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Long Span Roofs - LVL Portal Frames and Trusses

Technical Design Guide issued by Forest and Wood Products Australia

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Introduction

The aim of this Long Span Roof Design Guide is to provide optimised design solutions for a range of long span Laminated Veneer Lumber (LVL) portal frames and trusses under different loadings. These optimised design solutions respect the required structural capacities and deflection performances under the Australian Standards while using the minimum volume of LVL.

Engineers may use the solutions from this Guide as a starting point to their own design and adjust the design factors accordingly for specific design requirements. Engineers and future owners of the proposing properties may also use the solutions from this Guide to estimate the costs and allow comparisons with other design options.

Three types of efficient timber roof configurations have been included in this Guide. They are mono-pitch portal frames, double-pitch portal frames and Pratt trusses. Each of these three roof configurations have been designed over a range of large clear spans (10 metres to 70 metres) and at different clear heights.

Each portal frame and truss design has been done using high-strength engineered timber product – Laminated Veneer Lumber (LVL). All portal frames solutions are designed using a box section of LVL. All truss solutions are designed using solid sections of LVL.

Extensive finite element analysis has been carried out for each roof configuration to ensure an optimised solution has been reached. Result tables and configuration drawings of the final optimised solutions for portal frames and trusses are provided. The Guide also includes supporting materials for helping in design, as given in Section 8. Design examples are provided in the last sections.

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Scope

2.1 Summary of Design Parameters

This section contains a summary of the design parameters and assumptions for each type of long span roof design. The detailed explanations are provided in later sections.

2.1.1 Portal Frames

Two common types of portal frames are included in design: a portal frame with an internal prop and a gable portal frame.

Portal frame with internal prop

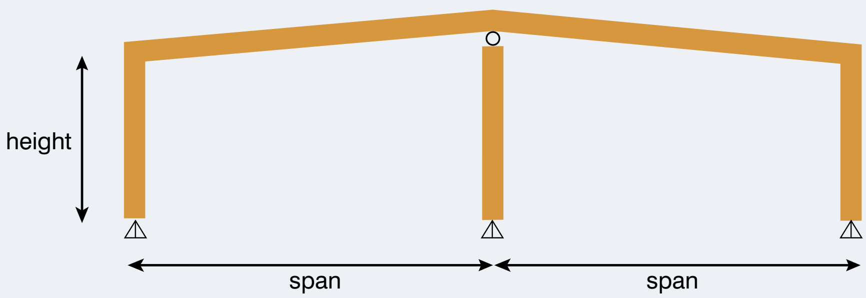

Figure 2.1: Portal frame with internal prop

- Design spans of 20 m, 25 m, 30 m, 35 m, 40 m, 45 m & 50 m
- Side column heights of 5 m, 6 m & 7 m
- Pinned column bases

Gable portal frame

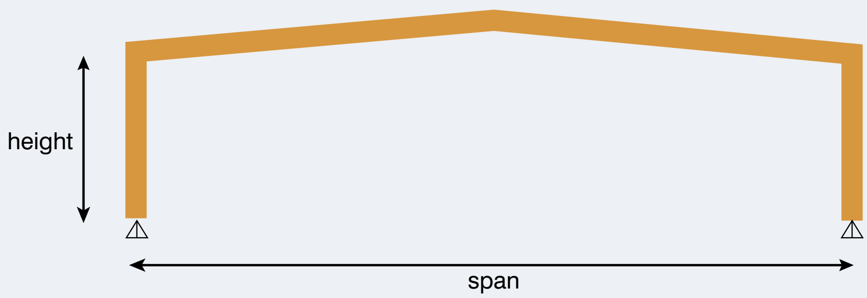

Figure 2.2: Gable portal frame

- Spans of 15 m, 20 m, 25 m, 30 m, 35 m, 40 m & 45 m
- Column heights of 5 m, 6 m & 7 m
- Pinned column bases

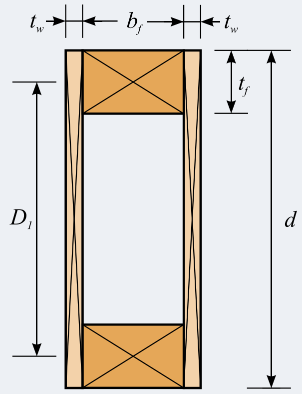

Figure 2.3: Typical box beam.

Cross section and material

All portal frame solutions are designed as box sections of Grade 11 LVL.

- The depth (d) of the box sections ranges from 400 mm to 1200 mm.
- The width (b_f) is selected to maximise material utilisation from a 1200 mm-wide LVL billet. Refer to Section 8.3.
- Two optimised solutions are provided for every portal frame, one in 45 mm web thicknesses (t_w), the other in 63 mm web thicknesses (t_w).

All webs of the box sections are with two cross-bands.

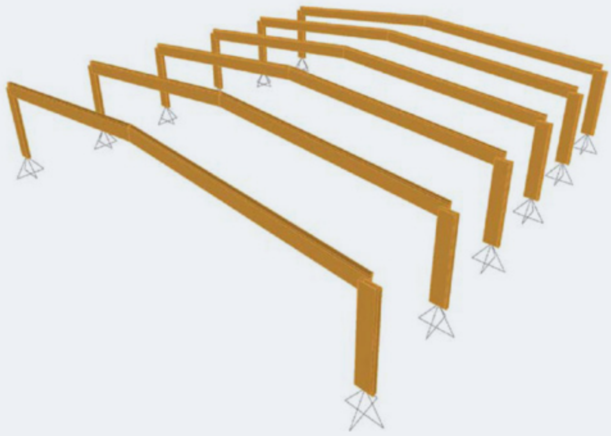

Figure 2.4: Gable portal frame.

Other assumptions

- 8 m frame spacing
- 5° degrees roof pitch
- Importance Level 2
- Design location: Auckland
- Design life: 50 years
- Pre-cambering equal to self-weight deflection
- Fixed rafter to column and apex connections
- Same cross-section throughout the whole portal frame

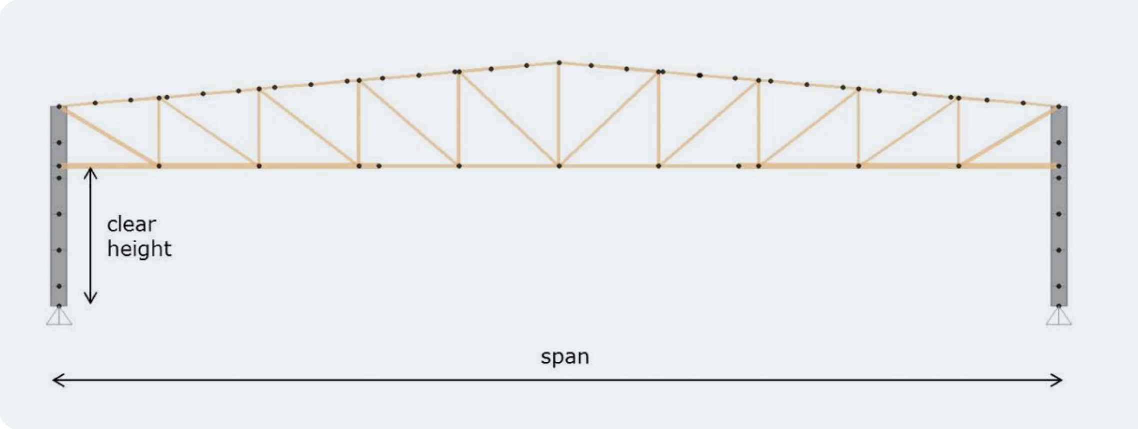

Figure 2.5: Trussed roof.

2.1.2 Truss Design Parameters

- Design spans of 50 m, 60 m, 70 m
- Column clear heights of 7 m
- Pinned column bases

Cross section and material

All truss members are designed as solid sections of Grade 11 LVL.

- The depth (*d*) of the truss members ranges from 150 mm to 400 mm.
- The width (*b*) of the truss members are either 126 mm or 180 mm.

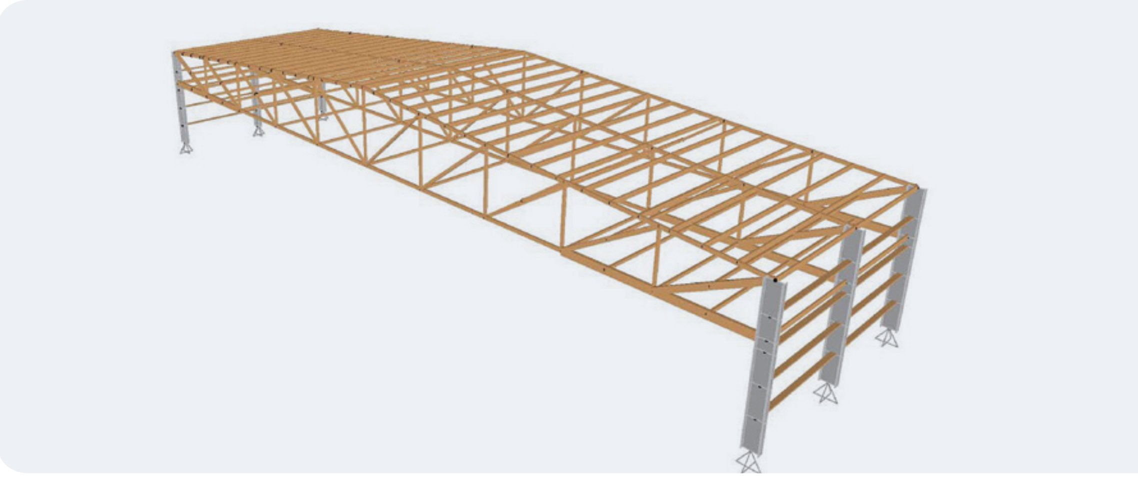

Figure 2.6: Trussed roof.

Other assumptions

- Pratt truss configuration
- 8 m truss spacing
- 5° degrees roof pitch
- Importance Level 2
- Design location: Auckland
- Design life: 50 years
- Pre-cambering equal to self-weight deflection
- Simple pinned connections throughout the truss
- All connection requirements to be met using timber rivets

2.2 Design Solution Criteria

The following sections are provided to clarify the design criteria, design conditions, loadings and assumptions made in each design.

All design solutions must satisfy two important criteria:

1. Optimal solution: All final solutions must achieve the required structural capacities and deflection performances under the Australian Standards while using the minimum volume of timber (see Section 8.4).
2. Minimised wastage: In order to minimise the wastage of LVL within each portal frame and truss project, the flange width of a box section will always be a width that maximises material utilisation from a 1200 mm-wide LVL billet (see Sections 8.3 and 8.4).

Both criteria have a common objective of saving costs. By adopting optimised design solutions that use the minimum volume of timber and have minimised wastage in mind, the material cost for a project will be reduced to a minimum and the LVL supplied for the project will be efficiently used.

2.3 Portal Frame Arrangements

2.3.1 Portal Frame with Internal Prop

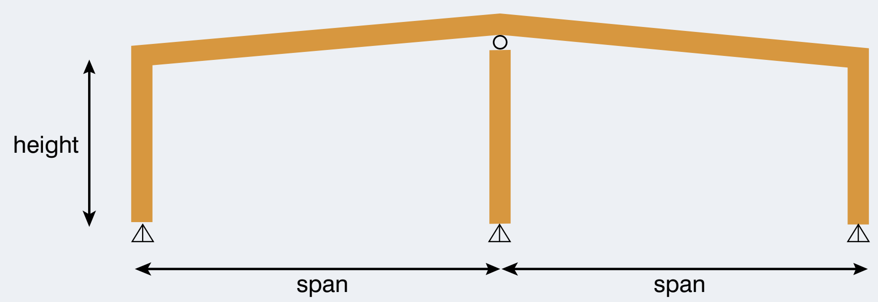

Figure 2.7: Portal frame with internal prop.

This arrangement is constructed by a double-pitch frame with an inner prop column that is pinned to the apex of the double-pitch frame.

The end columns to rafters (knee joints) and the apex joint between the rafters are fixed joints. The inner prop column carries axial loads only, and does not contribute to moment resisting.

2.3.2 Double-Pitch (Gable) Portal Frame

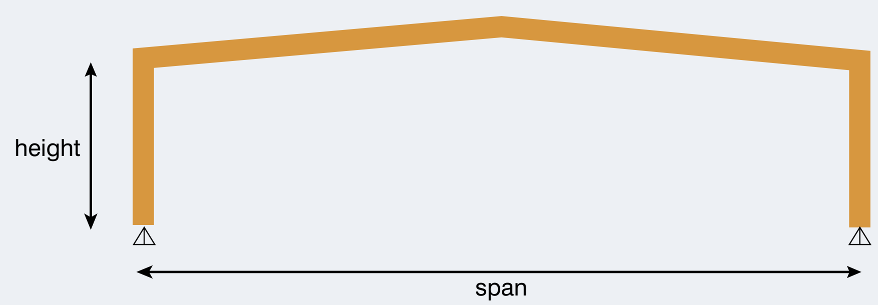

Figure 2.8: Double-pitch (gable) portal frame.

The double-pitch portal frame is the most standard configuration of a portal frame structure. The double-pitch portal frames are assumed to be a ‘two-pin’ configuration. The column to rafter joints (knee joints) and the apex joint between the rafters are fixed joints. The bases of the columns are pinned. The same cross-section is used to construct the entire portal frame.

2.4 Truss Arrangement

The Pratt truss configuration is adopted for all timber trusses. The truss members are assumed to be joined using simple connections throughout.

Steel columns are used to support the trusses. LVL columns are typically not stiff enough and the required cross-section makes them uneconomical.

The bases of the columns are pinned. In all the trusses, bottom chords are braced at every node. The top chords are assumed laterally supported by the roof purlins (spaced at 1.8 metres). For every truss solution, a constant member width has been maintained throughout to allow ease of detailing the connections.

2.5 Frame/Truss Spacing

All portal frames and trusses are designed at 8 metres spacing. Longer spacing is possible using either LVL roof purlins or I-joists. However, a longer spacing will increase frame/truss loads. For optimum use of roof purlin span and spacing, please refer to the WoodSolutions Technical Report*: Timber Portal Frames.*

2.6 Roof Inclination

All portal frames and trusses are designed to have a 5° degree roof pitch.

2.7 Importance Level

All structures are designed in Importance Level 2 under Table B1.2a of the BCA or Table F1 of AS 1170.0 *Structural design actions, General principles.*

2.8 Design Location

All portal frames and trusses designed in this Guide are assumed to be located in Auckland, New Zealand. However, the solutions are applicable to all other areas located within the same AS 1170.2 *Structural Design Actions Part 2: Wind Actions* region A6. None of the designs have been made considering seismic effects. However, if a lightweight steel cladding option is used for wall and roof, the sections provided should be valid for most locations affected by seismic activity.

2.9 Design Life

The design life for most buildings in Australia is 50 years. As a result, the design life of the portal frames and trusses in this Guide is also assumed to be 50 years.

2.10 Pre-Cambering

Pre-cambering is making a beam or rafter slightly curved/bowed upwards, so that under loads, usually gravity loads (also known as self-weight), the beam or rafter would settle into a position. In this way, the deflection of the member is eliminated or partially eliminated. For long span roofs and beams, it is common to pre-camber out the gravity deflection. In this Guide, all portal frames and trusses are assumed to have a pre-camber that is equal to the gravity deflection.

2.11 Connections

No attempt to provide working solutions for any of the connections for the portal frames or trusses has been made in this Guide. However, the magnitude of the forces and moments has been considered in order to ensure that usual portal frame moment connections (using the quick-connect moment connections or nailed gusset moment connections) are feasible or that timber rivet solutions could be used for the truss member connections. For portal frame moment connection solutions, please refer to the WoodSolutions Technical report: *Timber Portal Frames* and WoodSolutions Design Guide #33*: Quick-Connect Moment Connection.*

2.12 Loadings

Permanent, imposed and wind loads were considered in the design of portal frames and trusses. Auckland is a low earthquake activity city, and the designed structures are large span low-rise portal frames and trusses, which means the earthquake action (E) is small compared to the other lateral design action, wind (W). Therefore, earthquake action (E) is not the critical horizontal design action. Also, it is not likely to snow in Auckland. Other than permanent and live loads, wind loads are likely to be dominant in the design actions. Therefore, the permanent, imposed and wind loads are the three main design actions considered in this Guide, the earthquake and snow loads are less significant and it is safe to neglect them in the structural designs of this Guide. For detail considerations of loadings, refer to *AS 1170.0 Structural design actions, General principles*.

2.12.1 Permanent Loads (G)

The Permanent loads (G) are taken as 10 kg/m3 plus the self-weight of the frame or truss.

2.12.2 Imposed Loads (Q)

The imposed loads (Q) are taken as 0.25 kPa for all designs according to Table 3.2 in *AS 1170.1 Structural design actions, Permanent, imposed and other actions.*

2.12.3 Wind Loads (W)

For single-storey large span roof structures, wind actions are one of the dominant types of loads and are most likely to govern the design. Therefore, precise wind actions experienced by the structures in every direction must be carefully modelled and analysed. Wind loads are generally categorized in two directions, Wind Across the building and Wind Along the building.

For each of the Wind Across and Wind Along, direction of wind may result in upward lifting or downward pressing of the roof. As a result, there are an overall of four critical cases of wind actions to be designed for. They are:

- Wind Across – maximum uplift
- Wind Across – minimum uplift
- Wind Along – maximum uplift
- Wind Along – minimum uplift

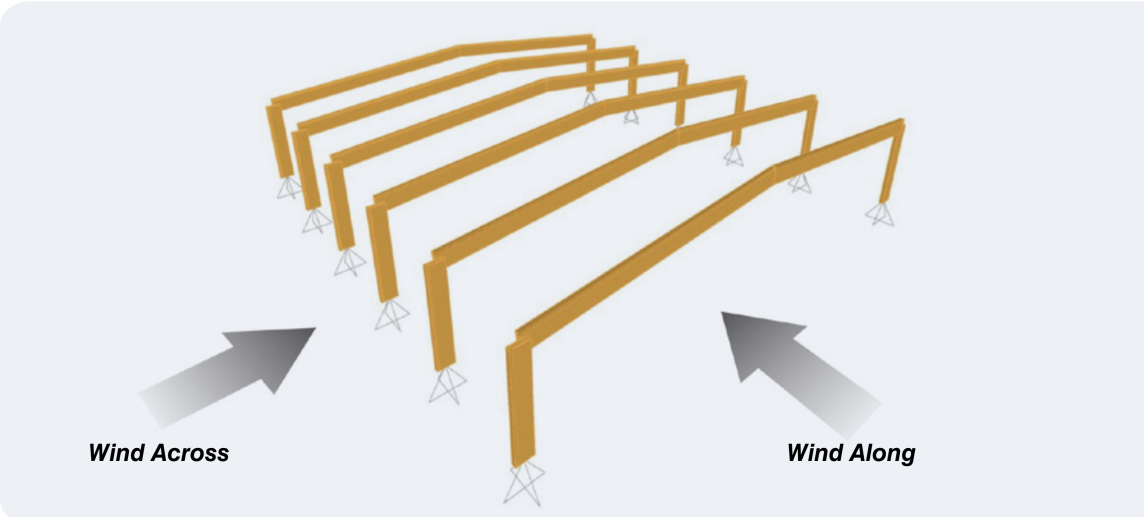

Figure 2.9: Portal frame under two wind directions.

Wind loads generally vary across and along the building, depending on the terrain category, size of the building, wind zone and some other factors.

This Guide provides solutions under Terrain Category 2 and Terrain Category 3.

Supporting materials are provided to help with determining wind loads (refer to Section 8). For a comprehensive wind action calculation, refer to Section W5 of *AS 1170.2 Structural Design Actions Part 2: Wind Actions*. Examples for calculating the wind loads are also provided in Section 7.

2.12.4 Load Combinations

The load combinations for ultimate limit state strength capacity included in the design are:

- [1.35G]
- [1.2G, 1.5Q]
- [0.9G, $W_{across,\ maximum\ uplift\ -\ ULS}$]
- [0.9G, $W_{along,\ maximum\ uplift\ -\ ULS}$]
- [1.2G, $W_{across,\ minimum\ uplift\ -\ ULS}$]
- [1.2G, $W_{along,\ minimum\ uplift\ -\ ULS}$]

The load combinations for serviceability limit states deflection checks included in the design are:

- [2G]
- [0.7Q]
- [$W_{across,\ maximum\ uplift\ -\ SLS}$]
- [$W_{along,\ maximum\ uplift\ -\ SLS}$]
- [$W_{across,\ minimum\ uplift\ -\ SLS}$]
- [$W_{along,\ minimum\ uplift\ -\ SLS}$]

It is noted to take away the pre-cambering effect when conducting serviceability deflection checks.

3

Portal Frame with Inner Prop Solutions

The following tables are optimised solutions for portal frames with inner prop under different loadings.

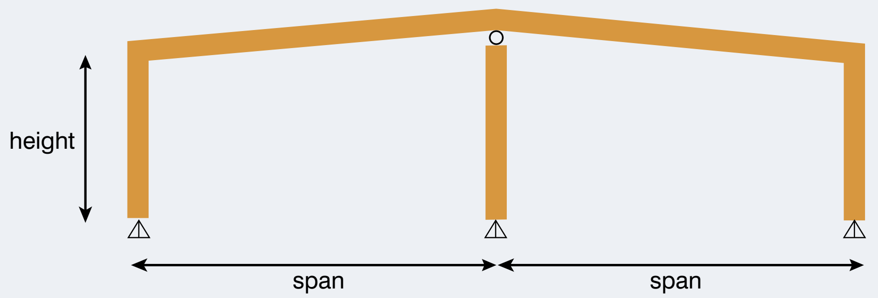

Figure 3.1: Portal frame with inner prop.

3.1 Gravity and Wind Terrain – Category 2

Column Height (m)	Box Beam	Portal Frame Span (m)							
		20		25		30		35	
		Frame	Mid-Column	Frame	Mid-Column	Frame	Mid-Column	Frame	Mid-Column
5	web size (d x t_w) flange size (b_f x t_f)	600 x 45 150 x 90	200 x 45 150 x 63	800 x 45 200 x 90	240 x 45 200 x 90	900 x 45 240 x 45	300 x 45 240 x 63	1000 x 45 300 x 90	300 x 45 300 x 90
	Volume of LVL (m^3)	4.31		6.91		9.16		12.21	
6	web size (d x t_w) flange size (b_f x t_f)	600 x 45 200 x 90	200 x 45 200 x 63	800 x 45 200 x 90	240 x 45 200 x 90	1000 x 45 240 x 90	300 x 45 240 x 90	1200 x 45 240 x 90	400 x 45 200 x 45
	Volume of LVL (m^3)	5.03		7.19		10.23		12.96	
7	web size (d x t_w) flange size (b_f x t_f)	600 x 45 200 x 90	200 x 45 200 x 63	800 x 45 240 x 90	240 x 45 240 x 90	1000 x 45 240 x 90	300 x 45 240 x 90	1000 x 45 400 x 90	400 x 45 400 x 45
	Volume of LVL (m^3)	5.25		7.99		10.44		14.38	

Column Height (m)	Box Beam	Portal Frame Span (m)					
		40		45		50	
		Frame	Mid-Column	Frame	Mid-Column	Frame	Mid-Column
5	web size (d x t_w) flange size (b_f x t_f)	1200 x 45 400 x 90	400 x 45 400 x 63	1200 x 45 600 x 90	400 x 45 600 x 63	1200 x 45 600 x 126	400 x 45 600 x 63
	Volume of LVL (m^3)	16.99		22.67		29.66	
6	web size (d x t_w) flange size (b_f x t_f)	1200 x 45 400 x 90	400 x 45 400 x 63	1200 x 45 600 x 90	400 x 45 600 x 63	1200 x 45 600 x 126	400 x 45 600 x 90
	Volume of LVL (m^3)	17.44		23.22		30.62	
7	web size (d x t_w) flange size (b_f x t_f)	1200 x 45 400 x 90	400 x 45 400 x 63	1200 x 45 600 x 90	400 x 45 600 x 63	1200 x 45 600 x 126	400 x 45 600 x 90
	Volume of LVL (m^3)	17.88		23.76		31.29	

Table 3.1: 45 mm web thicknesses.

Column Height (m)	Box Beam	Portal Frame Span (m)							
		20		25		30		35	
		Frame	Mid-Column	Frame	Mid-Column	Frame	Mid-Column	Frame	Mid-Column
5	web size (d x t_w) flange size (b_f x t_f)	600 x 63 150 x 90	200 x 63 150 x 63	600 x 63 240 x 90	200 x 63 240 x 90	800 x 63 240 x 90	300 x 63 240 x 45	900 x 63 300 x 90	300 x 63 300 x 90
	Volume of LVL (m^3)	5.44		7.64		10.57		14.18	
6	web size (d x t_w) flange size (b_f x t_f)	600 x 63 150 x 90	200 x 63 150 x 63	800 x 45 150 x 90	240 x 63 150 x 90	900 x 63 200 x 90	300 x 63 200 x 63	1000 x 63 300 x 90	400 x 63 300 x 45
	Volume of LVL (m^3)	5.69		8.42		11.33		15.51	
7	web size (d x t_w) flange size (b_f x t_f)	600 x 63 150 x 90	200 x 63 150 x 63	800 x 63 200 x 90	240 x 63 200 x 90	800 x 63 300 x 90	300 x 45 300 x 90	900 x 63 400 x 90	300 x 63 400 x 90
	Volume of LVL (m^3)	5.94		9.39		12.11		16.73	

Column Height (m)	Box Beam	Portal Frame Span (m)					
		40		45		50	
		Frame	Mid-Column	Frame	Mid-Column	Frame	Mid-Column
5	web size (d x t_w) flange size (b_f x t_f)	1000 x 63 400 x 90	400 x 63 400 x 45	1000 x 63 600 x 90	400 x 63 600 x 45	1200 x 63 600 x 90	400 x 63 600 x 63
	Volume of LVL (m^3)	18.61		24.41		29.79	
6	web size (d x t_w) flange size (b_f x t_f)	1200 x 63 300 x 90	400 x 63 300 x 63	1000 x 63 600 x 90	400 x 63 600 x 63	1200 x 63 600 x 90	400 x 63 600 x 63
	Volume of LVL (m^3)	19.78		25.20		30.44	
7	web size (d x t_w) flange size (b_f x t_f)	900 x 63 600 x 90	400 x 63 600 x 45	1200 x 63 600 x 90	400 x 63 600 x 63	1200 x 63 600 x 126	400 x 63 600 x 90
	Volume of LVL (m^3)	21.98		28.42		36.39	

Table 3.2: 63 mm web thicknesses.

3.2 Gravity and Wind Terrain – Category 3

Column Height (m)	Box Beam	Portal Frame Span (m)							
		20		25		30		35	
		Frame	Mid-Column	Frame	Mid-Column	Frame	Mid-Column	Frame	Mid-Column
5	web size (d x t_w) flange size (b_f x t_f)	600 x 45 150 x 90	200 x 45 150 x 45	600 x 45 240 x 90	200 x 45 240 x 90	800 x 45 200 x 90	300 x 45 200 x 90	1000 x 45 240 x 90	300 x 45 240 x 90
	Volume of LVL (m^3)	4.27		6.29		8.07		11.26	
6	web size (d x t_w) flange size (b_f x t_f)	600 x 45 150 x 90	200 x 45 150 x 63	600 x 45 240 x 90	200 x 45 240 x 90	800 x 45 240 x 90	300 x 45 240 x 90	1000 x 45 240 x 90	300 x 45 240 x 90
	Volume of LVL (m^3)	4.51		6.55		8.93		11.59	
7	web size (d x t_w) flange size (b_f x t_f)	600 x 45 150 x 90	200 x 45 150 x 63	600 x 45 240 x 90	200 x 45 240 x 90	800 x 45 240 x 90	300 x 45 240 x 90	1000 x 45 240 x 90	400 x 45 240 x 45
	Volume of LVL (m^3)	4.71		6.80		9.23		11.80	

Column Height (m)	Box Beam	Portal Frame Span (m)					
		40		45		50	
		Frame	Mid-Column	Frame	Mid-Column	Frame	Mid-Column
5	web size (d x t_w) flange size (b_f x t_f)	1200 x 45 240 x 90	400 x 45 240 x 63	1200 x 45 400 x 90	400 x 45 400 x 63	1200 x 45 600 x 90	400 x 45 600 x 63
	Volume of LVL (m^3)	14.22		18.83		24.89	
6	web size (d x t_w) flange size (b_f x t_f)	1200 x 45 240 x 90	400 x 45 240 x 63	1200 x 45 400 x 90	400 x 45 400 x 63	1200 x 45 600 x 90	400 x 45 600 x 63
	Volume of LVL (m^3)	14.59		19.28		25.43	
7	web size (d x t_w) flange size (b_f x t_f)	1200 x 45 240 x 90	400 x 45 240 x 63	1200 x 45 400 x 90	400 x 45 400 x 63	1200 x 45 600 x 90	400 x 45 600 x 63
	Volume of LVL (m^3)	14.95		19.73		25.98	

Table 3.3: 45 mm web thicknesses.

Column Height (m)	Box Beam	Portal Frame Span (m)							
		20		25		30		35	
		Frame	Mid-Column	Frame	Mid-Column	Frame	Mid-Column	Frame	Mid-Column
5	web size (d x t_w) flange size (b_f x t_f)	400 x 63 240 x 90	200 x 63 240 x 45	600 x 63 200 x 90	200 x 63 200 x 90	800 x 63 200 x 90	300 x 63 200 x 45	800 x 63 300 x 90	300 x 63 300 x 63
	Volume of LVL (m^3)	5.01		7.16		10.03		13.03	
6	web size (d x t_w) flange size (b_f x t_f)	600 x 63 150 x 90	200 x 63 150 x 45	600 x 63 200 x 90	200 x 63 200 x 90	800 x 63 200 x 90	300 x 63 200 x 45	800 x 63 300 x 90	300 x 63 300 x 63
	Volume of LVL (m^3)	5.65		7.44		10.36		13.42	
7	web size (d x t_w) flange size (b_f x t_f)	600 x 63 150 x 90	200 x 63 150 x 45	600 x 63 200 x 90	200 x 63 200 x 90	800 x 63 200 x 90	300 x 63 200 x 45	800 x 63 300 x 90	300 x 63 300 x 90
	Volume of LVL (m^3)	5.89		7.73		10.69		13.97	

Column Height (m)	Box Beam	Portal Frame Span (m)					
		40		45		50	
		Frame	Mid-Column	Frame	Mid-Column	Frame	Mid-Column
5	web size (d x t_w) flange size (b_f x t_f)	1000 x 63 300 x 90	400 x 63 300 x 45	1200 x 63 300 x 90	400 x 63 300 x 63	1000 x 63 600 x 90	400 x 63 600 x 45
	Volume of LVL (m^3)	16.91		21.38		26.81	
6	web size (d x t_w) flange size (b_f x t_f)	1000 x 63 300 x 90	400 x 63 300 x 45	1200 x 63 300 x 90	400 x 63 300 x 90	1000 x 63 600 x 90	400 x 63 600 x 45
	Volume of LVL (m^3)	17.35		22.04		27.38	
7	web size (d x t_w) flange size (b_f x t_f)	1000 x 63 300 x 90	400 x 63 300 x 45	1200 x 63 300 x 90	400 x 63 300 x 90	1000 x 63 600 x 90	400 x 63 600 x 45
	Volume of LVL (m^3)	17.79		22.55		27.95	

Table 3.4: 63 mm web thicknesses.

4

Double-Pitch Portal Frame Solutions

The following tables are optimised solutions for double-pitch portal frames under different loadings.

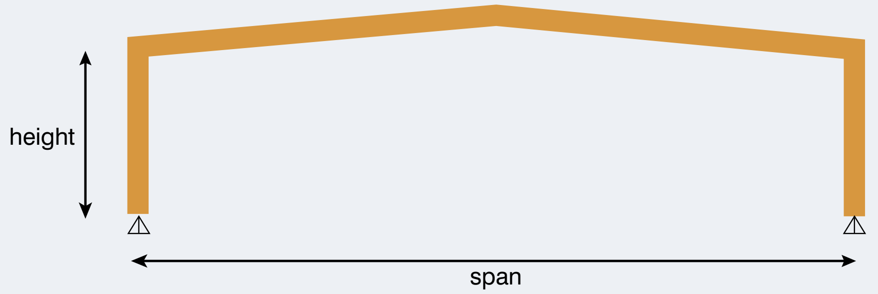

Figure 4.1: Double-pitch portal frame.

4.1 Gravity and Wind Terrain – Category 2

Column Height (m)	Box Beam	Portal Frame Span (m)						
		15	20	25	30	35	40	45
5	web size (d x t_w) flange size (b_f x t_f)	600 x 45 150 x 90	600 x 45 150 x 90	600 x 45 200 x 90	800 x 45 200 x 90	900 x 45 240 x 90	1000 x 45 300 x 90	1200 x 45 300 x 90
	Volume of LVL (m^3)	2.03	2.44	3.16	4.33	5.61	7.22	8.94
6	web size (d x t_w) flange size (b_f x t_f)	600 x 45 150 x 90	600 x 45 200 x 90	600 x 45 240 x 90	800 x 45 200 x 90	900 x 45 240 x 90	1000 x 45 300 x 90	1200 x 45 300 x 90
	Volume of LVL (m^3)	2.19	2.89	3.61	4.55	5.85	7.51	9.26
7	web size (d x t_w) flange size (b_f x t_f)	800 x 45 150 x 90	800 x 45 150 x 90	800 x 45 200 x 90	800 x 45 240 x 90	1000 x 45 240 x 90	1200 x 45 240 x 90	1200 x 45 400 x 90
	Volume of LVL (m^3)	2.88	3.37	4.22	5.08	6.54	8.19	10.65

Table 4.1: 45 mm web thicknesses.

Column Height (m)	Box Beam	Portal Frame Span (m)						
		15	20	25	30	35	40	45
5	web size (d x t_w) flange size (b_f x t_f)	400 x 63 240 x 90	600 x 63 150 x 90	600 x 63 150 x 90	800 x 63 150 x 90	800 x 63 240 x 90	900 x 63 300 x 90	1200 x 63 240 x 90
	Volume of LVL (m^3)	2.35	3.09	3.60	5.13	6.50	8.40	10.73
6	web size (d x t_w) flange size (b_f x t_f)	600 x 63 150 x 90	600 x 63 150 x 90	600 x 63 200 x 90	800 x 63 150 x 90	900 x 63 200 x 90	900 x 63 300 x 90	1200 x 63 240 x 90
	Volume of LVL (m^3)	2.78	3.29	4.14	5.38	7.05	8.73	11.11
7	web size (d x t_w) flange size (b_f x t_f)	800 x 63 150 x 90	800 x 63 150 x 90	800 x 63 150 x 90	800 x 63 200 x 90	800 x 63 300 x 90	1000 x 63 300 x 90	1000 x 63 400 x 90
	Volume of LVL (m^3)	3.71	4.35	5.00	6.03	7.61	9.75	11.72

Table 4.2: 63 mm web thicknesses.

4.2 Gravity and Wind Terrain – Category 3

Column Height (m)	Box Beam	Portal Frame Span (m)						
		15	20	25	30	35	40	45
5	web size (d x t_w) flange size (b_f x t_f)	400 x 45 200 x 90	600 x 45 150 x 90	600 x 45 150 x 90	800 x 45 150 x 90	800 x 45 240 x 90	1000 x 45 240 x 90	1200 x 45 240 x 90
	Volume of LVL (m^3)	1.80	2.44	2.84	3.97	5.20	6.68	8.34
6	web size (d x t_w) flange size (b_f x t_f)	600 x 45 150 x 90	600 x 45 150 x 90	600 x 45 150 x 90	800 x 45 150 x 90	800 x 45 240 x 90	1000 x 45 240 x 90	1200 x 45 240 x 90
	Volume of LVL (m^3)	2.19	2.60	3.00	4.17	5.43	6.95	8.64
7	web size (d x t_w) flange size (b_f x t_f)	600 x 45 240 x 90	800 x 45 150 x 90	800 x 45 150 x 90	800 x 45 150 x 90	800 x 45 240 x 90	1000 x 45 240 x 90	1200 x 45 240 x 90
	Volume of LVL (m^3)	2.82	3.37	3.87	4.37	5.66	7.21	8.95

Table 4.3: 45 mm web thicknesses.

Column Height (m)	Box Beam	Portal Frame Span (m)						
		15	20	25	30	35	40	45
5	web size (d x t_w) flange size (b_f x t_f)	400 x 63 150 x 90	400 x 63 240 x 90	600 x 63 150 x 90	800 x 63 240 x 90	800 x 63 200 x 90	800 x 63 300 x 90	1000 x 63 300 x 90
	Volume of LVL (m^3)	1.94	2.82	3.60	4.77	6.17	7.76	9.93
6	web size (d x t_w) flange size (b_f x t_f)	600 x 63 150 x 90	600 x 63 150 x 90	600 x 63 150 x 90	800 x 63 150 x 90	800 x 63 200 x 90	800 x 63 300 x 90	1000 x 63 300 x 90
	Volume of LVL (m^3)	2.78	3.29	3.81	5.38	6.45	8.07	10.29
7	web size (d x t_w) flange size (b_f x t_f)	600 x 63 200 x 90	600 x 63 240 x 90	800 x 63 150 x 90	800 x 63 150 x 90	800 x 63 200 x 90	900 x 63 240 x 90	1000 x 63 300 x 90
	Volume of LVL (m^3)	3.24	4.05	5.00	5.64	6.72	8.48	10.65

Table 4.4: 63 mm web thicknesses.

Note:

1. The volume of LVL shown is the volume required for constructing one whole double-pitch portal frame, which includes the rafters and two columns, see diagram on the upper corner for clarification.

2. The unit for web size and flange size are millimetres (mm).

Truss Solutions

The optimised solutions for each truss span under different loadings are presented in this Section.

5.1 Gravity and Wind Terrain – Category 2

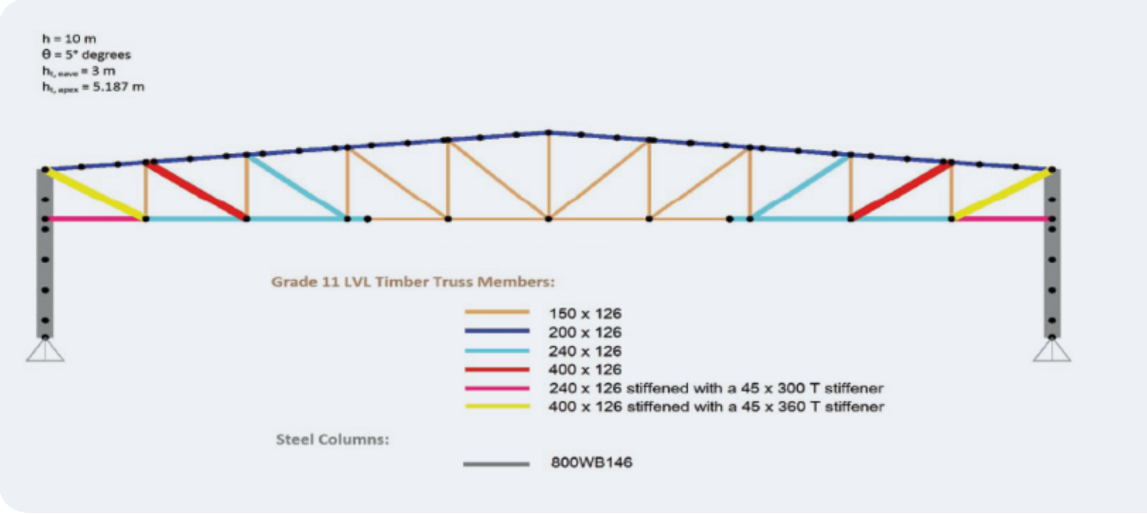

Figure 5.1: 50 m span.

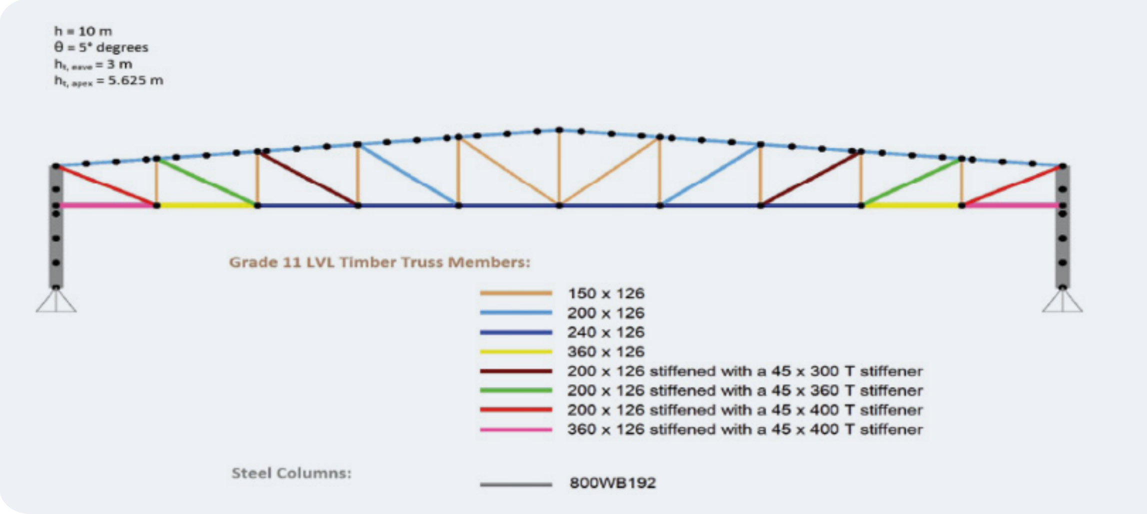

Figure 5.2: 60 m span.

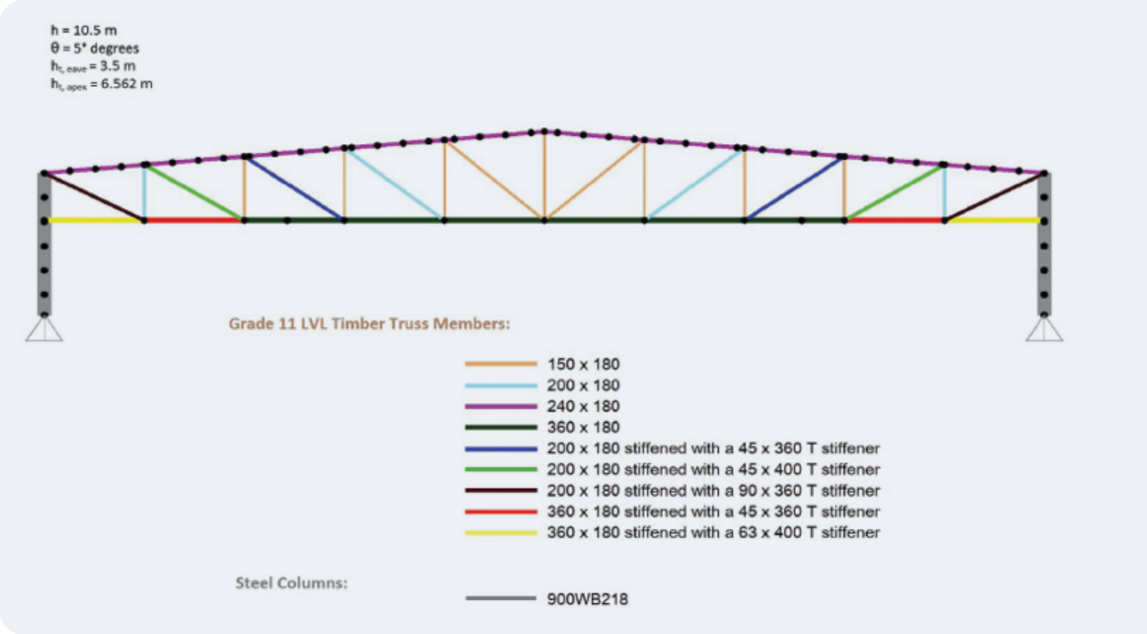

Figure 5.3: 70 m span

5.2 Gravity and Wind Terrain – Category 3

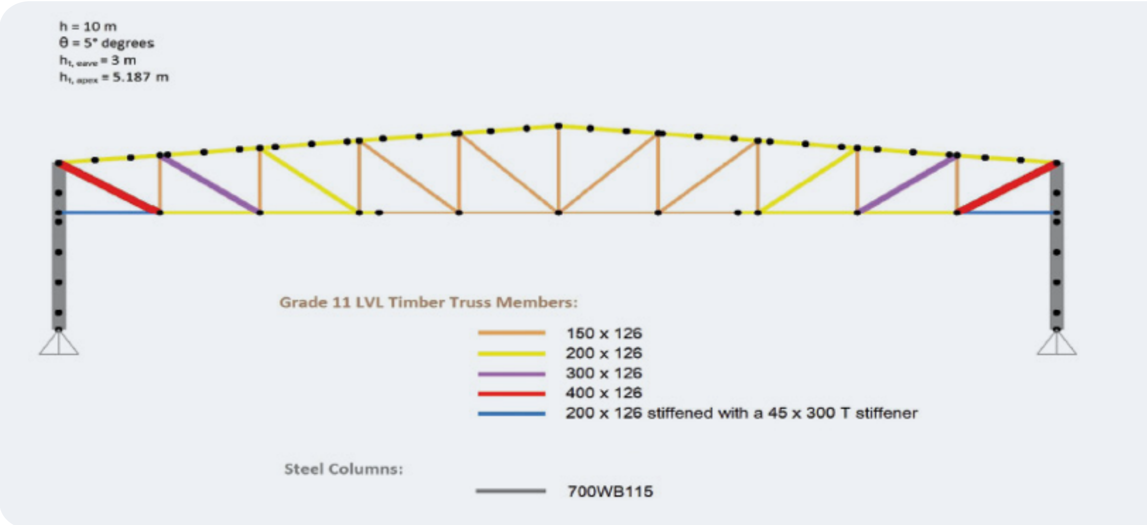

Figure 5.4: 50 m span.

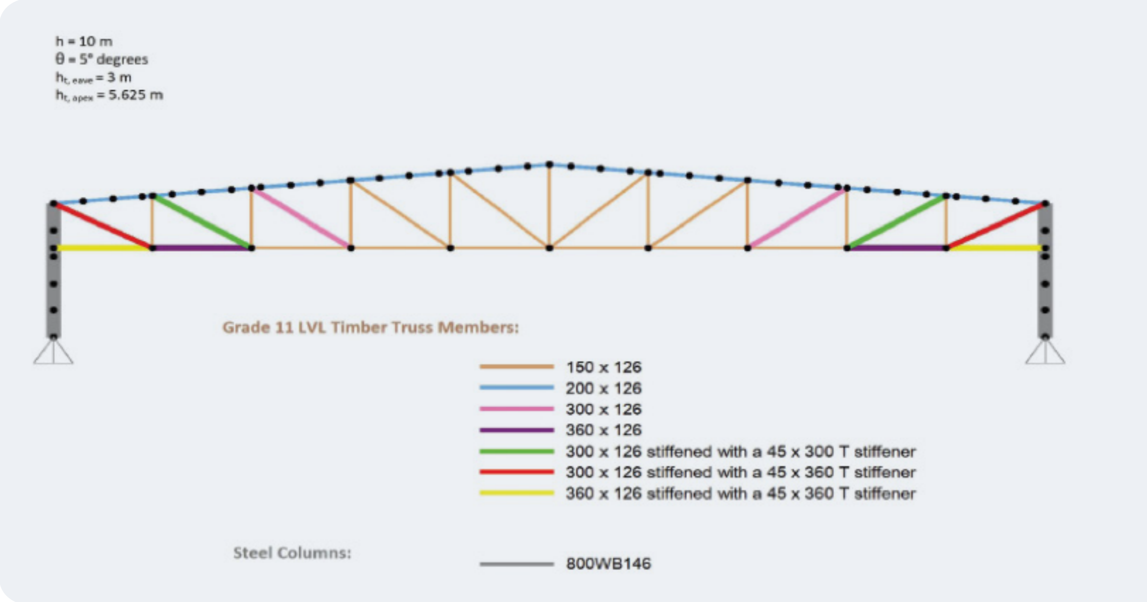

Figure 5.5: 60 m span.

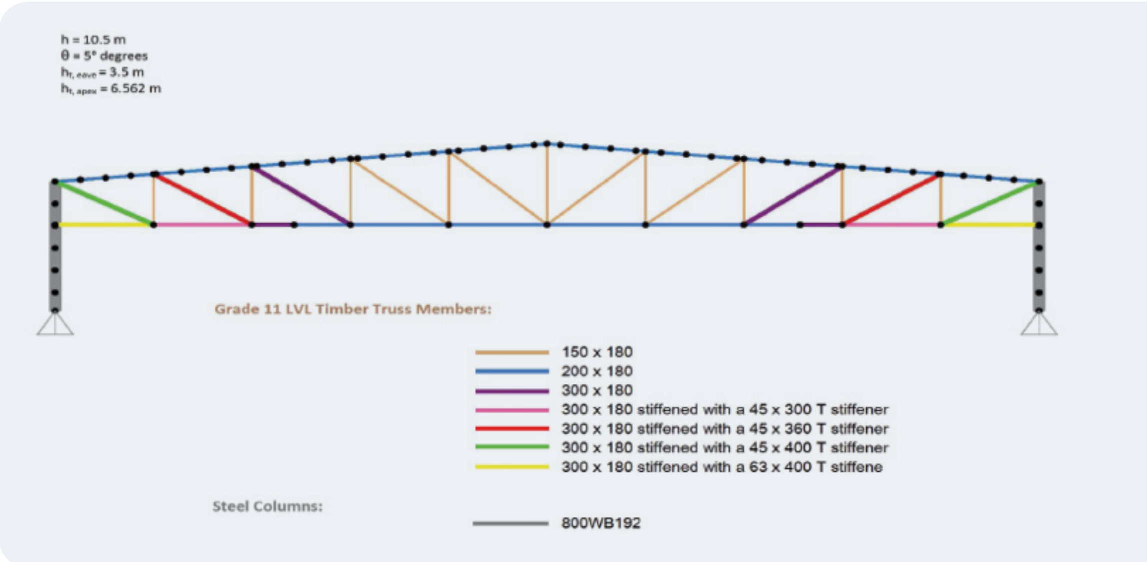

Figure 5.6: 70 m span.

6 Summary of Trends and Findings

6.1 Portal Frames

6.1.1 Double-Pitch Portal Frame

Governing factor

For small spans (15 m, 20 m) of portal frame design, the lateral deflection at the column top governs the design. Final solutions provided for the portal frames have a column top deflection at around 38 mm to 40 mm, where the lateral deflection limit is 40 mm. Cross sections that satisfy the deflection limits exceed the bending and axial load capacity requirements by a large margin, especially for portal frames with the greater clear heights.

For medium spans (25 m, 30 m, and 35 m), the gravity plus wind minimum uplift loading condition is most critical and governs the design, closely followed by the gravity plus live loading condition. Lateral deflection at the top of the column is no longer critical as larger sections are now being used (depth greater than 900 mm), and the box section that is able to resist the required loading is always sufficiently by stiff to resist the lateral deflection.

When the spans are increased to 40 metres and 45 metres, the rafters are now very long and become quite heavy. The mid-span gravity deflection becomes the most critical and governs the design.

Slenderness and load carrying capacity

In 15 and 20 m spans, where the loads are relatively small and the lateral deflection from wind is critical, very slender box sections such as 600 x 63 by 20 x 90, 800 x 63, 20 x 90, 900 x 45 and 20 x 90 are able to provide sufficient strength capacities. But when the spans get larger (30 m, 35 m, 40 m and 45 m), very slender sections must be avoided, since the loads are now getting quite large and very slender sections are not able to provide sufficient load carrying capacities. It is not unusual that some less slender box sections, even with a smaller total cross sectional area, would have a larger load carrying capacity than a cross section that has a larger cross sectional area but more slender.

Effectiveness of increasing dimensions

The following observations can be made. One can conclude that the greater the depth of the box section, the smaller the deflections. Another conclusion possible is that the wider the box section, the greater the load carrying capacity. However, increasing the width of a box section helps relatively little in reducing the deflection. Increasing the depth of a box section also helps to increase the load carrying capacity, but increasing the width is more effective at increasing load carrying capacity as the lateral stability governs the moment resistance in most cases.

Compression in rafters and columns

One can note that for smaller spans (15 m to 35 m), the compression force in the columns is greater than in the rafters. But in larger spans (40 m and 45 m), the compression force in the rafter is greater than in the columns. This is because in smaller spans, the compression force due to the gravity downward/supporting effect in the columns is greater than the mid span pressing effect in the rafter minus the relieving effect caused by the upward pointing 5° degrees roof pitch. But in larger spans, due to the huge mid span downward forces in the rafter, the pressing effect minus the relieving effect caused by the upward pointing 5° degrees roof pitch in the rafter is now greater than the gravity downward/supporting effect in the columns. Therefore, the compression force in the rafter is now greater than the compression force in the columns. Suggestions to reduce the deflection and compression force in the rafter would be to use a steeper roof pitch or increase the pre-camber in the rafter.

Critical loads

Comparing the critical loads that govern the designs between the different Wind Terrain Categories: in Terrain Category 2, wind load governs the design for spans from 15 metres to 25 metres. In Terrain Category 3, wind load governs the design for spans from 15 metres to 20 metres and also in the 7 metres clear height designs.

In all others spans, gravity load governs the design. This indicates that gravity load governs most designs in long span timber portal frame design, especially for spans greater than 20 metres. When designing long span LVL portal frames the gravity loads should be calculated precisely and never be underestimated.

Comparison between 45 mm and 63 mm web thicknesses

Results from the solution tables show that for the same span and height, box sections with 45 mm web thicknesses use less volume of LVL than the 63 mm web thicknesses box sections. This indicates that the 45 mm web thickness box sections are more efficient than the 63 millimetres web thicknesses box sections.

Cross sectional area

This Guide uses web thicknesses of 45 mm or 63 mm and flange thicknesses of 90 mm as the starting thicknesses in design.

The flange thickness is increased if needed. Since the web thicknesses are always thinner than the flange thicknesses, increasing the depth of the box section will result in a smaller increase in cross sectional area than increasing the width of the box section. Therefore, when it is necessary to increase the box section size, try increasing the depth first, before increasing the width. Some 1200 mm depth sections have a smaller total area than a 1000 mm depth section. One should not be surprised when seeing a solution of a larger span or greater height that has a smaller depth. Use the cross sectional area supporting table to compare and use the smallest section that can provide the required ultimate and serviceability capacity.

6.1.2 Internal Propped Portal Frame and Comparison

Mid-span deflection

Since there is an inner column at the centre of the roof, the deflection at the apex joint does not occur. For internal propped portal frames, the vertical deflections are measured at mid span of each of the rafters.

Compression force in the columns

It is found that the compression force in the inner column is greater than the side columns. This is because the inner column supports a greater contributory area than the side columns.

Trends

The trends found from the internal propped portal frame results are similar to the double-pitch portal frame results, except for the following differences.

Comparison of individual spans

Comparing internal propped and double-pitch solutions for the same clear span, internal propped solutions require larger size of sections than double-pitch solutions. This is because the rafter of the internal propped portal frames are straight within each span, and do not have the upward pointing that double-pitch portal frames have at mid span to reduce the force and the deflection.

Comparison of total structure spans

Comparing results of two times the internal propped spans with the double-pitch span, the internal propped solutions use smaller cross sections and smaller volumes of LVL. This indicates that for the same total span, internal propped portal frame is more efficient than double-pitch portal frame. If architecturally allowed, internal propped portal frames are a more efficient option to be used.

6.2 Trusses

6.2.1 Thicknesses

For the 50 metre and 60 metre span trusses, 135 mm thick solid sections of LVL are sufficient to provide the required strengths and deformation performances. However, the 135 mm thick solid sections are not able to provide sufficient strength for the 70 m trusses, even with the use of T stiffeners. As a result, all 70 metres trusses use 180 mm thick solid sections. It is assumed that the LVL solid sections are fabricated from layers of 45 mm thick LVL sections. However, in the design of T stiffeners both 45 mm and 63 mm thicknesses are used.

6.2.2 Effect of T Stiffener on Compression and Tension Capacities

T stiffeners are useful for increasing the compression capacity of the truss members only and do not contribute to resisting tension forces. When both compression and tension forces have exceeded the capacity of a member, the compression force may be overcome by the addition of a T stiffener, but the tension force is still exceeding the capacity. This can only be resolved by increasing the size of the section.

6.2.3 Top Chord

The top chords are governed by tension forces caused by the upward wind forces. It is assumed that the top chords are laterally restrained by the purlins. As a result, the compression capacity will always be sufficient to take the compression loads. But the tension capacity is independent to the lateral restraints. Therefore, the top chords are governed by tension.

6.2.4 Bottom Chord

The outer sections of the bottom chords carry the largest compression forces, especially when the wind is blowing downwards. This is because they transfer all the forces from the truss to the columns. For the same reason, the outer sections of the bottom chord also carry the largest tension forces when the wind is blowing upwards. Since all truss members can have different depths but they must have the same thicknesses for efficiency of load transfer at the connections, the outer sections of the bottom chord are always the critical member for deciding the thickness of the whole truss.

7

Section 7
Example A: Wind Load Calculation

This is a spreadsheet example for Wind Load Calculations. The *n* values are provided in Section 8 - Supporting Materials for Portal Frames.

$n = 0.5 \times \rho_{air} \times V_{des,\theta}^{2} \times C_{dyn} \times 10^{3}$

Pressure $= n \times C_{fig}$ (kPa)

For this double-pitch portal frame example, the *n* value is taken from Section 8.2. The *n* values provided in this Guide are for wind loads of Terrain Category 1. In order to convert the wind loads to Terrain Category 2 or Terrain Category 3, one will need to multiply the pressures by the ratio table provided in Section 8.

Building Element	Distance from windward edge (m)			C_{pe}	K_a $K_{c,e}$ K_l K_p	$C_{fig,e}$	C_{pi}	$K_{c,i}$	$C_{fig,i}$	$0.5\,\rho_{air} V_{des,\theta}^{2} C_{dyn} \times 10^{-3}$	P (kPa)	UDL at 8 m spacings
Windward wall	-	to	-	0.7	0.8	0.56	0.7	0.8	0.56	1.449	0.00	0.00
Leeward wall	-	to	-	-0.5	0.8	-0.4	0.7	0.8	0.56	1.449	-1.39	-11.13
Sidewalls	0.000	to	7.984	-0.65	0.8	-0.52	0.7	0.8	0.56	1.449	-1.56	-12.52
Sidewalls	7.984	to	15.968	-0.5	0.8	-0.4	0.7	0.8	0.56	1.449	-1.39	-11.13
Sidewalls	15.968	to	23.952	-0.3	0.8	-0.24	0.7	0.8	0.56	1.449	-1.16	-9.27
Sidewalls	23.952	to	onwards ~	-0.2	0.8	-0.16	0.7	0.8	0.56	1.449	-1.04	-8.35
Roof	0.000	to	3.992	-0.9	0.8	-0.72	0.7	0.8	0.56	1.449	-1.85	-14.84
Roof	3.992	to	7.984	-0.9	0.8	-0.72	0.7	0.8	0.56	1.449	-1.85	-14.84
Roof	7.984	to	15.968	-0.5	0.8	-0.4	0.7	0.8	0.56	1.449	-1.39	-11.13
Roof	15.968	to	23.952	-0.3	0.8	-0.24	0.7	0.8	0.56	1.449	-1.16	-9.27
Roof	23.952	to	onwards ~	-0.2	0.8	-0.16	0.7	0.8	0.56	1.449	-1.04	-8.35

Table 7.1: Wind across (maximum uplift). ***roof angle = 5° h = 7.984 m L = 45 m***

Building Element	Distance from windward edge (m)			C_{pe}	K_a $K_{c,e}$ K_l K_p	$C_{fig,e}$	C_{pi}	$K_{c,i}$	$C_{fig,i}$	$0.5\,\rho_{air} V_{des,\theta}^{2} C_{dyn} \times 10^{-3}$	P (kPa)	UDL at 8 m spacings
Windward wall	-	to	-	0.7	0.8	0.56	-0.65	0.8	-0.52	1.449	1.56	12.52
Leeward wall	-	to	-	-0.2	0.8	-0.16	-0.65	0.8	-0.52	1.449	0.52	4.17
Sidewalls	0.000	to	7.984	-0.65	0.8	-0.52	-0.65	0.8	-0.52	1.449	0.00	0.00
Sidewalls	7.984	to	15.968	-0.5	0.8	-0.4	-0.65	0.8	-0.52	1.449	0.17	1.39
Sidewalls	15.968	to	23.952	-0.3	0.8	-0.24	-0.65	0.8	-0.52	1.449	0.41	3.25
Sidewalls	23.952	to	onwards ~	-0.2	0.8	-0.16	-0.65	0.8	-0.52	1.449	0.52	4.17
Roof	0.000	to	3.992	-0.4	0.8	-0.32	-0.65	0.8	-0.52	1.449	0.29	2.32
Roof	3.992	to	7.984	-0.4	0.8	-0.32	-0.65	0.8	-0.52	1.449	0.29	2.32
Roof	7.984	to	15.968	0	0.8	0	-0.65	0.8	-0.52	1.449	0.75	6.03
Roof	15.968	to	23.952	0.1	0.8	0.08	-0.65	0.8	-0.52	1.449	0.87	6.96
Roof	23.952	to	onwards ~	0.2	0.8	0.16	-0.65	0.8	-0.52	1.449	0.99	7.88

Table 7.2: Wind across (minimum uplift). ***roof angle = 5° h = 7.984 m L = 45 m***

8

Supporting Materials – Portal Frames

Please see Example A in Section 7 for how to use the n values provided in this section.

8.1 Internal Propped Portal Frame Wind Pressures and Ratios

TC1		10 m			15 m			20 m		
		z	$M_{z,cat}$	*n*	*z*	$M_{z,cat}$	*n*	*z*	$M_{z,cat}$	*n*
Height (m)	5	5.437	1.056	1.416	5.656	1.059	1.424	5.875	1.062	1.432
	6	6.437	1.070	1.454	6.656	1.073	1.462	6.875	1.076	1.47
	7	7.437	1.084	1.492	7.656	1.087	1.5	7.875	1.090	1.508

TC1		25 m			30 m			35 m		
		z	$M_{z,cat}$	*n*	*z*	$M_{z,cat}$	*n*	*z*	$M_{z,cat}$	*n*
Height (m)	5	6.094	1.065	1.44	6.312	1.068	1.448	6.531	1.071	1.456
	6	7.094	1.079	1.478	7.312	1.082	1.486	7.531	1.085	1.495
	7	8.094	1.093	1.517	8.312	1.096	1.525	8.531	1.099	1.533

TC1		40 m			45 m			50 m		
		z	$M_{z,cat}$	*n*	*z*	$M_{z,cat}$	*n*	*z*	$M_{z,cat}$	*n*
Height (m)	5	6.750	1.074	1.464	6.968	1.078	1.475	7.187	1.081	1.484
	6	7.750	1.088	1.503	7.968	1.092	1.514	8.187	1.095	1.522
	7	8.750	1.102	1.542	8.968	1.106	1.553	9.187	1.109	1.561

Table 8.1: Internal propped portal frame – Wind Terrain Category 1 pressures.

Note:

$n = 0.5 \times \rho_{air} \times V_{des,\theta}^{2} \times C_{dyn} \times 10^{3}$

Pressure $= n \times C_{fig}$ (kPa)

For Importance Level 3 structures in Region A6 only.

TC2		10 m			15 m			20 m		
		z	$M_{z,cat}$	*n*	*z*	$M_{z,cat}$	*n*	*z*	$M_{z,cat}$	*n*
Height (m)	5	5.437	0.918	1.07	5.656	0.922	1.079	5.875	0.926	1.089
	6	6.437	0.936	1.112	6.656	0.940	1.122	6.875	0.944	1.131
	7	7.437	0.954	1.155	7.656	0.958	1.165	7.875	0.962	1.175

TC2		25 m			30 m			35 m		
		z	$M_{z,cat}$	*n*	*z*	$M_{z,cat}$	*n*	*z*	$M_{z,cat}$	*n*
Height (m)	5	6.094	0.930	1.098	6.312	0.934	1.108	6.531	0.938	1.117
	6	7.094	0.948	1.141	7.312	0.952	1.151	7.531	0.956	1.16
	7	8.094	0.966	1.185	8.312	0.970	1.195	8.531	0.974	1.204

TC2		40 m			45 m			50 m		
		z	$M_{z,cat}$	*n*	*z*	$M_{z,cat}$	*n*	*z*	$M_{z,cat}$	*n*
Height (m)	5	6.750	0.941	1.124	6.968	0.945	1.134	7.187	0.949	1.143
	6	7.750	0.959	1.168	7.968	0.963	1.177	8.187	0.967	1.187
	7	8.750	0.977	1.212	8.968	0.981	1.222	9.187	0.985	1.232

Table 8.2: Internal propped portal frame – Wind Terrain Category 2 pressures.

Note:

$n = 0.5 \times \rho_{air} \times V_{des,\theta}^{2} \times C_{dyn} \times 10^{3}$

Pressure $= n \times C_{fig}$ (kPa)

For Importance Level 3 structures in Region A6 only.

TC3		10 m			15 m			20 m		
		z	$M_{z,cat}$	*n*	*z*	$M_{z,cat}$	*n*	*z*	$M_{z,cat}$	*n*
Height (m)	5	5.437	0.830	0.875	5.656	0.830	0.875	5.875	0.830	0.875
	6	6.437	0.830	0.875	6.656	0.830	0.875	6.875	0.830	0.875
	7	7.437	0.830	0.875	7.656	0.830	0.875	7.875	0.830	0.875

TC3		25 m			30 m			35 m		
		z	$M_{z,cat}$	*n*	*z*	$M_{z,cat}$	*n*	*z*	$M_{z,cat}$	*n*
Height (m)	5	6.094	0.830	0.875	6.312	0.830	0.875	6.531	0.830	0.875
	6	7.094	0.830	0.875	7.312	0.830	0.875	7.531	0.830	0.875
	7	8.094	0.830	0.875	8.312	0.830	0.875	8.531	0.830	0.875

TC3		40 m			45 m			50 m		
		z	$M_{z,cat}$	*n*	*z*	$M_{z,cat}$	*n*	*z*	$M_{z,cat}$	*n*
Height (m)	5	6.750	0.830	0.875	6.968	0.830	0.875	7.187	0.830	0.875
	6	7.750	0.830	0.875	7.968	0.830	0.875	8.187	0.830	0.875
	7	8.750	0.830	0.875	8.968	0.830	0.875	9.187	0.830	0.875

Table 8.3: Internal propped portal frame – Wind Terrain Category 3 pressures

Note:

$n = 0.5 \times \rho_{air} \times V_{des,\theta}^2 \times C_{dyn} \times 10^3$

Pressure $= n \times C_{fig}$ (kPa)

For Importance Level 3 structures in Region A6 only.

TC2/TC1 ratio		10 m		15 m		20 m		25 m		30 m	
		z	ratio	*z*	ratio	*z*	ratio	*z*	ratio	*z*	ratio
Height (m)	5	5.437	0.756	5.656	0.758	5.875	0.760	6.094	0.763	6.312	0.765
	6	6.437	0.765	6.656	0.767	6.875	0.769	7.094	0.772	7.312	0.775
	7	7.437	0.774	7.656	0.777	7.875	0.779	8.094	0.781	8.312	0.784

TC2/TC1 ratio		35 m		40 m		45 m		50 m	
		z	ratio	*z*	ratio	*z*	ratio	*z*	ratio
Height (m)	5	6.531	0.767	6.750	0.768	6.968	0.769	7.187	0.770
	6	7.531	0.776	7.750	0.777	7.968	0.777	8.187	0.780
	7	8.531	0.785	8.750	0.786	8.968	0.787	9.187	0.789

Table 8.4: Internal propped portal frame wind pressures –
ratio between Terrain Category 2 & Terrain Category 1.

TC3/TC1 ratio		10 m		15 m		20 m		25 m		30 m	
		z	ratio	*z*	ratio	*z*	ratio	*z*	ratio	*z*	ratio
Height (m)	5	5.437	0.618	5.656	0.614	5.875	0.611	6.094	0.608	6.312	0.604
	6	6.437	0.602	6.656	0.598	6.875	0.595	7.094	0.592	7.312	0.589
	7	7.437	0.586	7.656	0.583	7.875	0.580	8.094	0.577	8.312	0.574

TC3/TC1 ratio		35 m		40 m		45 m		50 m	
		z	ratio	*z*	ratio	*z*	ratio	*z*	ratio
Height (m)	5	6.531	0.601	6.750	0.598	6.968	0.593	7.187	0.590
	6	7.531	0.585	7.750	0.582	7.968	0.578	8.187	0.575
	7	8.531	0.571	8.750	0.567	8.968	0.563	9.187	0.561

Table 8.5: Internal propped portal frame wind pressures –
ratio between Terrain Category 3 & Terrain Category 1.

8.2 Double-Pitch Portal Frame Wind Pressures and Ratios

TC1		15 m			20 m			25 m			30 m		
		z	$M_{z,cat}$	n	z	$M_{z,cat}$	n	z	$M_{z,cat}$	n	z	$M_{z,cat}$	n
Height (m)	5	5.328	1.055	1.413	5.437	1.056	1.416	5.547	1.058	1.421	5.656	1.059	1.424
	6	6.328	1.069	1.451	6.437	1.070	1.454	6.547	1.072	1.459	6.656	1.073	1.462
	7	7.328	1.083	1.489	7.437	1.084	1.492	7.547	1.086	1.497	7.656	1.087	1.5

TC1		35 m			40 m			45 m		
		z	$M_{z,cat}$	n	z	$M_{z,cat}$	n	z	$M_{z,cat}$	n
Height (m)	5	5.766	1.061	1.429	5.875	1.062	1.432	5.984	1.064	1.437
	6	6.766	1.075	1.467	6.875	1.076	1.47	6.984	1.078	1.475
	7	7.766	1.089	1.506	7.875	1.090	1.508	7.984	1.092	1.514

Table 8.6: Double-pitch portal frame – Wind Terrain Category 1 pressures.

Note:

$n = 0.5 \times \rho_{air} \times V_{des,\theta}^2 \times C_{dyn} \times 10^3$

Pressure $= n \times C_{fig}$ (kPa)

For Importance Level 3 structures in Region A6 only.

TC2		15 m			20 m			25 m			30 m		
		z	$M_{z,cat}$	n	z	$M_{z,cat}$	n	z	$M_{z,cat}$	n	z	$M_{z,cat}$	n
Height (m)	5	5.328	0.916	1.065	5.437	0.918	1.07	5.547	0.920	1.075	5.656	0.922	1.079
	6	6.328	0.934	1.108	6.437	0.936	1.112	6.547	0.938	1.117	6.656	0.940	1.122
	7	7.328	0.952	1.151	7.437	0.954	1.155	7.547	0.956	1.16	7.656	0.958	1.165

TC2		35 m			40 m			45 m		
		z	$M_{z,cat}$	n	z	$M_{z,cat}$	n	z	$M_{z,cat}$	n
Height (m)	5	5.766	0.924	1.084	5.875	0.926	1.089	5.984	0.928	1.093
	6	6.766	0.942	1.127	6.875	0.944	1.131	6.984	0.946	1.136
	7	7.766	0.960	1.17	7.875	0.962	1.175	7.984	0.964	1.180

Table 8.7: Double-pitch portal frame – Wind Terrain Category 2 pressures.

Note:

$n = 0.5 \times \rho_{air} \times V_{des,\theta}^2 \times C_{dyn} \times 10^3$

Pressure $= n \times C_{fig}$ (kPa)

For Importance Level 3 structures in Region A6 only.

TC3		15 m			20 m			25 m			30 m		
		z	$M_{z,cat}$	n	z	$M_{z,cat}$	n	z	$M_{z,cat}$	n	z	$M_{z,cat}$	n
Height (m)	5	5.328	0.830	0.875	5.437	0.830	0.875	5.547	0.830	0.875	5.656	0.830	0.875
	6	6.328	0.830	0.875	6.437	0.830	0.875	6.547	0.830	0.875	6.656	0.830	0.875
	7	7.328	0.830	0.875	7.437	0.830	0.875	7.547	0.830	0.875	7.656	0.830	0.875

TC3		35 m			40 m			45 m		
		z	$M_{z,cat}$	n	z	$M_{z,cat}$	n	z	$M_{z,cat}$	n
Height (m)	5	5.766	0.830	0.875	5.875	0.830	0.875	5.984	0.830	0.875
	6	6.766	0.830	0.875	6.875	0.830	0.875	6.984	0.830	0.875
	7	7.766	0.830	0.875	7.875	0.830	0.875	7.984	0.830	0.875

Table 8.8: Double-pitch portal frame – Wind Terrain Category 3 pressures.

Note:

$n = 0.5 \times \rho_{air} \times V_{des,\theta}^2 \times C_{dyn} \times 10^3$

Pressure $= n \times C_{fig}$ (kPa)

For Importance Level 3 structures in Region A6 only.

TC2/TC1 ratio		15 m		20 m		25 m		30 m		35 m		40 m		45 m	
		z	ratio	z	ratio	z	ratio	z	ratio	z	ratio	z	ratio	z	ratio
Height (m)	5	5.328	0.754	5.437	0.756	5.547	0.757	5.656	0.758	5.766	0.759	5.875	0.760	5.984	0.761
	6	6.328	0.764	6.437	0.765	6.547	0.766	6.656	0.767	6.766	0.768	6.875	0.769	6.984	0.770
	7	7.328	0.773	7.437	0.774	7.547	0.775	7.656	0.777	7.766	0.777	7.875	0.779	7.984	0.779

Table 8.9: Double-pitch portal frame wind pressures – ratio between Terrain Category 2 & Terrain Category 1.

TC3/TC1 ratio		15 m		20 m		25 m		30 m		35 m		40 m		45 m	
		z	ratio	z	ratio	z	ratio	z	ratio	z	ratio	z	ratio	z	ratio
Height (m)	5	5.328	0.619	5.437	0.618	5.547	0.616	5.656	0.614	5.766	0.612	5.875	0.611	5.984	0.609
	6	6.328	0.603	6.437	0.602	6.547	0.600	6.656	0.598	6.766	0.596	6.875	0.595	6.984	0.593
	7	7.328	0.588	7.437	0.586	7.547	0.585	7.656	0.583	7.766	0.581	7.875	0.580	7.984	0.578

Table 8.10: Double-pitch portal frame wind pressures – ratio between Terrain Category 3 & Terrain Category 1.

8.3 Flange Width Selection to Minimise Wastage

In order to minimise wastage of LVL in a project, the design flange width (b_f) of the box sections considered in this Guide are ones that can be equally cut from a 1200 mm LVL billet. Therefore, the flange width (b_f) of a box section can be selected from the following two tables:

Starting size (mm)	Cut into No. of pieces	Flange width, b_f (mm)
1200	1	**1200**
1200	2	**600**
1200	3	**400**
1200	4	**300**
1200	5	**240**
1200	6	**200**
1200	8	**150**

Table 8.11: Optimised flange widths.

b_f (mm)	Total width = b_f + 2 x web thicknesses t_w (mm)	
	t_w = 45 mm	t_w = 63 mm
150	240	276
200	290	326
240	330	366
300	390	426
400	490	526
600	690	726

Table 8.12: Total widths.

8.4 Box Section

d (mm)	t_w (mm)	b_f (mm)	t_f (mm)	A (m^2)	I (m^4)	d (mm)	t_w (mm)	b_f (mm)	t_f (mm)	A (m^2)	I (m^4)	d (mm)	t_w (mm)	b_f (mm)	t_f (mm)	A (m^2)	I (m^4)
400	45	150	90	0.0630	0.0011	600	45	150	90	0.810	0.00339	800	45	150	90	0.0990	0.0073
400	45	200	90	0.0720	0.0014	600	45	200	90	0.0900	0.00399	800	45	200	90	0.1080	0.0084
400	45	240	90	0.0792	0.0015	600	45	240	90	0.0972	0.00446	800	45	240	90	0.1152	0.0093
400	45	300	90	0.0900	0.0018	600	45	300	90	0.1080	0.00517	800	45	300	90	0.1260	0.0107
400	45	400	90	0.1080	0.0023	600	45	400	90	0.1260	0.00635	800	45	400	90	0.1440	0.0130
400	45	600	90	0.1440	0.0031	600	45	600	90	0.1620	0.00872	800	45	600	90	0.1800	0.0175

d (mm)	t_w (mm)	b_f (mm)	t_f (mm)	A (m^2)	I (m^4)	d (mm)	t_w (mm)	b_f (mm)	t_f (mm)	A (m^2)	I (m^4)	d (mm)	t_w (mm)	b_f (mm)	t_f (mm)	A (m^2)	I (m^4)
900	45	150	90	0.1080	0.00991	1000	45	150	90	0.1170	0.0131	1200	45	150	90	0.1350	0.02129
900	45	200	90	0.1170	0.01140	1000	45	200	90	0.1260	0.0150	1200	45	200	90	0.1440	0.02407
900	45	240	90	0.1242	0.01258	1000	45	240	90	0.1332	0.0165	1200	45	240	90	0.1512	0.02630
900	45	300	90	0.1350	0.01436	1000	45	300	90	0.1440	0.0187	1200	45	300	90	0.1620	0.02963
900	45	400	90	0.1530	0.01733	1000	45	400	90	0.1620	0.0225	1200	45	400	90	0.1800	0.03519
900	45	600	90	0.1890	0.02326	1000	45	600	90	0.1980	0.0299	1200	45	600	90	0.2160	0.04630

d (mm)	t_w (mm)	b_f (mm)	t_f (mm)	A (m^2)	I (m^4)	d (mm)	t_w (mm)	b_f (mm)	t_f (mm)	A (m^2)	I (m^4)	d (mm)	t_w (mm)	b_f (mm)	t_f (mm)	A (m^2)	I (m^4)
1200	45	150	126	0.1458	0.02391	1200	45	150	180	0.1620	0.02715	1200	45	150	270	0.1890	0.03097
1200	45	200	126	0.1584	0.02756	1200	45	200	180	0.1800	0.03188	1200	45	200	270	0.2160	0.03697
1200	45	240	126	0.1685	0.03048	1200	45	240	180	0.1944	0.03567	1200	45	240	270	0.2376	0.04177
1200	45	300	126	0.1836	0.03486	1200	45	300	180	0.2160	0.04134	1200	45	300	270	0.2700	0.04897
1200	45	400	126	0.2088	0.04216	1200	45	400	180	0.2520	0.05080	1200	45	400	270	0.3240	0.06098
1200	45	600	126	0.2592	0.05676	1200	45	600	180	0.3240	0.06972	1200	45	600	270	0.4320	0.08499

Table 8.13 Cross-Sectional Area and Moment of Inertia- t_w = 45 mm

d (mm)	t_w (mm)	b_f (mm)	t_f (mm)	A (m^2)	I (m^4)	d (mm)	t_w (mm)	b_f (mm)	t_f (mm)	A (m^2)	I (m^4)	d (mm)	t_w (mm)	b_f (mm)	t_f (mm)	A (m^2)	I (m^4)
400	63	150	90	0.0774	0.0013	600	63	150	90	0.1620	0.02715	800	63	150	90	0.1890	0.03097
400	63	200	90	0.0864	0.0016	600	63	200	90	0.1800	0.03188	800	63	200	90	0.2160	0.03697
400	63	240	90	0.0936	0.0017	600	63	240	90	0.1944	0.03567	800	63	240	90	0.2376	0.04177
400	63	300	90	0.1044	0.0020	600	63	300	90	0.2160	0.04134	800	63	300	90	0.2700	0.04897
400	63	400	90	0.1224	0.0025	600	63	400	90	0.2520	0.05080	800	63	400	90	0.3240	0.06098
400	63	600	90	0.1584	0.0033	600	63	600	90	0.3240	0.06972	800	63	600	90	0.4320	0.08499

d (mm)	t_w (mm)	b_f (mm)	t_f (mm)	A (m^2)	I (m^4)	d (mm)	t_w (mm)	b_f (mm)	t_f (mm)	A (m^2)	I (m^4)	d (mm)	t_w (mm)	b_f (mm)	t_f (mm)	A (m^2)	I (m^4)
900	63	150	90	0.1404	0.01210	1000	63	150	90	0.1530	0.0161	1200	63	150	90	0.1782	0.02648
900	63	200	90	0.1494	0.01358	1000	63	200	90	0.1620	0.0180	1200	63	200	90	0.1872	0.02926
900	63	240	90	0.1566	0.01477	1000	63	240	90	0.1692	0.0195	1200	63	240	90	0.1944	0.03148
900	63	300	90	0.1674	0.01655	1000	63	300	90	0.1800	0.0217	1200	63	300	90	0.2052	0.03481
900	63	400	90	0.1854	0.01951	1000	63	400	90	0.1980	0.0255	1200	63	400	90	0.2232	0.04037
900	63	600	90	0.2214	0.02544	1000	63	600	90	0.2340	0.0329	1200	63	600	90	0.2592	0.05148

d (mm)	t_w (mm)	b_f (mm)	t_f (mm)	A (m^2)	I (m^4)	d (mm)	t_w (mm)	b_f (mm)	t_f (mm)	A (m^2)	I (m^4)	d (mm)	t_w (mm)	b_f (mm)	t_f (mm)	A (m^2)	I (m^4)
1200	63	150	126	0.1890	0.02909	1200	63	150	180	0.2052	0.03234	1200	63	150	270	0.2322	0.03615
1200	63	200	126	0.2016	0.03274	1200	63	200	180	0.2232	0.03707	1200	63	200	270	0.2592	0.04215
1200	63	240	126	0.2117	0.03566	1200	63	240	180	0.2376	0.04085	1200	63	240	270	0.2808	0.04695
1200	63	300	126	0.2268	0.04004	1200	63	300	180	0.2592	0.04653	1200	63	300	270	0.3132	0.05416
1200	63	400	126	0.2520	0.04734	1200	63	400	180	0.2952	0.05599	1200	63	400	270	0.3672	0.06616
1200	63	600	126	0.3024	0.06195	1200	63	600	180	0.3672	0.07491	1200	63	600	270	0.4752	0.09017

Table 8.14: Cross-Sectional Area and Moment of Inertia- t_w = 63 mm.

9 Example B: Truss Design Example

This is an example of the final solution of a 60 metre span truss under Gravity and Wind Terrain Category 1 loadings.

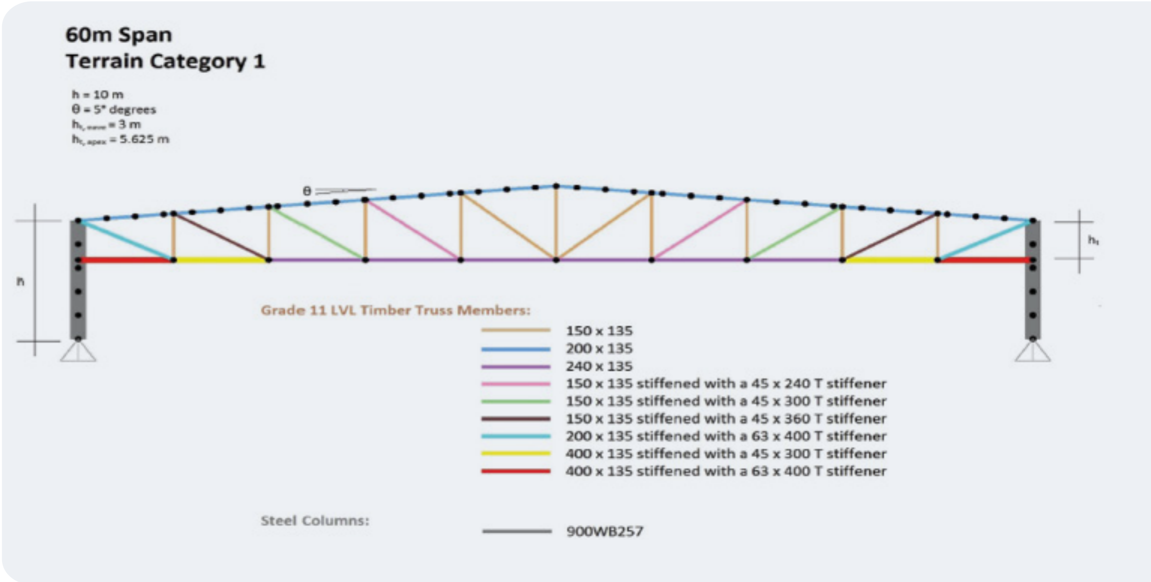

Figure 9.1: 60 m span – Terrain Category 1.

9.1 Deflection Check

Vertical deflections at mid-span									
ΔG	=	98.43	mm	<	$L/360$	=	166.67	mm	OK
ΔQ	=	31.26	mm	<	$L/240$	=	250.00	mm	OK
$\Delta W_{across\ max.}$	=	165.91	mm	<	$L/150$	=	400.00	mm	OK
$\Delta W_{along\ max.}$	=	246.27	mm	<	$L/150$	=	400.00	mm	OK
Horizontal deflection at column tip									
$\Delta W_{along\ max.}$	=	17.14	mm	<	spacing/200	=	40.00	mm	OK

Table 9.1: Deflection check.

9.2 Member Design

9.2.2 Column

Try 900 WB 257

$M^*_{1.2G+Walong\ min}$	=	2091.17	kNm	<	ΦM_{sx}	=	3074.40	kNm	OK
$N^*_{1.2G+Walong\ min}$	=	370.85	kN	<	ΦN_{ncy}	=	1765.85	kN	OK
$(M^*/\Phi M_{nx})^2+(N_c^*/\Phi N_{ncy})$	=	0.67		<	1				OK
$M^*_{0.9G+Walong\ max}$	=	2281.91	kNm	<	ΦM_{sx}	=	3074.40	kNm	OK
$N^*_{t\ 0.9G+Walong\ max}$	=	382.70	kN	<	ΦN_{nt}	=	8240.40	kN	OK
$N^*_{t\ 0.9G+Walong\ max}$	=	382.70	kN	<	0.05 x ΦN_{nt}	=	412.02	kN	No Combined action check required

Table 9.2: Column.

9.2.2 Top Chord

Try 200 x 135 Grade 11 LVL

Compression									
$N^*_{1.35G}$	=	295.14	kN	<	ΦN_{ncy}	=	612.14	kN	OK
$N^*_{1.2G+1.5Q}$	=	411.48	kN	<	ΦN_{ncy}	=	816.19	kN	OK
$N^*_{1.2G+W\ across\ min.}$	=	520.43	kN	<	ΦN_{ncy}	=	1020.24	kN	OK
$N^*_{1.2G+W\ along\ min.}$	=	567.47	kN	<	ΦN_{ncy}	=	1020.24	kN	OK
Tension									
$N^*_{0.9G+W\ across\ max.}$	=	400.24	kN	<	ΦN_t	=	729.00	kN	OK
$N^*_{0.9G+W\ along\ max.}$	=	682.61	kN	<	ΦN_t	=	729.00	kN	OK

Table 9.3: Top chord.

9.2.3 Bottom Chord

Try 400 x 135 Grade 11 LVL (with T stiffener 63 x 400)

Compression									
$N^*_{1.35G}$	=	558.19	kN	<	ΦN_{ncy}	=	771.28	kN	OK
$N^*_{1.2G+1.5Q}$	=	775.13	kN	<	ΦN_{ncy}	=	1028.37	kN	OK
$N^*_{1.2G+W\ across\ min.}$	=	997.65	kN	<	ΦN_{ncy}	=	1285.46	kN	OK
$N^*_{1.2G+W\ along\ min.}$	=	1053.76	kN	<	ΦN_{ncy}	=	1285.46	kN	OK
Tension									
$N^*_{0.9G+W\ across\ max.}$	=	776.03	kN	<	ΦN_t	=	1239.30	kN	OK
$N^*_{0.9G+W\ along\ max.}$	=	1205.71	kN	<	ΦN_t	=	1239.30	kN	OK

Table 9.4: Outer sections 1 of bottom chord.

Try 400 x 135 Grade 11 LVL (with T stiffener 45 x 300)

Compression									
$N^*_{1.35G}$	=	216.18	kN	<	ΦN_{ncy}	=	248.80	kN	OK
$N^*_{1.2G+1.5Q}$	=	301.48	kN	<	ΦN_{ncy}	=	331.73	kN	OK
$N^*_{1.2G+W\text{ across min.}}$	=	382.63	kN	<	ΦN_{ncy}	=	414.66	kN	OK
$N^*_{1.2G+W\text{ along min.}}$	=	414.65	kN	<	ΦN_{ncy}	=	414.66	kN	OK
Tension									
$N^*_{0.9G+W\text{ across max.}}$	=	283.72	kN	<	ΦN_t	=	1239.30	kN	OK
$N^*_{0.9G+W\text{ along max.}}$	=	497.35	kN	<	ΦN_t	=	1239.30	kN	OK

Table 9.5: Outer sections 2 of bottom chord.

Try 400 x 135 Grade 11 LVL (with T stiffener 45 x 300)

Compression									
$N^*_{1.35G}$	=	28.11	kN	<	ΦN_{ncy}	=	101.33	kN	OK
$N^*_{1.2G+1.5Q}$	=	39.64	kN	<	ΦN_{ncy}	=	135.11	kN	OK
$N^*_{1.2G+W\text{ across min.}}$	=	77.95	kN	<	ΦN_{ncy}	=	168.88	kN	OK
$N^*_{1.2G+W\text{ along min.}}$	=	61.06	kN	<	ΦN_{ncy}	=	168.88	kN	OK
Tension									
$N^*_{0.9G+W\text{ across max.}}$	=	78.74	kN	<	ΦN_t	=	729.00	kN	OK
$N^*_{0.9G+W\text{ along max.}}$	=	102.75	kN	<	ΦN_t	=	729.00	kN	OK

Table 9.6: Outer sections 3 of bottom chord.

Try 240 x 135 Grade 11 LVL

Compression									
$N^*_{0.9G+W\text{ across max.}}$	=	116.02	kN	<	ΦN_{ncy}	=	202.66	kN	OK
$N^*_{0.9G+W\text{ along max.}}$	=	181.84	kN	<	ΦN_{ncy}	=	202.66	kN	OK
Tension									
$N^*_{1.35G}$	=	106.70	kN	<	ΦN_t	=	482.89	kN	OK
$N^*_{1.2G+1.5Q}$	=	149.67	kN	<	ΦN_t	=	643.85	kN	OK
$N^*_{1.2G+W\text{ across min.}}$	=	183.21	kN	<	ΦN_t	=	804.82	kN	OK
$N^*_{1.2G+W\text{ along min.}}$	=	193.90	kN	<	ΦN_t	=	804.82	kN	OK

Table 9.7: Inner sections of bottom chord.

9.2.4 Diagonal Lacings

Try 200 x 135 Grade 11 LVL (with T stiffener 63 x 400)

Compression								
$N^*_{0.9G+W\text{ across max.}}$	=	572.64	kN	<	ΦN_{ncy}	=	865.48	kN	OK
$N^*_{0.9G+W\text{ along max.}}$	=	792.32	kN	<	ΦN_{ncy}	=	865.48	kN	OK
Tension								
$N^*_{1.35G}$	=	382.90	kN	<	ΦN_t	=	437.40	kN	OK
$N^*_{1.2G+1.5Q}$	=	530.01	kN	<	ΦN_t	=	583.20	kN	OK
$N^*_{1.2G+W\text{ across min.}}$	=	688.08	kN	<	ΦN_t	=	729.00	kN	OK
$N^*_{1.2G+W\text{ along min.}}$	=	715.01	kN	<	ΦN_t	=	729.00	kN	OK

Table 9.8: First diagonal lacings.

Try 150 x 135 Grade 11 LVL (with T stiffener 45 x 360)

Compression									
$N^*_{0.9G+W\text{ across max.}}$	=	284.26	kN	<	ΦN_{ncy}	=	488.78	kN	OK
$N^*_{0.9G+W\text{ along max.}}$	=	458.03	kN	<	ΦN_{ncy}	=	488.78	kN	OK
Tension									
$N^*_{1.35G}$	=	218.56	kN	<	ΦN_t	=	328.05	kN	OK
$N^*_{1.2G+1.5Q}$	=	304.08	kN	<	ΦN_t	=	437.40	kN	OK
$N^*_{1.2G+W\text{ across min.}}$	=	389.90	kN	<	ΦN_t	=	546.75	kN	OK
$N^*_{1.2G+W\text{ along min.}}$	=	410.48	kN	<	ΦN_t	=	546.75	kN	OK

Table 9.9: Second diagonal lacings.

Try 150 x 135 Grade 11 LVL (with T stiffener 45 x 300)

Compression									
$N^*_{0.9G+W\text{ across max.}}$	=	131.51	kN	<	ΦN_{ncy}	=	279.39	kN	OK
$N^*_{0.9G+W\text{ along max.}}$	=	251.69	kN	<	ΦN_{ncy}	=	279.39	kN	OK
Tension									
$N^*_{1.35G}$	=	118.74	kN	<	ΦN_t	=	328.05	kN	OK
$N^*_{1.2G+1.5Q}$	=	166.26	kN	<	ΦN_t	=	437.40	kN	OK
$N^*_{1.2G+W\text{ across min.}}$	=	207.99	kN	<	ΦN_t	=	546.75	kN	OK
$N^*_{1.2G+W\text{ along min.}}$	=	224.34	kN	<	ΦN_t	=	546.75	kN	OK

Table 9.10: Third diagonal lacings.

Try 150 x 135 Grade 11 LVL (with T stiffener 45 x 240)

Compression								
$N^*_{0.9G+W \text{ across max.}}$	=	63.30	kN	<	ΦN_{ncy}	=	147.28	kN	OK
$N^*_{0.9G+W \text{ along max.}}$	=	96.18	kN	<	ΦN_{ncy}	=	147.28	kN	OK
Tension									
$N^*_{1.35G}$	=	46.71	kN	<	ΦN_t	=	328.05	kN	OK
$N^*_{1.2G+1.5Q}$	=	65.62	kN	<	ΦN_t	=	437.40	kN	OK
$N^*_{1.2G+W \text{ across min.}}$	=	90.67	kN	<	ΦN_t	=	546.75	kN	OK
$N^*_{1.2G+W \text{ along min.}}$	=	87.64	kN	<	ΦN_t	=	546.75	kN	OK

Table 9.11: Fourth diagonal lacings.

Try 150 x 135 Grade 11 LVL

Compression									
$N^*_{1.35G}$	=	15.91	kN	<	ΦN_{ncy}	=	42.65	kN	OK
$N^*_{1.2G+1.5Q}$	=	22.19	kN	<	ΦN_{ncy}	=	56.87	kN	OK
$N^*_{1.2G+W \text{ across min.}}$	=	40.20	kN	<	ΦN_{ncy}	=	71.09	kN	OK
$N^*_{1.2G+W \text{ along min.}}$	=	31.88	kN	<	ΦN_{ncy}	=	71.09	kN	OK
Tension									
$N^*_{0.9G+W \text{ across max.}}$	=	45.36	kN	<	ΦN_t	=	546.75	kN	OK
$N^*_{0.9G+W \text{ along max.}}$	=	42.11	kN	<	ΦN_t	=	546.75	kN	OK

Table 9.12: Fifth diagonal lacings.

9.2.5 Vertical Lacings

Try 150 x 135 Grade 11 LVL

Compression									
$N^*_{1.35G}$	=	162.71	kN	<	ΦN_{ncy}	=	212.14	kN	OK
$N^*_{1.2G+1.5Q}$	=	229.03	kN	<	ΦN_{ncy}	=	282.85	kN	OK
$N^*_{1.2G+W \text{ across min.}}$	=	299.42	kN	<	ΦN_{ncy}	=	353.57	kN	OK
$N^*_{1.2G+W \text{ along min.}}$	=	311.37	kN	<	ΦN_{ncy}	=	353.57	kN	OK
Tension									
$N^*_{0.9G+W \text{ across max.}}$	=	260.58	kN	<	ΦN_t	=	546.75	kN	OK
$N^*_{0.9G+W \text{ along max.}}$	=	357.83	kN	<	ΦN_t	=	546.75	kN	OK

Table 9.13: First vertical lacings.

Try 150 x 135 Grade 11 LVL

Compression								
$N^*_{1.35G}$	=	105.58	kN	<	ΦN_{ncy}	=	162.38	kN	OK
$N^*_{1.2G+1.5Q}$	=	149.77	kN	<	ΦN_{ncy}	=	216.51	kN	OK
$N^*_{1.2G+W\text{ across min.}}$	=	193.77	kN	<	ΦN_{ncy}	=	270.64	kN	OK
$N^*_{1.2G+W\text{ along min.}}$	=	203.96	kN	<	ΦN_{ncy}	=	270.64	kN	OK
Tension									
$N^*_{0.9G+W\text{ across max.}}$	=	148.53	kN	<	ΦN_t	=	546.75	kN	OK
$N^*_{0.9G+W\text{ along max.}}$	=	237.15	kN	<	ΦN_t	=	546.75	kN	OK

Table 9.14: Second vertical lacings.

Try 150 x 135 Grade 11 LVL

Compression									
$N^*_{1.35G}$	=	62.23	kN	<	ΦN_{ncy}	=	131.77	kN	OK
$N^*_{1.2G+1.5Q}$	=	89.22	kN	<	ΦN_{ncy}	=	175.69	kN	OK
$N^*_{1.2G+W\text{ across min.}}$	=	112.22	kN	<	ΦN_{ncy}	=	219.61	kN	OK
$N^*_{1.2G+W\text{ along min.}}$	=	121.64	kN	<	ΦN_{ncy}	=	219.61	kN	OK
Tension									
$N^*_{0.9G+W\text{ across max.}}$	=	80.13	kN	<	ΦN_t	=	546.75	kN	OK
$N^*_{0.9G+W\text{ along max.}}$	=	143.33	kN	<	ΦN_t	=	546.75	kN	OK

Table 9.15: Third vertical lacings.

Try 150 x 135 Grade 11 LVL

Compression									
$N^*_{1.35G}$	=	24.32	kN	<	ΦN_{ncy}	=	106.62	kN	OK
$N^*_{1.2G+1.5Q}$	=	36.26	kN	<	ΦN_{ncy}	=	142.16	kN	OK
$N^*_{1.2G+W\text{ across min.}}$	=	51.46	kN	<	ΦN_{ncy}	=	177.69	kN	OK
$N^*_{1.2G+W\text{ along min.}}$	=	49.64	kN	<	ΦN_{ncy}	=	177.69	kN	OK
Tension									
$N^*_{0.9G+W\text{ across max.}}$	=	40.23	kN	<	ΦN_t	=	546.75	kN	OK
$N^*_{0.9G+W\text{ along max.}}$	=	61.27	kN	<	ΦN_t	=	546.75	kN	OK

Table 9.16: Fourth vertical lacings.

Try 150 x 135 Grade 11 LVL

Compression									
$N^*_{0.9G+W\ \mathrm{across\ max.}}$	=	30.20	kN	<	ΦN_{ncy}	=	144.89	kN	OK
$N^*_{0.9G+W\ \mathrm{along\ max.}}$	=	51.69	kN	<	ΦN_{ncy}	=	144.89	kN	OK
Tension									
$N^*_{1.35G}$	=	25.04	kN	<	ΦN_t	=	328.05	kN	OK
$N^*_{1.2G+1.5Q}$	=	32.70	kN	<	ΦN_t	=	437.40	kN	OK
$N^*_{1.2G+W\ \mathrm{across\ min.}}$	=	40.80	kN	<	ΦN_t	=	546.75	kN	OK
$N^*_{1.2G+W\ \mathrm{along\ min.}}$	=	45.28	kN	<	ΦN_t	=	546.75	kN	OK

Table 9.17: Fifth vertical lacings.

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A

Appendix A – Notation

The symbols and letters used in the Guide are listed below:

A	cross-sectional area
b_f	width of box-beam
C_{dyn}	dynamic response factor, as given in Section 6 of AS 1170.2
C_{fig}	aerodynamic shape factor, as given in Section 5 of AS 1170.2
d	depth of member
E	modulus of elasticity of member
h	column height
$h_{t,eave}$	eave height
$h_{t,apex}$	apex height
I	cross-sectional area
L	span of the structure
M^*	design action moment
M_n	design moment capacity
N^*	design compression force
n	n value used in the calculation of wind pressure
P	design wind pressure in Pascals
t_f	flange thickness
t_w	web thickness
V	nominal shear strength
$V_{des,\theta}$	building orthogonal design wind speeds given in Clause 2.3 AS 1170.2
θ	roof pitch of the building
Φ	capacity factor
ρ_{air}	density of air, which shall be taken as 1.2 kg/m^3