



Structural Calculations
Using
MasterSeries

Prepared for
OAK STRUCTURES Ltd

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3-Bay Car Barn
standard product

September 2017



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Oak Structures Ltd Standard Product Summary

Standard green oak framed 3-Bay Car Barn from Oak Structures Ltd.

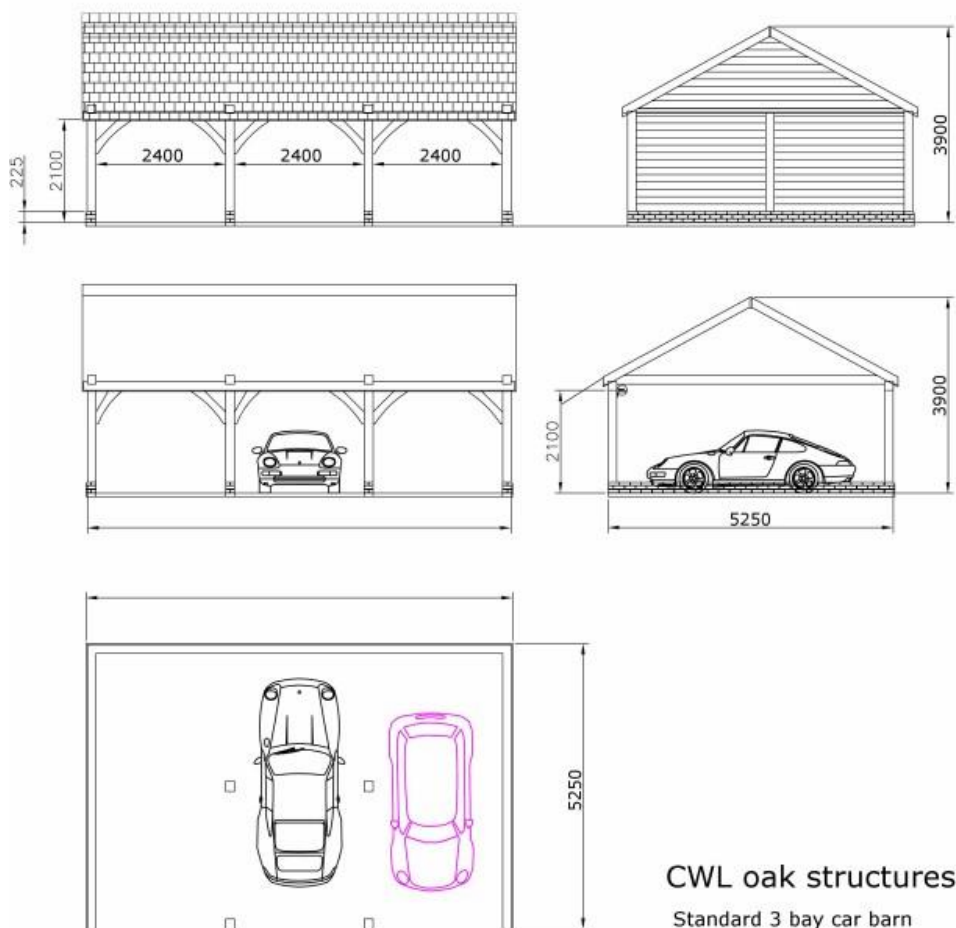


Figure 1 – Oak Structures Ltd Standard 3 Bay
Car Barn

Standard timber section sizes used in this design:

Frame Element	Material	Service Class	Section Size (width x depth mm)
All Posts	Green Oak - Class B	SC3 (external)	150 x 150
Wall Plates	Green Oak - Class B	SC3 (external)	150 x 150
Front to Rear Stretchers	Green Oak - Class B	SC3 (external)	100 x 150
Corner Braces	Green Oak - Class B	SC3 (external)	75 x 150
Ridge Beams	Green Oak - Class B	SC3 (external)	50 x 200
Rafters	Softwood C16	SC3 (external)	40 x 125
Collars (if required)	Softwood C16	SC3 (external)	50 x 150
Wall studs	Softwood C16	SC3 (external)	50 x 150



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Standard Product Analysis & Design

Required Loadings

This standard product is designed to be suitable for deployment at any location within Cheshire, **west** of the A523 (Bosley - Macclesfield - Prestbury - Poynton) main road. This allows the altitude of the site to be limited to a maximum of 200m which, in turn, limits the wind & snow loads to specific maximum values as defined by Eurocode 1 (EN 1991-1-3:2003 and EN1991-1-4:2005).

For wind loading, the design assumes one dominant opening on the long elevation leading to blocked internal wind pressure.

Design Parameters & Assumptions

1. All timber to be to Service Class 3 for external use.
2. Green Oak to Class B - use grade D30 in Masterseries as closest match to Class B
3. Wall panels simulated in Masterseries as FEA mesh using the following settings to replicate an arrangement of vertical posts, noggins and softwood board coverings robustly secured to the underlying frame:

FEA surface designed as 18mm OSB using the following values taken from BS EN 12369-:2001

- Emean (tension/compression parallel to span) = 3.80 kN/m²
- Poissons ratio = 0.16
- Density (mean) = 650 kg/m³
- G (shear modulus) racking = 1.08 kN/mm²
- $f_{c,0,k}$ compression parallel to span = 15.4 N/mm²
- $f_{t,0,k}$ tension parallel to span = 9.4 N/mm²

4. Roof panel simulated in Masterseries using an FEA surface using the following settings to replicate an arrangement of rafters, noggins, diagonal bracing, battening and softwood board coverings (where relevant) robustly secured to the underlying frame:

- FEA surface designed as 18mm OSB using the following values taken from BS EN 12369-:2001

- Emean (bending parallel to span) = 4.93 kN/m²
- Poissons ratio = 0.16
- Density (mean) = 650 kg/m³
- G (shear modulus) racking = 1.08 kN/mm²
- $f_{c,0,k}$ compression parallel to span = 15.4 N/mm²
- $f_{t,0,k}$ tension parallel to span = 9.4 N/mm²

All posts are assumed to have a pinned connection to underlying foundations (to be specified by Others) - this design assumes the foundations have enough weight to resist uplift (assuming required factor of safety = 1.5) and the underlying ground has adequate allowable ground bearing pressure using traditional methods for calculation (e.g. factor of safety of 3 for vertical displacement limited to 25mm).

Analysis Model

The following images show the masterseries analysis model.

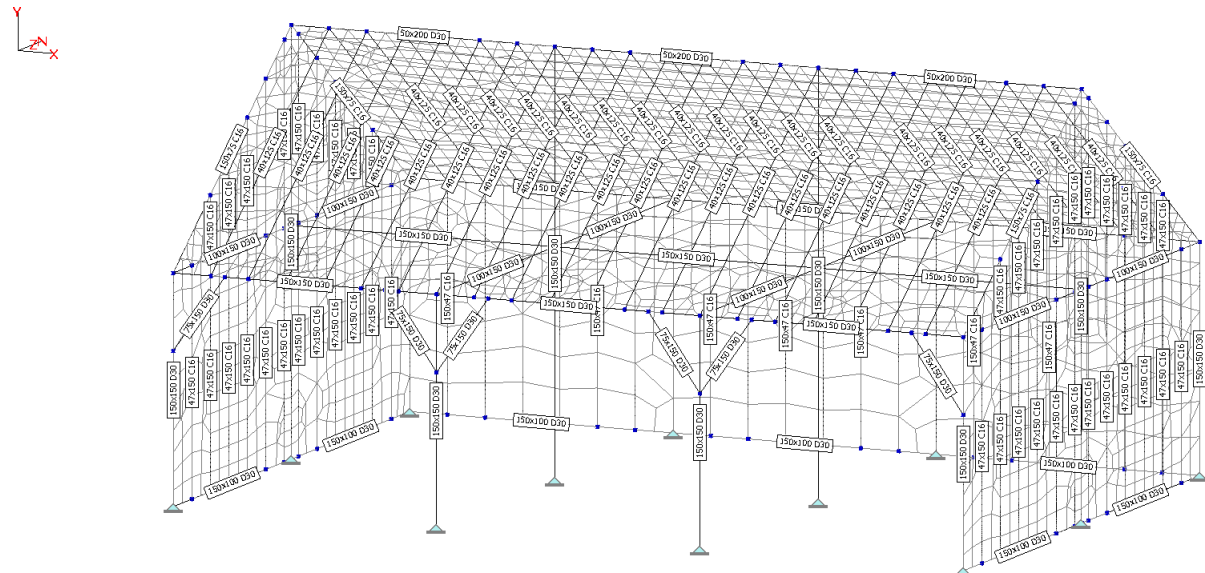


Figure 2 - Wireframe 3d Analysis model with sections

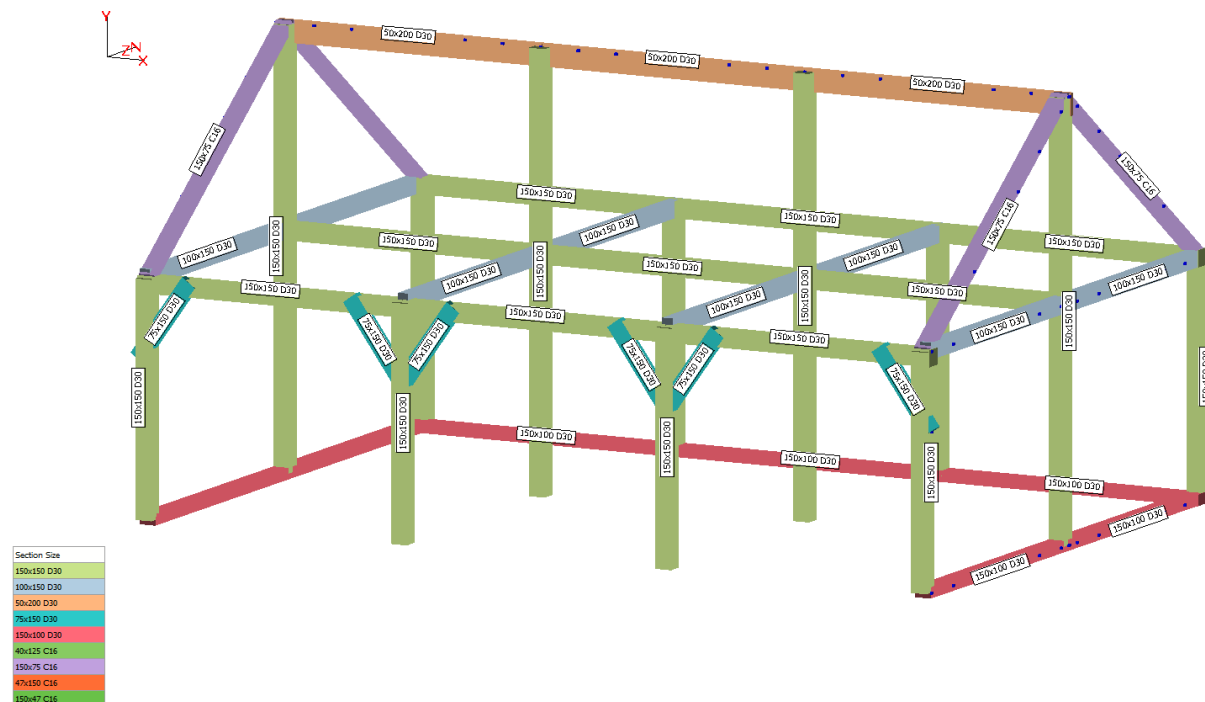


Figure 3 - 3d Analysis model with main green oak sections

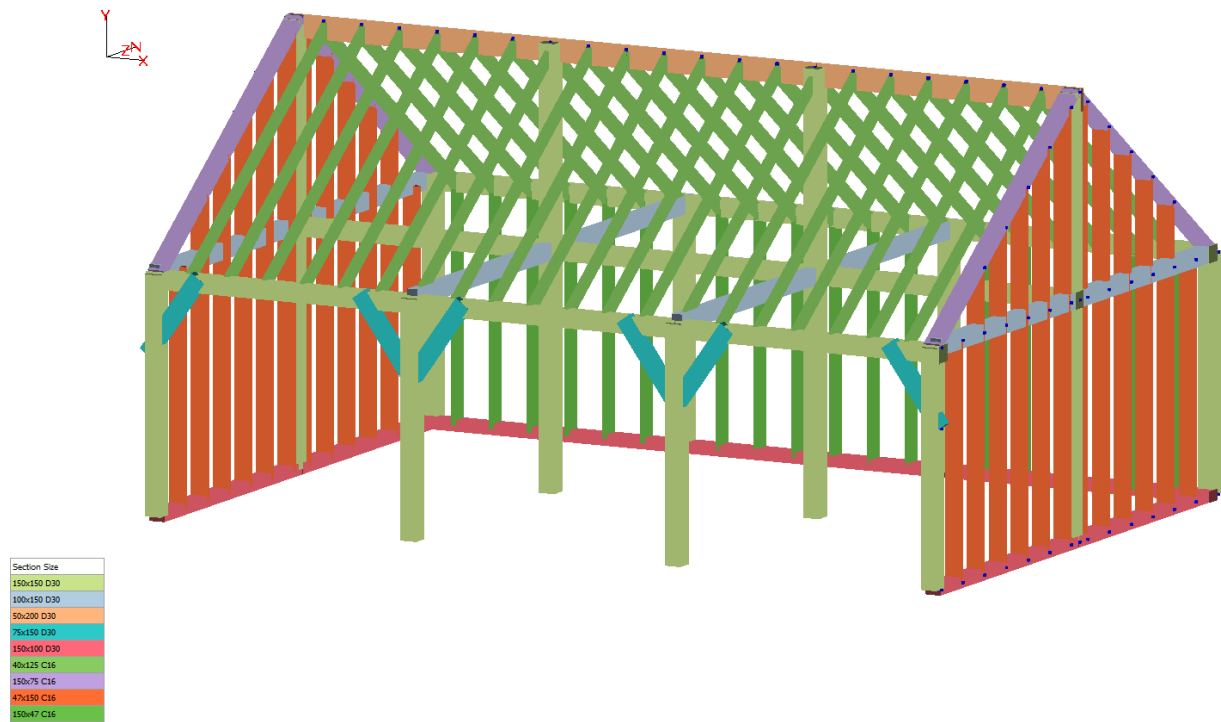


Figure 4 - 3d model with all timber sections including rafters and studs for walls

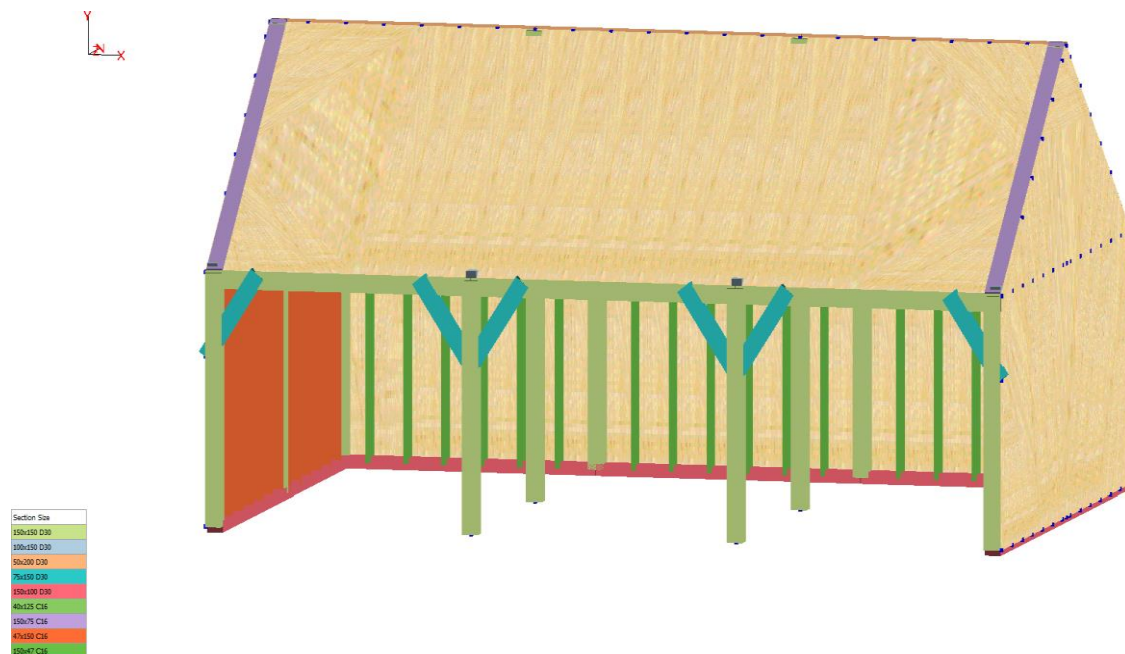


Figure 5 - 3d model with all timber sections and timber sheathing
(material information as shown in the design intent)

Analysis Data

The model frame data and loading information has been appended to appendix A.

Nodal numbers for the frame members are shown below along with member releases and frame supports.

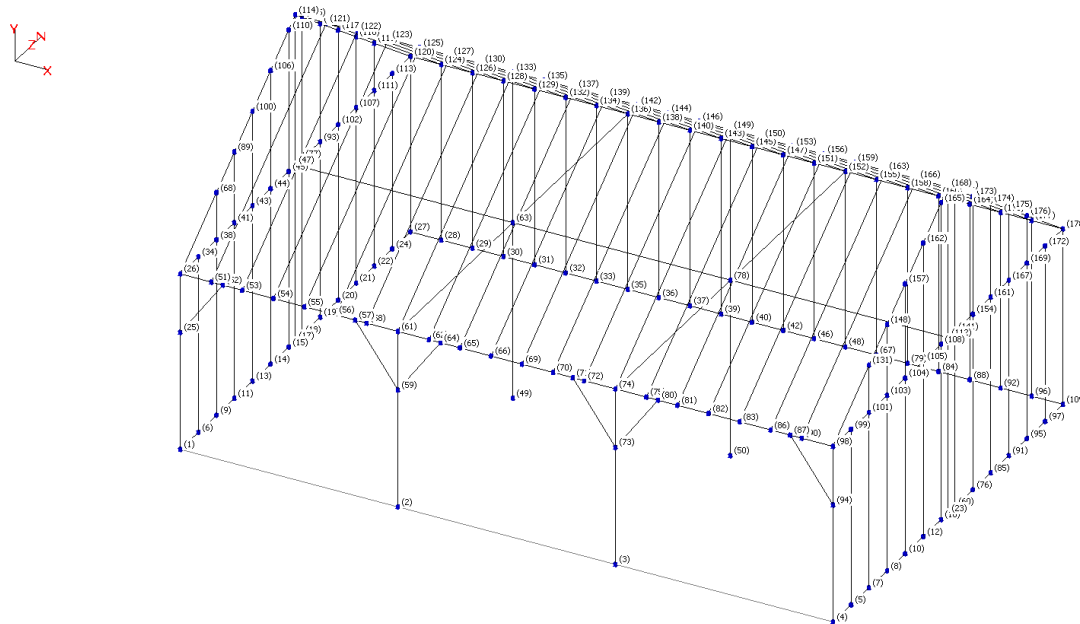


Figure 6 – Nodal numbers (1 of 2)

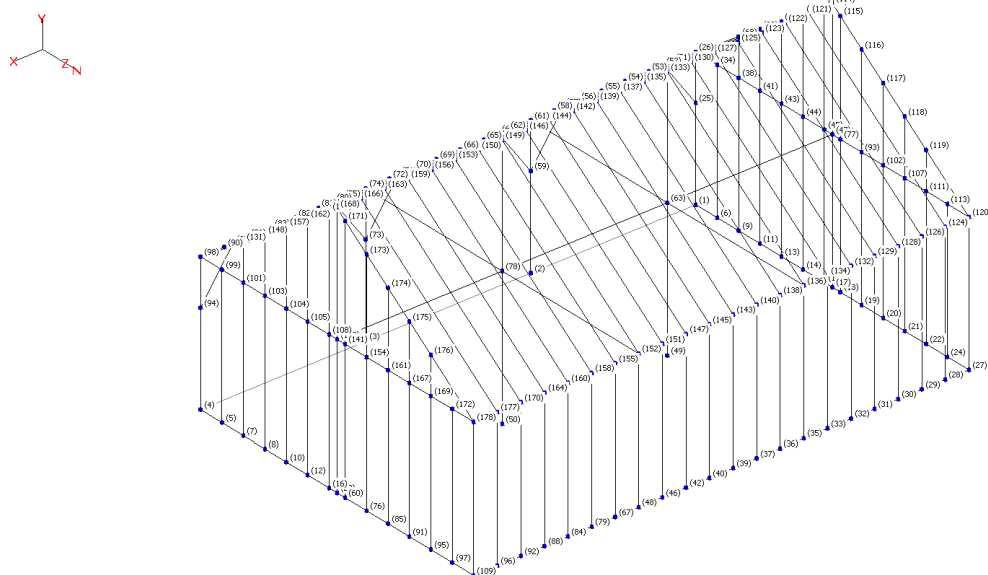


Figure 7 – Nodal numbers (2 of 2)

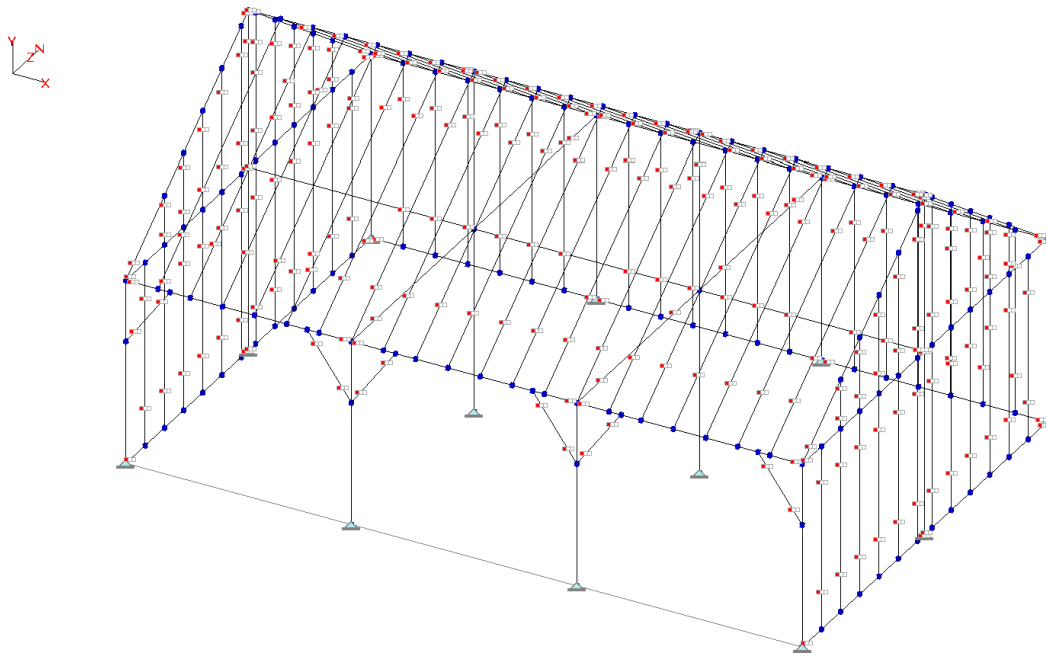


Figure 8 – Frame member releases and supports

Roof Loading Information

The following information shows graphical output for the design data that has been input into the analysis.

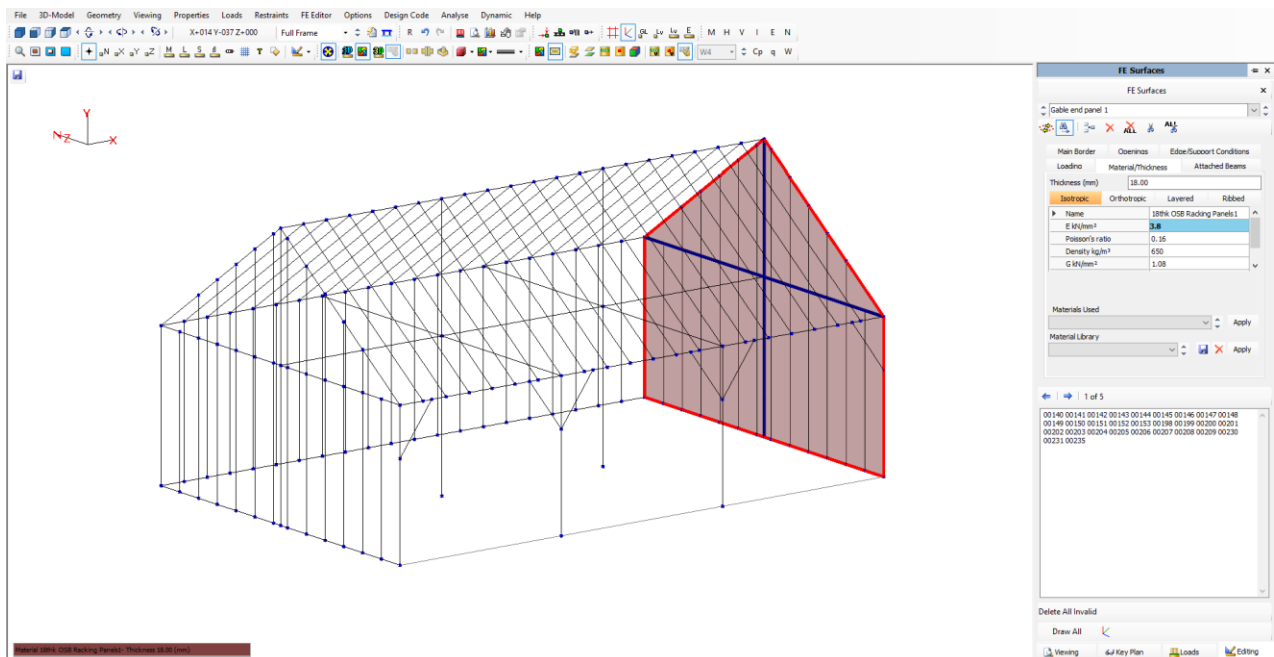


Figure 9 – Roof Loadings



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Roof loads have been calculated to BS EN 1991-1-1:2002

Loads have been derived from the following building material weights (excluding rafter self weight)

18mm OSB boarding = $(650 \text{ kg/m}^3 \times 9.81) \div 1000 = 6.4 \text{ kN/m}^3 \times 0.018\text{m} = 0.12 \text{ kN/m}^2$
Felt and battens = 0.05 kN/m^2
Timber Shingles = 0.05 kN/m^2
Total Dead Load = say 0.30 kN/m^2

Imposed loads for the following building are also to BS EN 1991-1-1:2002 and have been derived based on a 30° roof slope

Imposed load = 0.60 kN/m^2

Snow Loading

Snow loading has been based on the location of Cheshire using a maximum altitude of 200m. Site snow loading and roof snow loading have been calculated to BS EN 1991-1-3: 2003 (see appendix B for snow load calculations)

Maximum snow loading on roof = 0.59 kN/m^2

Wind loading

Wind loading has been based on a location in west Cheshire. Site wind loading has been calculated to BS EN 1991-1-4: 2005 (see appendix C for wind calculations)

The structure has a fully open front which is classed as a dominant opening to BS EN 1991-1-4: 2005, therefore the internal pressure coefficient (c_{pe}) value for this wind loading case = 0.9

The following pictures show the 4 directions of various wind loads applied to the structure. The structure has been orientated towards north to obtain accurate wind loads from all directions.

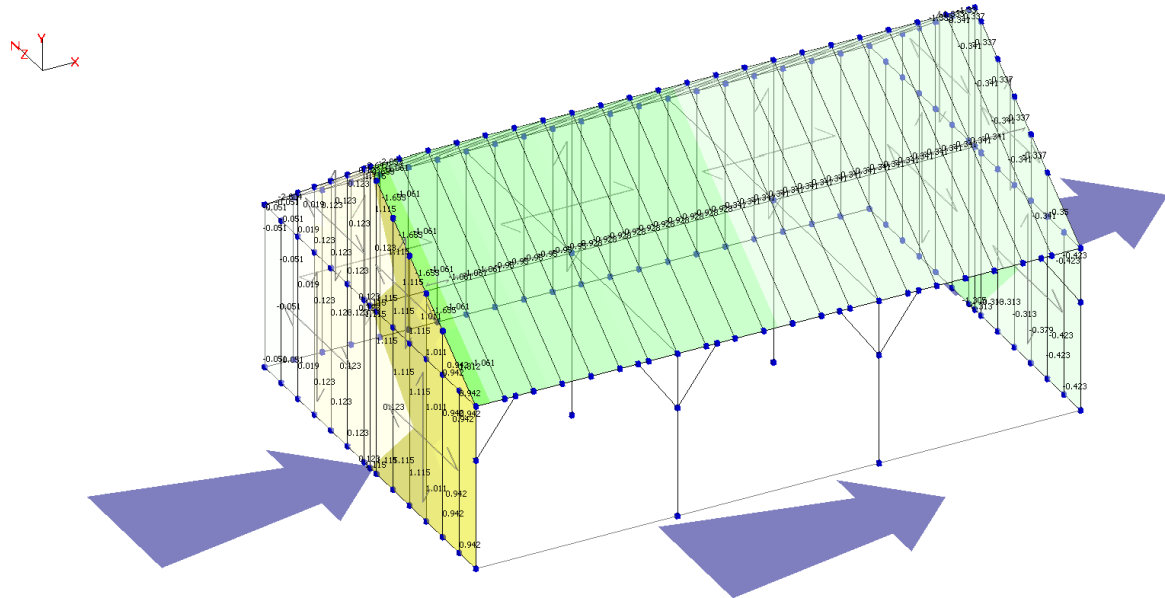


Figure 10 – Wind loading on gable wall ($W1 = 0^\circ$)

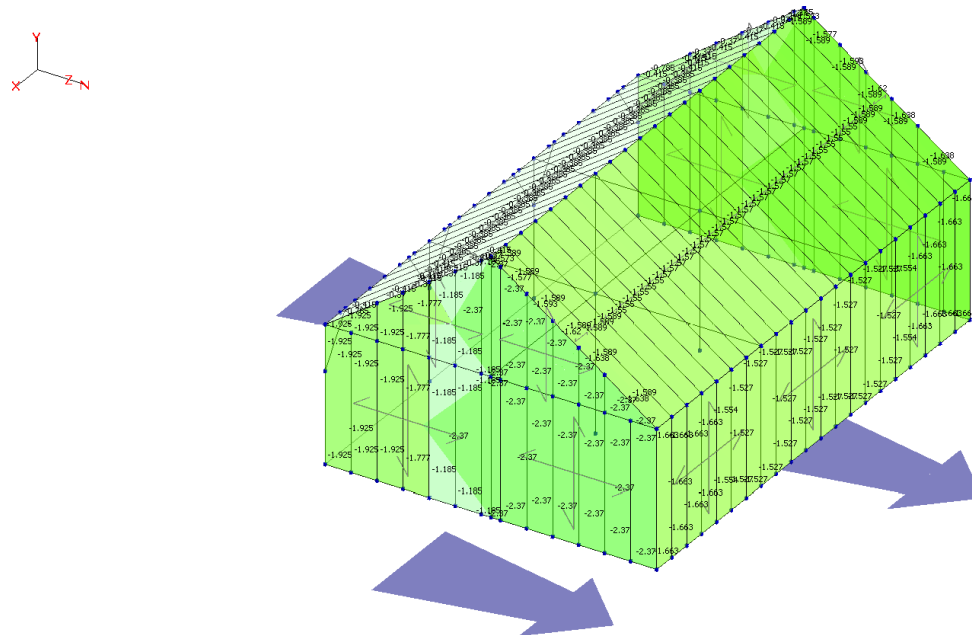


Figure 11 – Wind loading on open side of structure ($W2 = 90^\circ$)

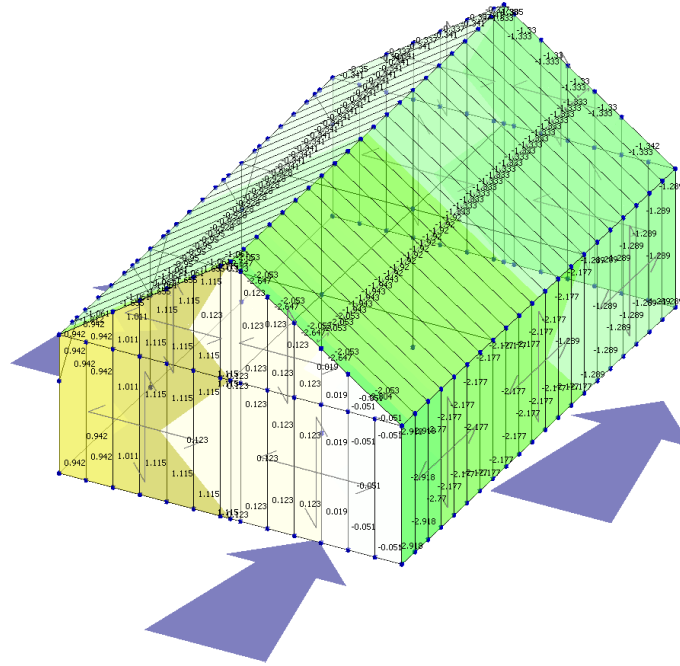


Figure 12 – Wind load on gable wall 2 (W3 = 180°)

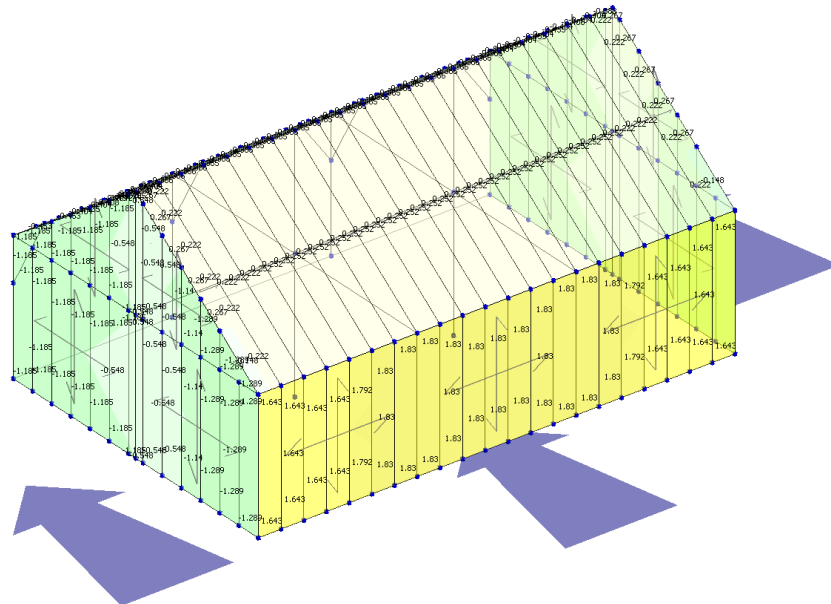


Figure 13 – Wind load on rear wall (W4 = 270°)

FEA data

The following image shows the material data input into the analysis model for the OSB racking surfaces.

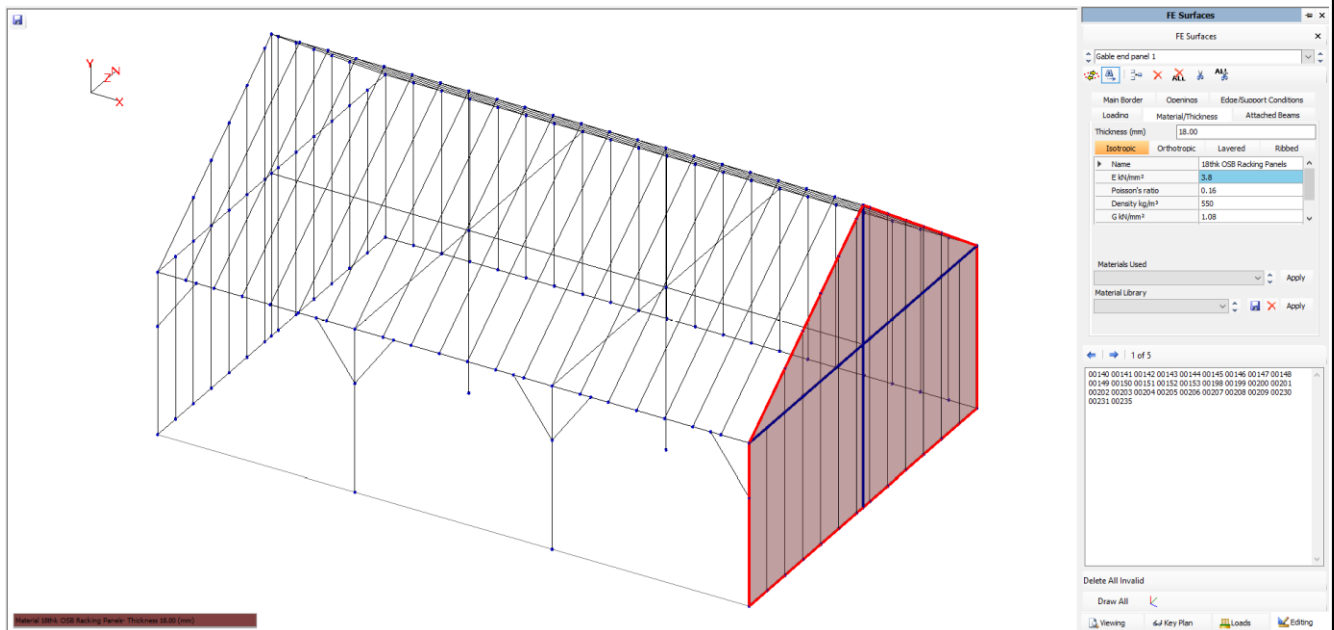


Figure 14 – FEA material input

The parameters are based on BS EN 12369-:2001 as shown in the earlier section.

Design Output

Bending Moment Diagrams

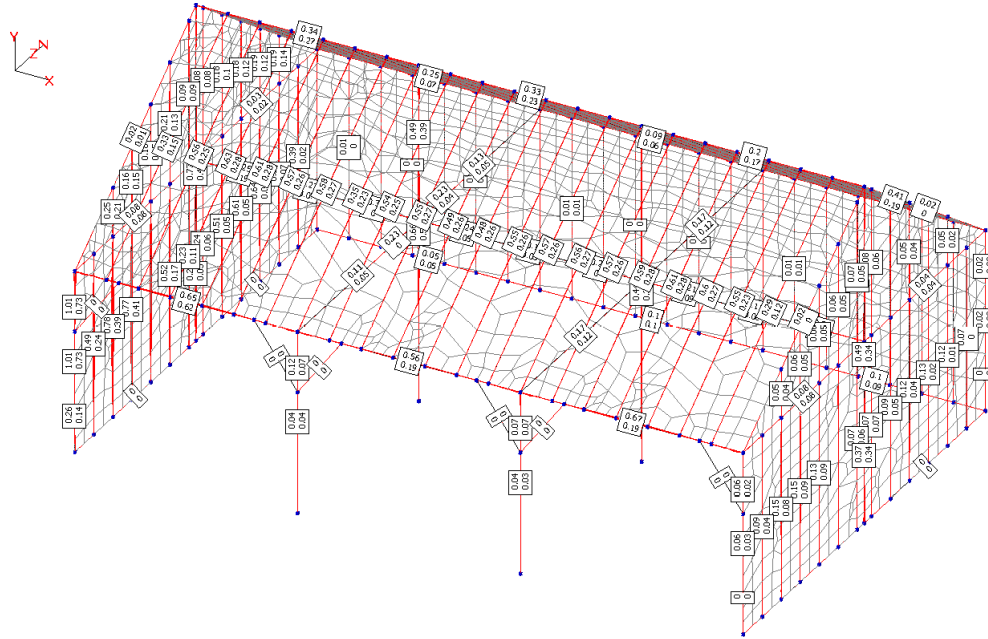


Figure 15 – Bending Moment Diagram (major axis) Ultimate Load

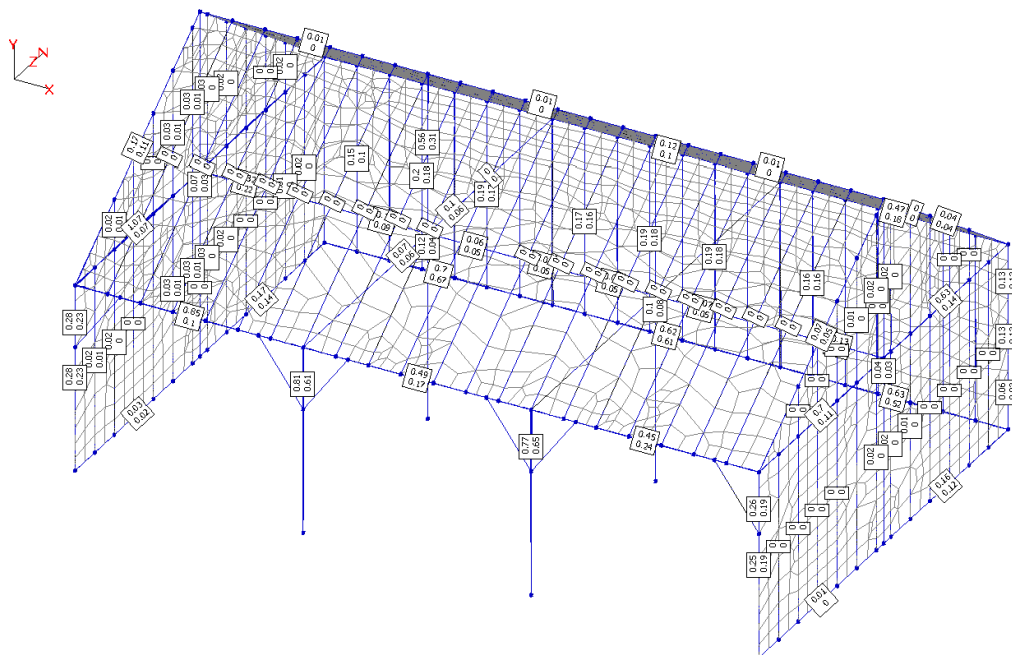


Figure 16 – Bending Moment Diagram (minor axis) Ultimate Load

Shear force diagrams

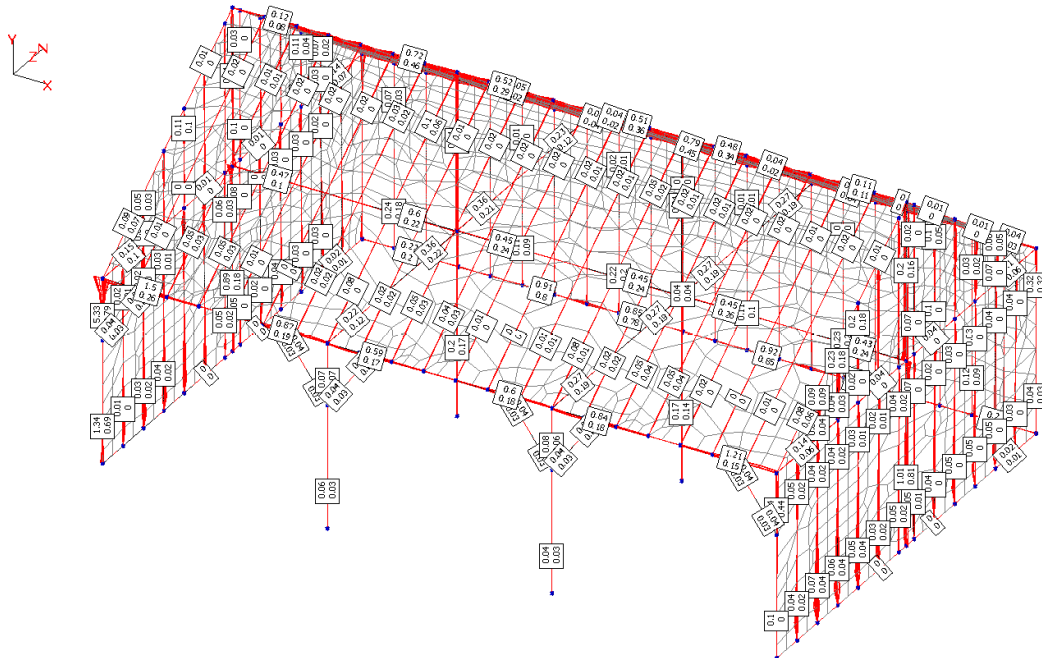


Figure 17 – Shear Force Diagram (major axis) Ultimate Load

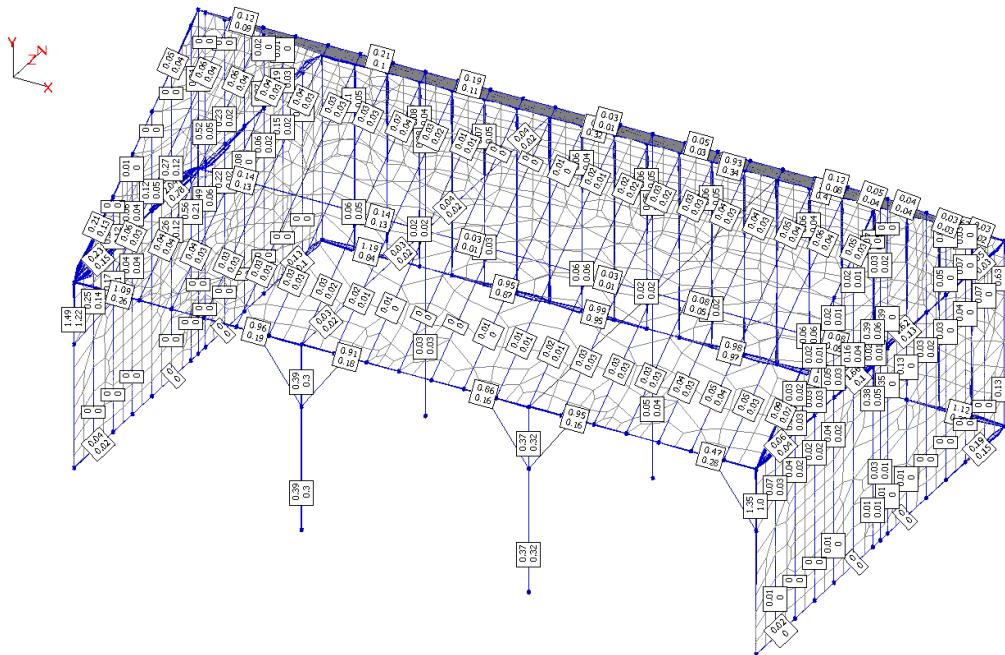


Figure 18 – Shear Force Diagram (minor axis) Ultimate Load

Axial Force Diagram

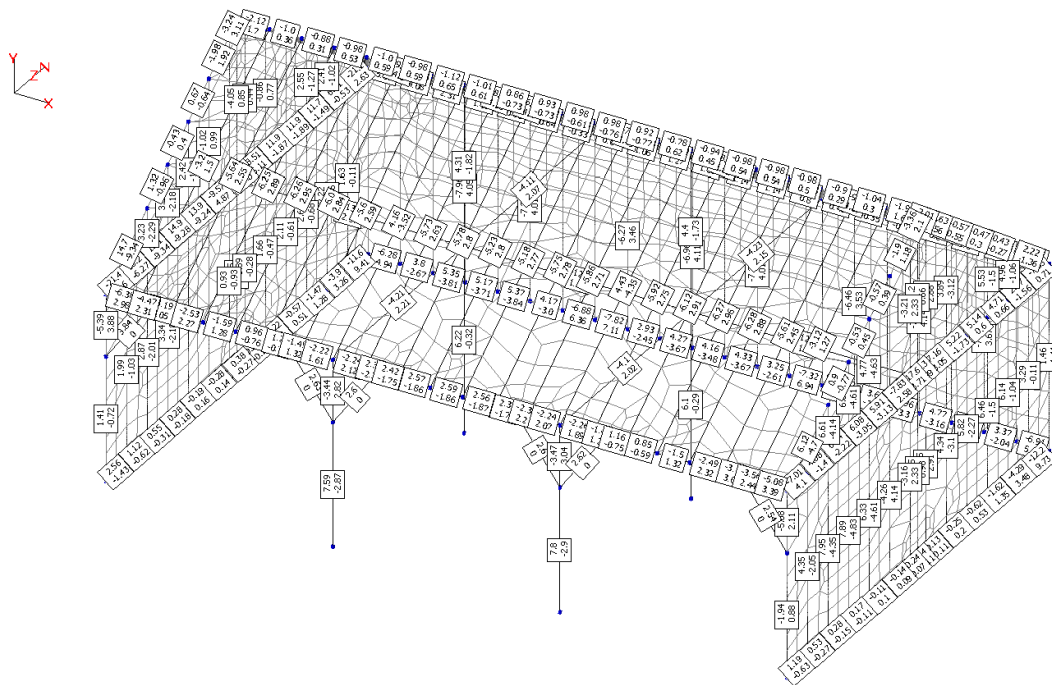


Figure 19 – Axial Forces (Ultimate Load)

Deflected Geometry

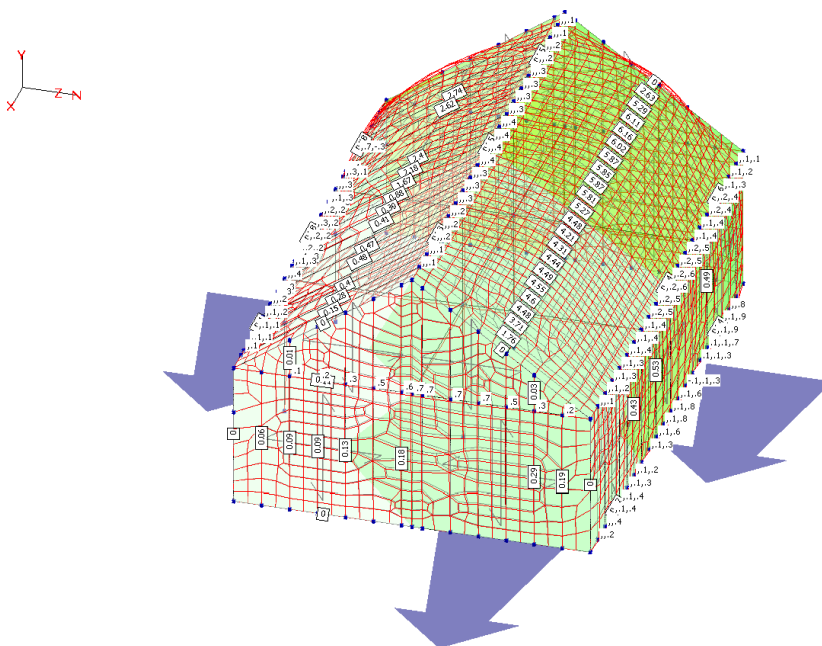


Figure 20 – Deflected geometry (Wind 1, 100 magnification)

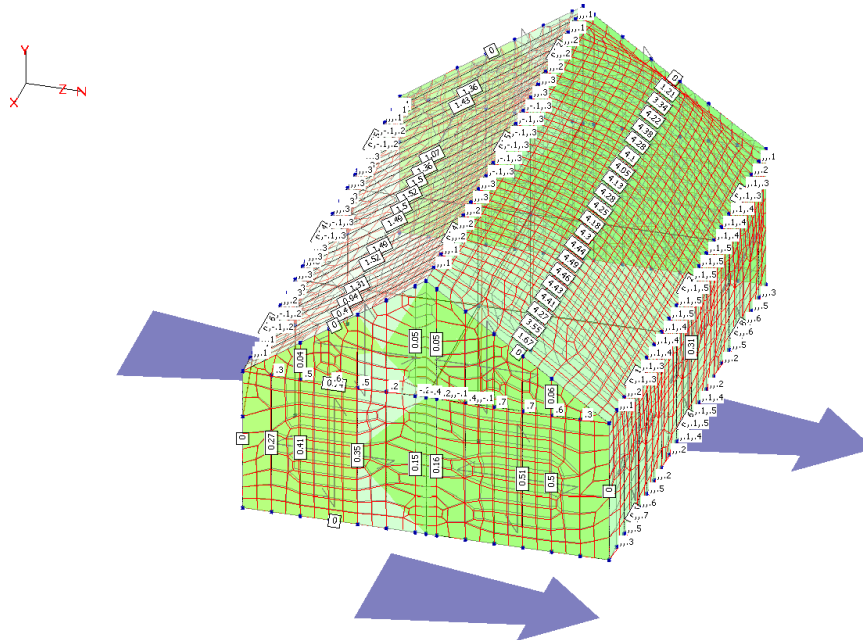


Figure 21 – Deflected geometry (Wind 2, 100 magnification)

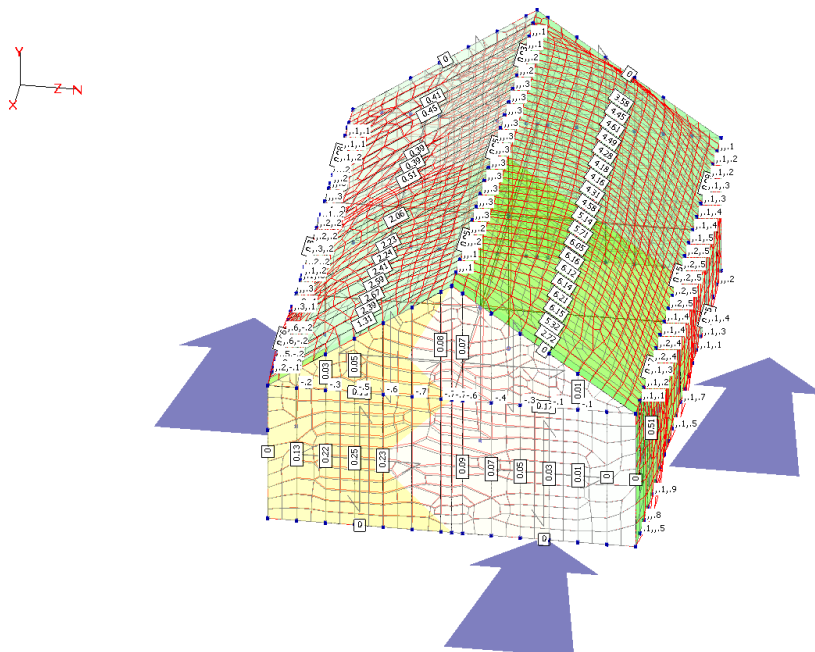


Figure 22 – Deflected geometry (Wind 3, 100 magnification)

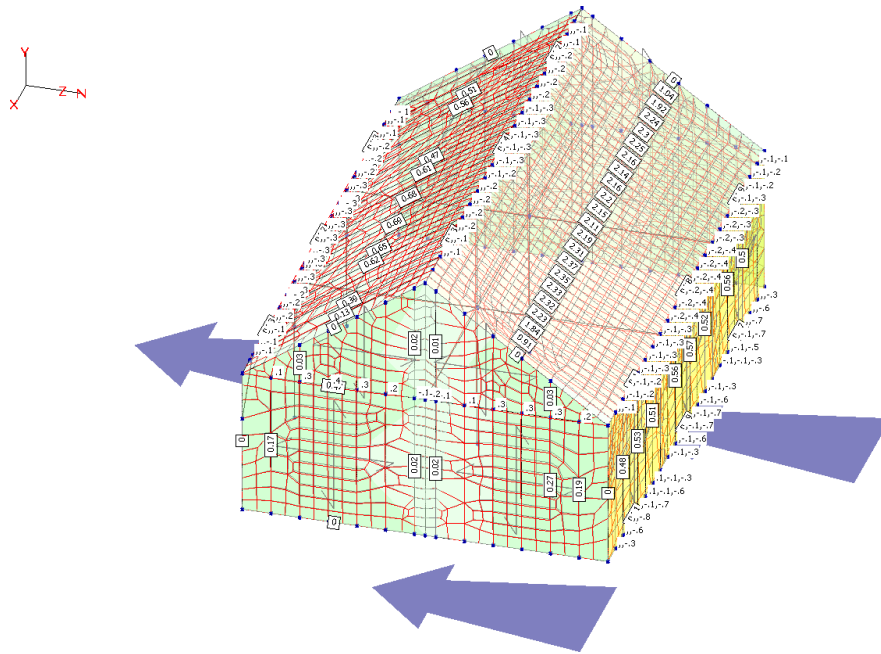


Figure 23 – Deflected geometry (Wind 4, 100 magnification)



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Member Design

The following table provides a summary of every member design brief from the output analysis. For clarity, members MUST be less than 1.0 utl to be deemed structurally adequate for supporting the proposed wind, snow and roof loads.

<u>Member</u>	<u>Structural description</u>	<u>Section size</u> (breadth x depth)	<u>Utl</u>	<u>Pass/Fail</u>
1-7, 8-14, 15-21, 43-51, 52-60, 61-69	Green oak eaves beam supporting the rafters (rear & front elevation) <u>(worst case design)</u>	150 x 150 D30 (green oak equivalent)	0.14	Pass
22-28, 29-35, 36-42	Green oak ridge beam <u>(worst case design)</u>	50 x 200 D30 (green oak equivalent)	0.17	Pass
70-76, 77-83, 84-90	Green oak 'sole plate' for supporting studs and sheathing along back wall <u>(worst case design)</u>	150 x 100 D30 (green oak equivalent)	0.26	Pass
94, 95, 96, 97, 243, 244, 245	Green oak internal ceiling beam <u>(worst case design)</u>	100 x 150 D30 (green oak equivalent)	0.11	Pass
98-104, 105-111, 112-118, 119-125	Green oak gable frame beam supporting vertical wall studs <u>(worst case design)</u>	100 x 150 D30 (green oak equivalent)	0.55	Pass
126-132, 133-139, 140-146, 147-153	Green oak gable frame 'sole plate' supporting vertical wall studs and sheathing <u>(worst case design)</u>	150 x 100 D30 (green oak equivalent)	0.17	Pass
154, 155, 156, 157, 158, 159	Green oak 'knee brace' along front elevation <u>(worst case design)</u>	75 x 150 D30 (green oak equivalent)	0.03	Pass
160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223	C16 Roof rafters <u>(worst case design)</u>	40 x 125 C16	0.98	Pass
186-191, 192-197, 198-203, 204-209,	C16 gable wall header plates <u>(worst case design)</u>	150 x 75 C16	0.77	Pass



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224-225, 226-227, 228-229, 230-231, 232, 233, 234, 235, 236-237, 238-239, 240-241, 242&246	Green oak frame posts <u>(worst case design)</u>	150 x 150 D30 (green oak equivalent)	0.16	Pass
247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308	C16 timber wall studs <u>(worst case design)</u>	47 x 150 C16	0.77	Pass

Table 2 – Member design summary showing worst case utilisation of each member type

Therefore all members are structurally adequate for the proposed design intent.

Extensive calculations for each member can be found in the supporting document C19878-MD-01-151 if required.

Foundation loads

Foundation loads for the design of the structural slab / concrete pad foundations required to resist any uplift or horizontal forces, are shown in Appendix D.

The below diagram shows the node numbers and locations of foundations to be designed.

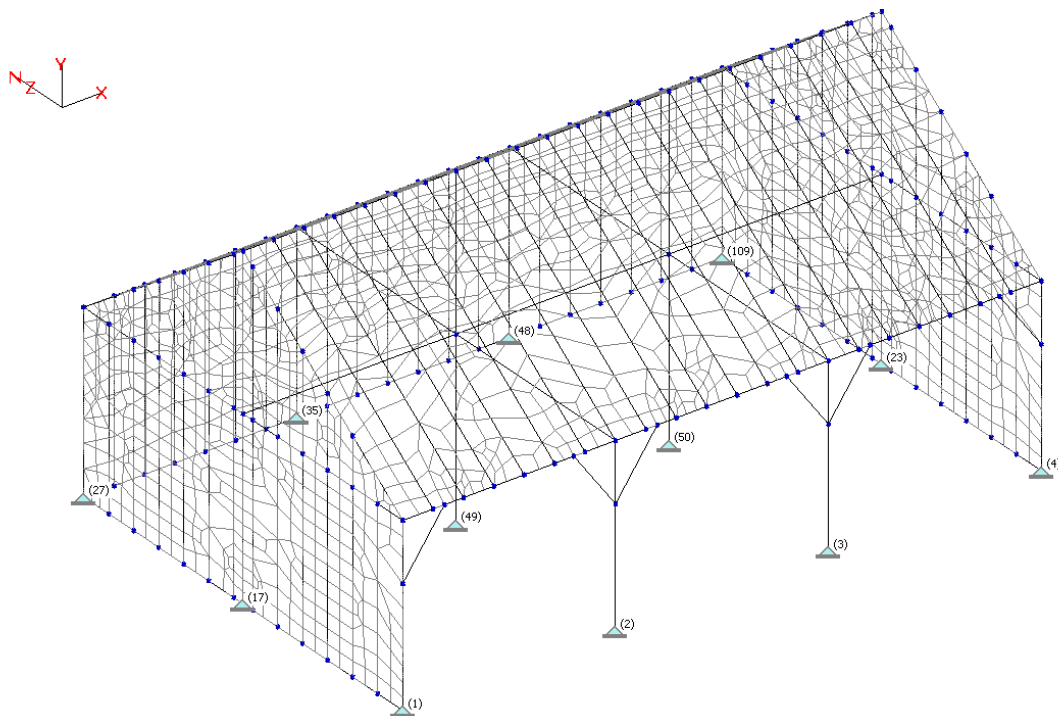


Figure 24 – Foundations to be designed