> × k<sub>sys</sub> × f<sub>m,k</sub> / γ<sub>M</sub> = 17.618 N/mm<sup>2</sup>

σ<sub>m,y,d</sub> / f<sub>m,y,d</sub> = 0.028

**PASS - Design bending strength exceeds design bending stress**

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#### Check combined bending and axial compression - Section 6.2.4

Combined loading checks - exp.6.19 & 6.20  $(\sigma_{c,0,d} / f_{c,0,d})^2 + \sigma_{m,y,d} / f_{m,y,d} = 0.029$   
 $(\sigma_{c,0,d} / f_{c,0,d})^2 + k_m \times \sigma_{m,y,d} / f_{m,y,d} = 0.021$

**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  $L_{e,y} = 0.9 \times 1682 \text{ mm} = 1514 \text{ mm}$   
 Slenderness ratio  $\lambda_y = L_{e,y} / i_y = 52.44$   
 Relative slenderness ratio - exp. 6.21  $\lambda_{rel,y} = \lambda_y / \pi \times \sqrt{(f_{c,0,k} / E_{0.05})} = 0.889$   
 Effective length for z-axis bending  $L_{e,z} = 0 \text{ mm}$   
 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  $k_y = 0.5 \times (1 + \beta_c \times (\lambda_{rel,y} - 0.3) + \lambda_{rel,y}^2) = 0.954$   
 $k_z = 0.5 \times (1 + \beta_c \times (\lambda_{rel,z} - 0.3) + \lambda_{rel,z}^2) = 0.470$   
 $k_{c,y} = 1 / (k_y + \sqrt{(k_y^2 - \lambda_{rel,y}^2)}) = 0.769$   
 $k_{c,z} = 1 / (k_z + \sqrt{(k_z^2 - \lambda_{rel,z}^2)}) = 1.064$

Column stability checks - exp.6.23 & 6.24  $\sigma_{c,0,d} / (k_{c,y} \times f_{c,0,d}) + \sigma_{m,y,d} / f_{m,y,d} = 0.064$   
 $\sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d}) + k_m \times \sigma_{m,y,d} / f_{m,y,d} = 0.045$

**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  $(\sigma_{m,y,d} / (K_{crit} \times f_{m,y,d}))^2 + \sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d}) = 0.026$

**PASS - Beam stability is acceptable**

#### Check design at end of span

##### Check shear force - Section 6.1.7

Design shear force  $F_{y,d} = 0.105 \text{ kN}$   
 Design shear stress - exp.6.60  $\tau_{y,d} = 1.5 \times F_{y,d} / (k_{cr} \times b \times h) = 0.031 \text{ N/mm}^2$   
 Design shear strength  $f_{v,y,d} = k_{mod} \times k_{sys} \times f_{v,k} / \gamma_M = 2.708 \text{ N/mm}^2$   
 $\tau_{y,d} / f_{v,y,d} = 0.012$

**PASS - Design shear strength exceeds design shear stress**

##### Check bending moment - Section 6.1.6

Design bending moment  $M_{y,d} = 0.075 \text{ kNm}$   
 Design bending stress  $\sigma_{m,y,d} = M_{y,d} / W_y = 0.601 \text{ N/mm}^2$   
 Design bending strength  $f_{m,y,d} = k_{h,m,y} \times k_{mod} \times k_{sys} \times f_{m,k} / \gamma_M = 17.618 \text{ N/mm}^2$   
 $\sigma_{m,y,d} / f_{m,y,d} = 0.034$

**PASS - Design bending strength exceeds design bending stress**

#### Check combined bending and axial compression - Section 6.2.4

Combined loading checks - exp.6.19 & 6.20  $(\sigma_{c,0,d} / f_{c,0,d})^2 + \sigma_{m,y,d} / f_{m,y,d} = 0.035$   
 $(\sigma_{c,0,d} / f_{c,0,d})^2 + k_m \times \sigma_{m,y,d} / f_{m,y,d} = 0.025$

**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  $L_{e,y} = 0.9 \times 1682 \text{ mm} = 1514 \text{ mm}$

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Slenderness ratio  $\lambda_y = L_{e,y} / i_y = \mathbf{52.44}$   
Relative slenderness ratio - exp. 6.21  $\lambda_{rel,y} = \lambda_y / \pi \times \sqrt{(f_{c,0,k} / E_{0.05})} = \mathbf{0.889}$   
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  $\lambda_{rel,z} = \lambda_z / \pi \times \sqrt{(f_{c,0,k} / E_{0.05})} = \mathbf{0}$   
 $\lambda_{rel,y} > 0.3$  column stability check is required

Straightness factor  $\beta_c = \mathbf{0.2}$   
Instability factors - exp.6.25, 6.26, 6.27 & 6.28  $k_y = 0.5 \times (1 + \beta_c \times (\lambda_{rel,y} - 0.3) + \lambda_{rel,y}^2) = \mathbf{0.954}$   
 $k_z = 0.5 \times (1 + \beta_c \times (\lambda_{rel,z} - 0.3) + \lambda_{rel,z}^2) = \mathbf{0.470}$   
 $k_{c,y} = 1 / (k_y + \sqrt{(k_y^2 - \lambda_{rel,y}^2)}) = \mathbf{0.769}$   
 $k_{c,z} = 1 / (k_z + \sqrt{(k_z^2 - \lambda_{rel,z}^2)}) = \mathbf{1.064}$   
Column stability checks - exp.6.23 & 6.24  $\sigma_{c,0,d} / (k_{c,y} \times f_{c,0,d}) + \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.069}$   
 $\sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d}) + k_m \times \sigma_{m,y,d} / f_{m,y,d} = \mathbf{0.049}$   
**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  $(\sigma_{m,y,d} / (k_{crit} \times f_{m,y,d}))^2 + \sigma_{c,0,d} / (k_{c,z} \times f_{c,0,d}) = \mathbf{0.027}$   
**PASS - Beam stability is acceptable**

#### Consider Combination 2 - 1.0G + 1.0Q + 1.0RQ (Service)

##### Check design 3 mm along span

##### Check y-y axis deflection - Section 7.2

Instantaneous deflection  $\delta_y = \mathbf{0.6}$  mm  
Allowable deflection  $\delta_{y,Allowable} = \text{Min}(L_{m6\_s1} / 250, 14 \text{ mm}) = \mathbf{6.7}$  mm  
 $\delta_y / \delta_{y,Allowable} = \mathbf{0.089}$   
**PASS - Allowable deflection exceeds instantaneous deflection**

