BUILT-UP WARM ROOF SYSTEM DESIGN & PS1
For
INDUSTRIAL INVESTMENT GROUP LTD

LOADSPAN TABLES

STRUCTURAL REPORT		Project No. **21154-5**	Issue No. **10**
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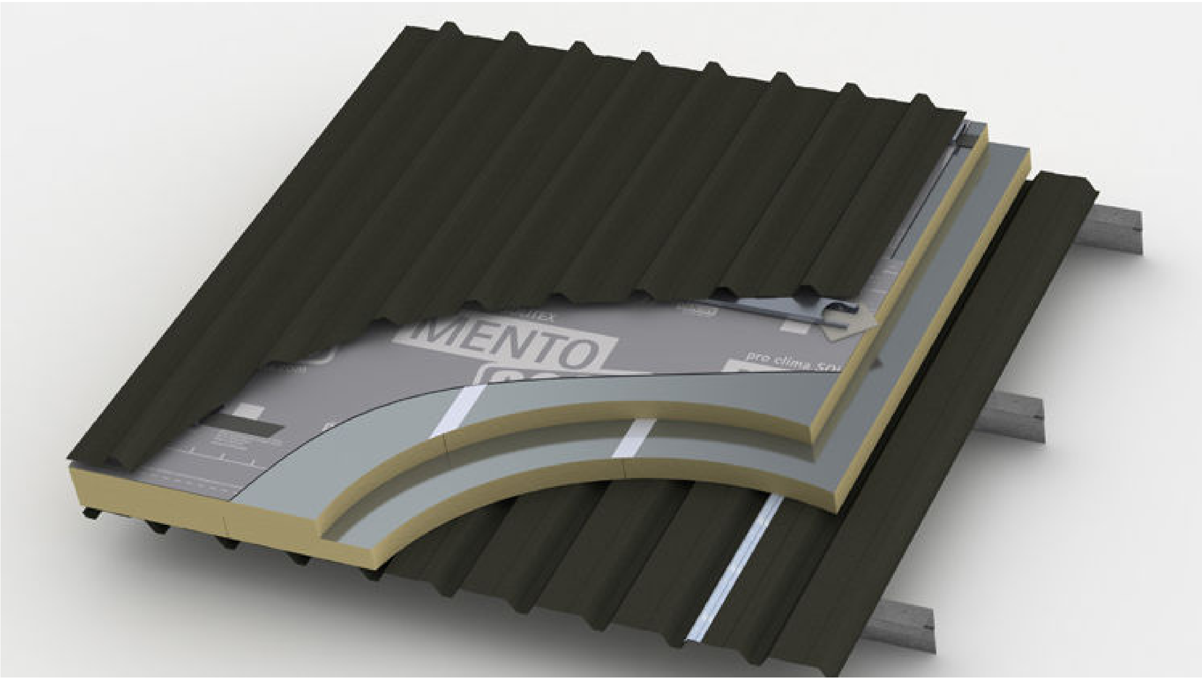

DOCUMENT CONTROL

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1	4 April 2023		Draft For Comment
2	24 May 2023	PS1 on request	Draft For Approval
3	31 July 2023	PS1 on request	Updated test results
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EXECUTIVE SUMMARY

Industrial Investment Group Ltd have requested Redco NZ Ltd to prepare safe load tables for their warm roof concept. A 'Met-Therm' built-up warm roof from Metalcraft is proposed made up from 2 sheets of Metalcraft roofing sheets with underlay, insulation, vapour barrier and optional acoustic board, fixed to timber of steel purlins.

The purpose of this document is to present guidance to architects and engineers on the use of this built-up warm roof system and the background to this guidance. The design philosophy for the built-up roof is that the wind load applied to the outer faces of the roof is carried by the top sheet, while the bottom sheet carries the wind load applied to the inner faces of the roof as well as the gravity loads arising from additional components such as acoustic board. The top sheet also carries live load on the roof. There is no intermediate structure between the purlins. Thus, both top and bottom sheets need to span independently between purlins. This configuration means that no composite action is possible. Detailed Load-Span tables and graphs are shown in Appendix A. These indicates the maximum uniform load that can be applied at serviceability limit state before permanent deformation of the sheet around the fixing occurs. A summary is provided below. Where required, a project specific producer statement PS1 can be provided on request.

Members Designed
Warm Roof Components: Steel Sheeting & Fixings.

Design Standards and Codes Referenced
The structure has been designed in accordance with the following Standards and Codes.

AS/NZS 1170 (Loadings)	AS/NZS 4600 (Light Steel)	NZS 3604
NZMRM Code of Practice 3.0	Manufacturers' literature, span tables, testing or SED, as included herein	

Compliance Path for the Works
The elements have been designed in compliance with the New Zealand Building Code using the following design path:

- B1/VM1

B1 - STRUCTURE

1.0 LOADING & DEMAND

Roof and wall cladding must structurally comply with the requirements of the NZBC Clause B1 Structure. Strength demand may be calculated in accordance with AS/NZS 1170:2 or NZS 3604.

Manufacturer's printed technical literature, using different criteria or test values can cause confusion when it is compared to the latest requirements.

1.1 AS/NZS 1170

The Loadings Code (AS/NZS 1170) identifies four load categories relevant to metal roof and wall cladding:

1. **Wind actions:** Wind loads are the result of local changes in wind speed as the wind flows over and around the building. High positive forces (pressure) apply where the wind is slowed, high negative pressures (suction) apply where the wind accelerates over the cladding. Wind force varies with the shape and position of the building. It also increases with height because the influence of ground surface drag decreases.
2. **Permanent action:** Dead load is the permanent weight of the roof structure and the permanent part of an imposed load, such as an air conditioning unit.
3. **Imposed action:** Live loads are variable loads imposed on the building by its occupants and contents, such as a person standing on the roof (point load).
4. **Induced actions:** Loads such as snow or ice, and ponding rainwater.

When a structure, or part of it, fails to fulfil its expected basic functions, it is said to have reached a limit state. There are two limit states:

1. **Serviceability limit state (SLS)** is a state when a building, or any part of it, becomes unfit for its intended use due to deformation or deflection.
2. **Ultimate limit state (ULS)** is a state associated with collapse or failure, or when a building or any part of it becomes unstable or unsafe.

These limit states are not limited to the metal roof and wall cladding but are intended to be applied to the entire building structure.

Because the prime function of metal roof and wall cladding is to exclude water from the structure, irreversible failure at the serviceability limit state, for example permanent distortion around the fastener head, is generally the governing limit state for pierce fastened roof and wall cladding. The New Zealand Metal Roofing Manufacturers Association (NZMRM) Code of Practice treats serviceability as the criterion of failure for pierce fastened roofs, as these failure thresholds are far lower than those at which ultimate limit state failure is experienced.

1.2 NZS 3604

NZS 3604: "Timber Framed Buildings" is an acceptable solution to comply with the NZBC for light timber frame buildings not requiring specific design. NZS 3604 is a simplified 'Code of Practice' which minimizes the involvement of engineers in the design of light timber frame residential type buildings.

Some of the limitations in the scope of NZS 3604 are:

- Timber frame construction.
- Height from lowest ground to the highest point on the roof may not exceed 10 m.
- A snow load may not exceed 1.0kPa, although Section 15 of NZS 3604 does provide additional criteria for 1.5kPa and 2.0kPa snow loads.

NZS 3604 includes:

- private dwellings, hostels, hotels and nurse's homes;
- factories with restricted floor loadings; and
- institutional and educational buildings with restricted floor loadings.

NZS 3604 excludes:

- buildings dedicated to the preservation of human life;
- buildings which may host crowds;
- publicly owned buildings containing high value contents; and
- curved roof construction.

NZS 3604 contains prescriptive dimensions for purlin spacing and fasteners, based on maximum design wind speeds:

1. Low (32 m/s)
2. Medium (37 m/s)
3. High (44 m/s)
4. Very High (50 m/s)
5. Extra High (55 m/s)

The load calculations for NZS 3604 were based on a simplified interpretation of AS/NZS 1170. These values can be used for calculation of loads on the cladding of structures designed using NZS 3604.

1.3 WIND LOAD

1.3.1 Local Pressure factors

The local pressure factor (K_l) is an important design consideration required by AS/AZS 1170.2. The peripheral areas of roof and wall surfaces are subjected to greater uplift loads than the main body of the roof. Designers need to include local pressure factors in the calculation of wind loads on the cladding and members that directly support cladding and relevant connections.

When designing to NZS 3604, the local pressure factor (K_l) is set to 1.0. When designing to NZS 1170 the local pressure factors used are 1.5, 2.0, or 3.0, depending on the location.

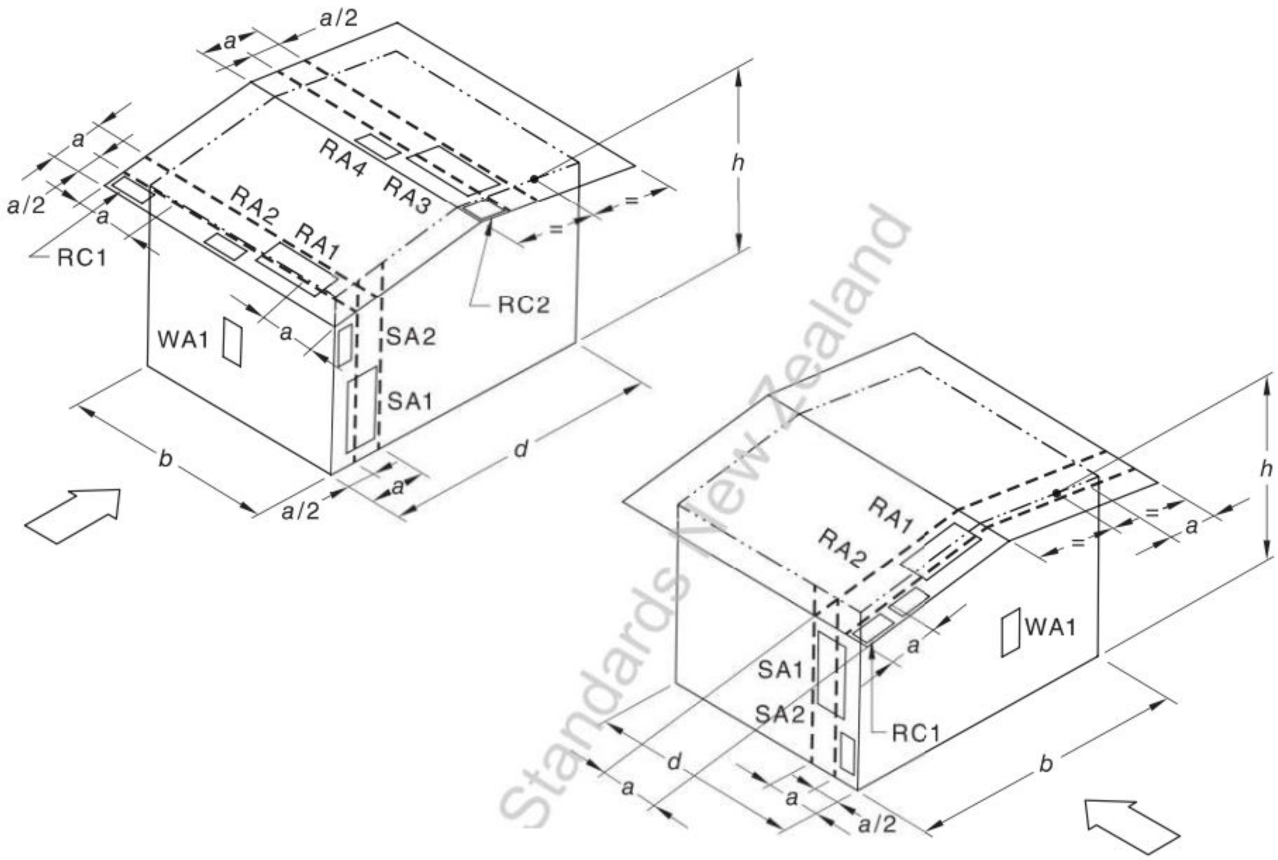


Figure 1: Areas where Local Pressure factors apply (from AS/NZS 1170.2)

1.3.2 NZMRM Code of Practice

The Code of Practice published by the New Zealand Metal Roofing Manufacturers Association (NZMRM) provides load-span tables for a range of corrugated and trapezoidal profiled steel and aluminium roofing products. The graphs provided are for intermediate spans only. End spans must be reduced by one-third.

The performance of profiled metal cladding depends on the profile shape, thickness of the metal, the span, and the fastening type and pattern. These values can be greatly enhanced by using load spreading washers or thicker material.

The capacity of the supporting purlin should also be checked.

The NZMRM load-span graphs also present pressures for each of the design wind speeds listed in NZS 3604. The pressures shown are SLS wind pressures.

For the purposes of this document, the ratio between SLS and ULS wind pressures is calculated using AS/AZS 1170.2: 2011 for Wind Zones A1-A7 as 0.676. The pressures shown in the NZMRM load-span graphs effectively use a combined pressure factor (C_{fig}) of 1.7, over the values used in NZS 3604, as illustrated below.

Wind Pressures (2011)

Dynamic Wind Pressure (Cl 2.4.1 / Eq 2.4(1))

- $p_{dyn} = 0.5 \cdot \rho_{air} \cdot V_{des,\theta}^{2} \cdot C_{fig} \cdot C_{dyn}$
- Internal: $C_{fig,i} = C_{p,i} \cdot K_{c,i}$ (Eq 5.2(1)) Carried on the bottom deck
- External: $C_{fig,e} = C_{p,e} \cdot K_a \cdot K_{c,e} \cdot K_l \cdot K_p$ (Eq 5.2(2)) Carried on the top deck

k_p = 1.0 k_a = 1.0 k_c = 1.0 k_l = 1.5

$C_{p,e} + C_{p,i}$ = 1.133 SLS/ULS : 0.676 V_{R500} = 45 V_{R25} = 37

Net Pressure Coefficient C_{fig} =			1.70 NZMRM		1.5	2	3	Internal 0.3 ULS	*NZMRM Published CoP*
Wind Zone	**Speed *m/s***	***p***	**Pressure (kPa)**		***C_{fig} x p_z (kPa)***			***C_{fig} x p_z (kPa)***	***Pressure (kPa)***
			ULS	**SLS**					**SLS**
Low	32	0.61	1.04	0.71	0.92	1.23	1.84	0.18	***0.60***
Medium	37	0.82	1.40	0.94	1.23	1.64	2.46	0.25	***0.93***
High	44	1.16	1.97	1.33	1.74	2.32	3.48	0.35	***1.32***
Very High	50	1.50	2.55	1.72	2.25	3.00	4.50	0.45	***1.72***
Extra High	55	1.82	3.08	2.09	2.72	3.63	5.45	0.54	***2.09***

The internal pressure is also taken into consideration by applying the C_{pi} factor of 0.3 as an internal suction on the underside of the roof carried by the bottom roof sheet in addition to gravity loads.

1.4 IMPOSED LOADS

Roofs are typically required to carry the minimum imposed UDL (Uniformly Distributed Load) roof load defined by NZS 1170.1: i.e. 0.25kPa. In each case, this is lower than the wind load.

Roofs that may be accessed by foot traffic must be designed to withstand a point load which is representative of a worker with a bag of tools. It is calculated at 112 kg, which equals 1.1 kN force. Imposed loads are applied vertically downwards. How this is applied is summarized in the table below.

Table 1: Application of Imposed Point Loads on Roofs

Roof Type	Roof Pitch	Point Load	Applied To
unrestricted access	any	1.1kN	pan or single rib of profiled sheet
restricted access	>35	1.1kN	pan or over two ribs
non-trafficable	>60	0.5kN	pan or over two ribs

In most cases, the wind load will still dominate. For lighter roof sheets with lower capacities (such as E-span), the imposed point load may be the critical load case. This should be checked against the ultimate capacity of the roof sheeting. As the point load is supposed to represent maintenance personnel with tools, this will be spread over a small area. For spans over 1m, this concentrated load is carried by one span on 2 purlins. For spans less than 1m, it is spread over 2 spans and carried on 3 purlins, so the load carried by one span is 0.55kN.

The capacities shown by testing the roof sheets are for wind UPLIFT, and failure is due to the fixings. The imposed load is downwards, and dependent on the roof sheet, rather than the fixings. Hence the capacity of the sheet downwards is likely to be greater than the capacity of the sheet upwards. For example, the imposed point load exceeds the capacity of the Espan sheets, even though all samples passed the 1.32kN standard test load for walking on with spans up to 1.5m.

See Appendix C for the moments induced by downward loading.

1.5 DEAD LOAD

The dead load of the warm roof is made up of:

Item	Dead Load 0.55mm	Ref.	
Roofing (top deck)	0.055 kPa	Assume to be the same weight as Bottom deck	
Underlay	Negligible		
PIR Insulation	0.040 kPa		
Battens	0.020 kPa		
Acoustic Board	0.080 kPa	10mm	RL ACOUSTIC BOARD INFO. TABLE - 7.8KG FOR 10mm BOARD
Bottom Deck	0.055 kPa	Assume to have same weight as Colorsteel roofing	
Total	**0.250 kPa**		

This is carried by the bottom roof sheet.

1.6 LOAD COMBINATIONS

The load combinations at Ultimate Limit State (ULS) are:

Combinations			Pressure
ULS1	**1.35G**		**0.34 kPa**
ULS2	**1.2G+1.5Q**		**0.68 kPa**
ULS3	**1.2G+W (Internal)**	**Extra High**	**0.84 kPa**

See Appendix C for the moments induced by the downward loading, and Appendix D for capacities pf the roof sheets.

1.7 RESISTING LOADS

The performance of profiled metal cladding under wind, snow and point loads depends on its ability to resist the tension (pulling), compression (squashing), and shear (sliding) forces that it is likely to be subjected to during the lifetime of the building.

Failure under wind load for a clip fastened cladding is usually by the clips de-indexing (pulling apart) and the cladding sheets blowing off. This is an ultimate failure.

Initial failure under wind uplift for pierce-fastened cladding is usually local buckling of the rib crest adjacent to the fastener. While the cladding can still resist a load, **this permanent deformation is liable to cause leakage at that point; therefore, it is a serviceability failure.**

Therefore, if a standard corrugate or low rib trapezoidal product passes for serviceability it will comfortably exceed ultimate design load requirements.

See Appendix D for the properties and capacities of the roof sheets.

2.0 FASTENER DESIGN

Fastener design aims to avoid strength failure of the screw before failure of the sheeting or the structure. Most fastener failures happen due to negative load (or uplift) and testing procedures are designed to closely simulate these conditions.

Fasteners used to fix metal cladding can fail by pulling out of the structure or by shearing. The cladding can fail by pull-over or profile collapse.

Fastener design should be sufficient to avoid pull-out and prevent deformation of the cladding around the fastener heads that can cause leaks.

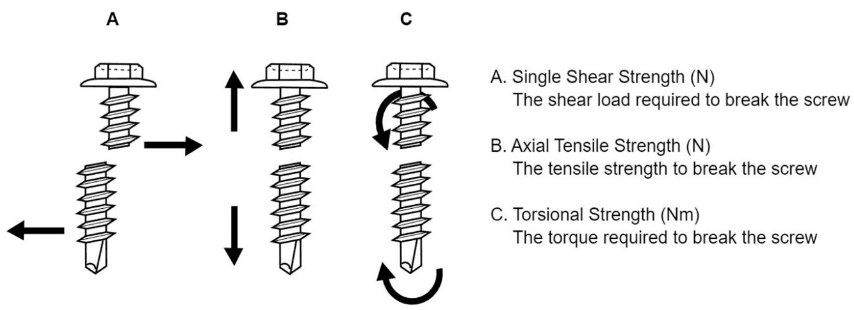


Figure 2: Fixing Failure Modes (reproduced from NZMRM Code of Practice)

Often the fasteners are the weakest link in the roofing system. Rather than the screws breaking in tension, failure is either by the roof sheet pulling-over the fixing, or the fixing pulling out of the supporting purlin.

Generally, when fixing through steel purlins thicker than 1 mm, a fastener penetration of three threads through the steel member is sufficient for the fastener to meet its full design capacity. Pull out failure is not normally a risk with high tensile steel purlins over 1 mm in thickness.

2.1 LOAD-SPREADING WASHERS (LSW)

Profiled load-spreading washers spread high wind uplift-loads over a larger area around the fastener head. Using load spreading washers under the fastener can increase the load resistance of each fastener by up to 50%.

The type, size and stiffness of washers are critical for performance. Where performance data incorporating load-spreading washers is used, the specification of the washer must be quoted with the fastener.

In general, load-spreading washers should have a minimum thickness of 0.95 mm for steel and 1.2 mm for non-ferrous metal. It should be noted that load-spreading washers can only prevent pull-over failure; beyond that, pull-out failure may then become the limiting failure mode.

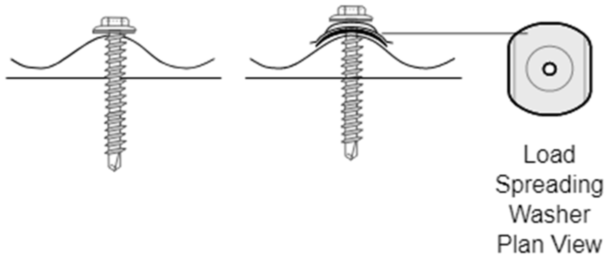


Figure 3: Load Spreading Washers (reproduced from NZMRM Code of Practice)

3.0 WARM ROOF CLADDING DESIGN

3.1 THE CONCEPT

A 'Met-Therm' built-up warm roof from Metalcraft is proposed. Load-Span tables are shown in Appendix A indicating the fixing pattern suitable for each of the local wind pressure areas, based on the intermediate span capacity.

The design philosophy for the built-up roof is the wind load applied to the outer faces of the roof (both positive and negative) is carried by the top sheet, while the bottom sheet carries the wind load applied to the inner faces of the roof as well as the gravity loads arising from additional components such as acoustic board. The top sheet also carries live load on the roof. There is no intermediate structure between the purlins. Thus, both top and bottom sheets need to span independently between purlins. This configuration means that no composite action is possible.

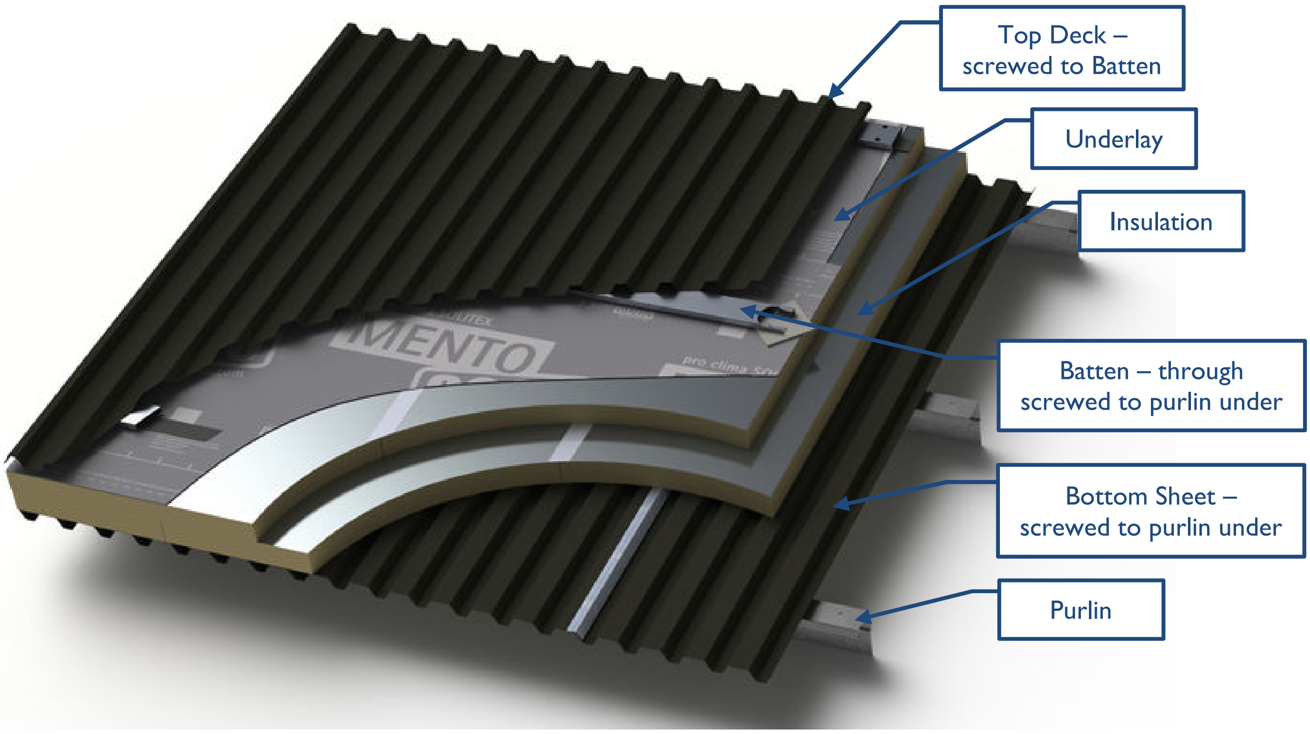


Figure 4: Composition of Warm Roof

The construction sequence is:

1. The lower roof sheet is laid on and fixed to the supporting purlins. (These fixings are to hold the bottom sheet in position while the rest of the components are placed on the bottom sheet.)
2. The 'warm roof' components – the vapour barrier, the acoustic board (if required) and the insulation - are then laid on the bottom sheet.
3. A batten is placed on a nylon packer on the insulation and screwed through to the purlin below. The battens are spaced to line up with the purlins below – thus the line of the purlins needs to be marked on the insulation as it is laid. (The packer provides ventilation and spreads the fixing loads.) The batten is 3.5mm 6061-T6 aluminium.
4. The underlay is placed over the battens.
5. The upper roof sheet is laid on and fixed to the battens.

3.2 THE FAMILIES

Six families of warm roof are proposed:

A. Metcom 7 (for the lower North Island)
B. Kahu (for the upper North Island and the South Island)
C. Metcom 965
D. Metcom 930
E. Espan 340
F. Espan 470

Generally, the same sheets will be used for top and bottom skins. However, with Espan as the top sheet, the bottom sheet can be either Metcom 7 or Kahu. (In either case, the capacity of the warm roof system is governed by the limitation of the top sheet.)

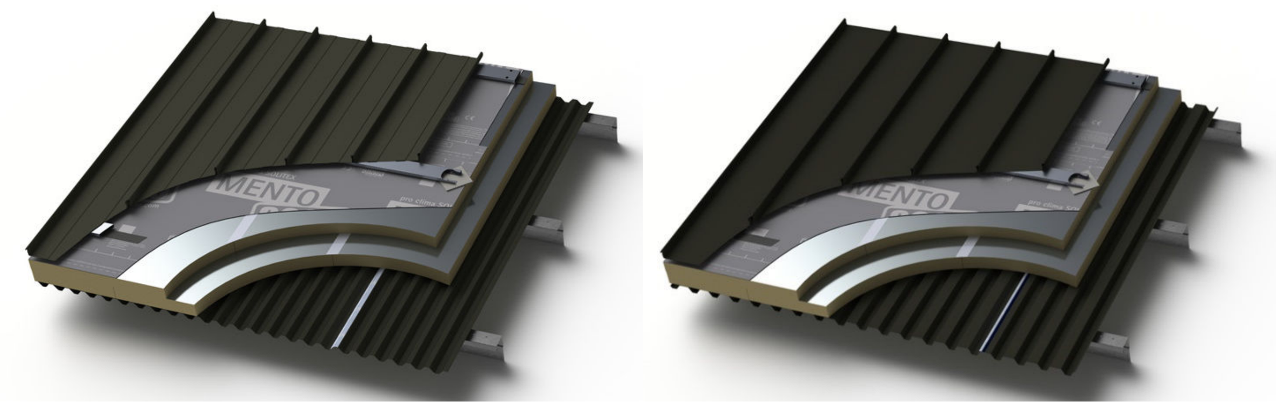


Figure 5: Espan Top Sheets with Kahu and Metcom 7 bottom Sheets

Table 2: Selected Roof sheets and their properties

Ref	Name	Material	Type	Depth (mm)	Width (mm)	Thickness (mm)	Ribs		Fixing spacing (mm)
							N°	Spacing (mm)	
A	**Metcom 7**	G550	Trapezoidal Asymmetrical	36	933	0.4 / 0.55	8	127	254
B	**Kahu**	G550	Trapezoidal Symmetrical	32	950	0.4 / 0.55	10	97.5	293
C	**Metcom 965**	G550	Trapezoidal Asymmetrical	45	1065	0.55	4	322	322
D	**Metcom 930**	G550	Trapezoidal Asymmetrical	45	1010	0.55	5	234	234
E	**Espan 340**	Aluminium	Standing Seam	47	340	0.9	1	340	344
		G300 Steel	Standing Seam	47	340	0.55	1	340	344
F	**Espan 470**	Aluminium	Standing Seam	47	470	0.9	1	470	474
		G300 Steel	Standing Seam	47	470	0.55	1	470	474

Table 3: Section Properties & Capacities of Roof Sheet Profiles

Ref	Roof Profile Name	Material	Depth D (mm)	Thickness t (mm)	Rib Spacing (mm)	I_x cm^4	Z_x cm^3	Bending $ØM_e$ kNm	Shear $ØV$ kN
A	Metcom 7	G550	36	0.4	127	10.5	5.07	1.88	24.4
			36	0.55	127	14.4	6.97	2.59	57.6
B	Kahu	G550	32	0.4	97.5	6.9	4.35	1.62	35.7
			32	0.55	97.5	9.5	5.99	2.23	75.1
C	Metcom 965	G550	45	0.55	322	17.6	5.54	2.06	20.0
D	Metcom 930	G550	45	0.55	234	19.2	6.59	2.45	27.5
E	Espan 340	Aluminium	47	0.9	340	17.3	4.02	0.68	25.4
		G300 Steel	47	0.55	340	10.6	2.45	0.91	18.1
F	Espan 470	Aluminium	47	0.9	470	17.3	4.02	0.68	18.4
		G300 Steel	47	0.55	470	10.5	2.46	0.91	13.0

See Appendix D for the derivation of the properties and capacities of the roof sheets.

3.3 BATTEN

The batten is 3.5mm thick 6061-T6 aluminium. The batten serves as a packer and lines up with the purlin below. The aluminium batten is a ventilated channel section.

Figure 6: Render of Aluminium Batten

The capacity of the battens is presented in Appendix E.

3.4 FIXINGS

Given the range of roof sheets proposed, 3 fixing scenarios have been considered and are presented in Appendix B. A summary of the minimum capacities for each scenario is presented in Table 4 below.

In all scenarios, the capacity of the fixing is dependent on the materials joined rather than the screw itself, i.e. failure is either by pull over or pull out rather than tensile failure of the screw.

Table 4: Maximum fixing capacities for each scenario

Fixing Scenario		Fixing	Metal Thickness	Minimum Capacity (kN)
F1 Sheet to Batten	F1A Steel Sheet	14g Tek	0.4mm	1.93kN Pull Over
			0.55mm	2.65kN Pull Over
	F1B Aluminium Batten 6061	14g Tek	3.5mm	2.91kN Pull Out
F2 Clip to Batten	F2A Steel Clip	10g Tek	1.15mm	2.93kN Pull Over
	F2A Aluminium Batten 6061		3.5mm	2.21kN Pull Out
F3 Batten to Purlin	F3B Aluminium Batten 6061	14g Tek	3.5mm	3.26kN Pull Over
	F3A Steel Purlin	14g Tek	1.0mm	1.39kN Pull Out
			1.2mm	1.67kN Pull Out
			1.0mm	1.39kN Pull Out
			1.2mm	1.67kN Pull Out
			1.45mm	2.02kN Pull Out
			1.6mm	2.06kN Pull Out
			1.8mm	2.31kN Pull Out

Table 5: Fixing capacity (kN/m) for Single 14g Tekscrews from Roof to Batten

Ref	Name	Rib Spacing (mm)	Fixing spacing (mm)	*Material*	Roof Sheet G550 Steel		Batten 6061 Aluminium
				Thickness	0.4mm	0.55mm	3.5mm
				Capacity (kN)	1.93	2.65	2.91
A	**Metcom 7**	127	254		7.60	10.43	11.46
B	**Kahu**	97.5	293		6.59	9.04	9.93
C	**Metcom 965**	322	322			8.23	9.04
D	**Metcom 930**	234	234			11.32	12.44

Table 5 (continued): Fixing capacity (kN/m) for Single 10g Tekscrews from Roof to Batten

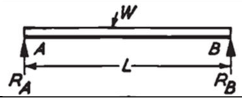
Ref	Name	Rib Spacing (mm)	Fixing spacing (mm)	*Material*	Clip Steel	Batten 6061 Aluminium
				Thickness	1.15	3.5mm
				Capacity (kN)	2.93	2.21
E	**Espan 340**	340	344		8.52	6.42
F	**Espan 470**	470	474		6.18	4.66

Table 6: Fixing capacity (kN/m) for pairs of 14g Tekscrews from Batten to Purlin

Fixing spacing (mm)	*Material*	Batten 6061 Aluminium	Purlin G550 Steel				
	Thickness	3.5mm	1.0mm	1.2mm	1.45mm	1.6mm	1.8mm
	Capacity (kN)	6.25	2.78	3.34	4.04	4.11	4.63
100		62.5	27.8	33.4	40.4	41.1	46.3
200		31.3	13.9	16.7	20.2	20.6	23.2
300		20.8	9.3	11.1	13.5	13.7	15.4
400		15.6	7.0	8.4	10.1	10.3	11.6
500		12.5	5.6	6.7	8.1	8.2	9.3

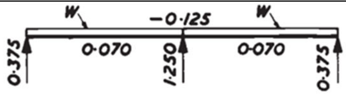
3.5 FIXING LOADS

Table 7: Fixing Loads (kN/m) for loading, spans & support arrangements



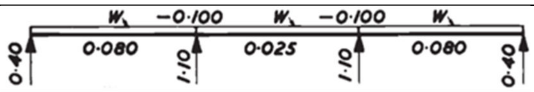
Fixing Load kN/m: Simply Supported Span

Load (kPa)	Span (m) 0.3	0.6	0.9	1.2	1.5
1	0.15	0.3	0.45	0.6	0.75
2	0.3	0.6	0.9	1.2	1.5
3	0.45	0.9	1.35	1.8	2.25
4	0.6	1.2	1.8	2.4	3
5	0.75	1.5	2.25	3	3.75
6	0.9	1.8	2.7	3.6	4.5
7	1.05	2.1	3.15	4.2	5.25



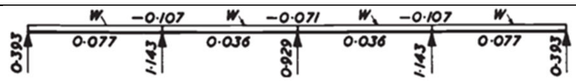
Fixing Load kN/m: 2-Span Continuous

Load (kPa)	Span (m) 0.3	0.6	0.9	1.2	1.5
1	0.38	0.75	1.13	1.50	1.88
2	0.75	1.50	2.25	3.00	3.75
3	1.13	2.25	3.38	4.50	5.63
4	1.50	3.00	4.50	6.00	7.50
5	1.88	3.75	5.63	7.50	9.38
6	2.25	4.50	6.75	9.00	11.25
7	2.63	5.25	7.88	10.50	13.13



Fixing Load kN/m: 3-Span Continous

Load (kPa)	Span (m) 0.3	0.6	0.9	1.2	1.5
1	0.33	0.66	0.99	1.32	1.65
2	0.66	1.32	1.98	2.64	3.3
3	0.99	1.98	2.97	3.96	4.95
4	1.32	2.64	3.96	5.28	6.6
5	1.65	3.3	4.95	6.6	8.25
6	1.98	3.96	5.94	7.92	9.9
7	2.31	4.62	6.93	9.24	11.55



Fixing Load kN/m: 4-Span Continuous

Load (kPa)	Span (m) 0.3	0.6	0.9	1.2	1.5
1	0.34	0.69	1.03	1.37	1.71
2	0.69	1.37	2.06	2.74	3.43
3	1.03	2.06	3.09	4.11	5.14
4	1.37	2.74	4.11	5.49	6.86
5	1.71	3.43	5.14	6.86	8.57
6	2.06	4.11	6.17	8.23	10.29
7	2.40	4.80	7.20	9.60	12.00

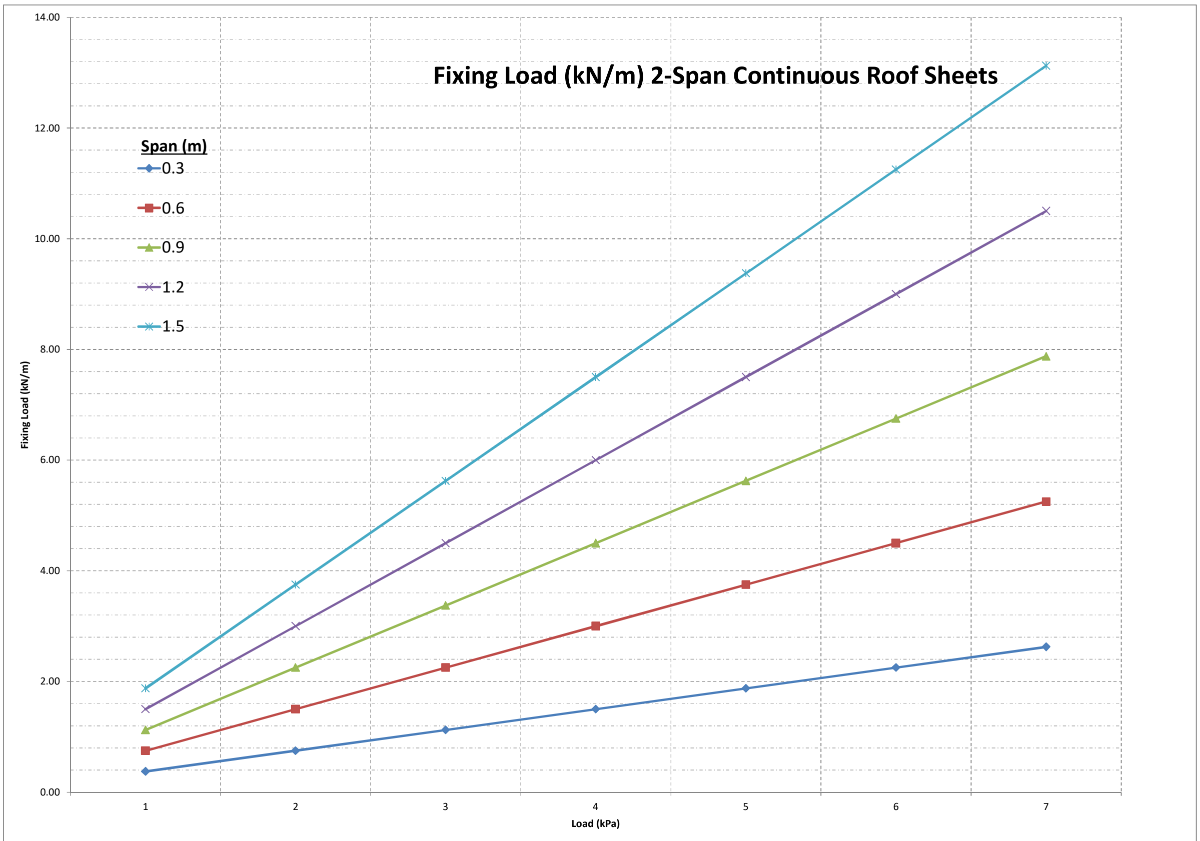


Figure 7: Fixing Loads (kN/m) for loading & spans on 2-span continuous sheet

4.0 CHOOSING A BUILT-UP WARM ROOF SYSTEM

4.1 WORKING WITHIN NZS 3604 WIND LOADS

1. Determine the wind zone for your building.
2. Determine the snow zone for your building.
3. Select the roof sheeting product type from the Metalcraft catalogue.
4. Determine the maximum span for the selected roof sheeting from the Load-Span Tables in Appendix A based on the wind zones. This sets the batten and purlin spacing.
5. Fixings are set as 14g Tekscrews (or 10g for Espan) at the spacing of given in Table 2
6. If the roof is subject to snow loading, check the maximum span for the roof sheeting from the Load-Span Tables or Graphs in Appendix A

4.2 WORKING BEYOND NZS 3604 WIND LOADS

1. Determine the wind zone for your building.
2. Determine the snow zone for your building.
3. Select the roof sheeting product type from the Metalcraft catalogue.
4. Determine the maximum span for the selected roof sheeting from the Load-Span Graphs in Appendix A based on the loading for the snow and wind zones. This sets the batten and purlin spacing.
5. Given the wind uplift load, determine the Fixing Load for the span arrangement from Table 7
6. Determine the Fixing capacity (kN/m) for <u>Single</u> Tekscrews from Roof to Batten from Table 5.
7. Determine the Fixing capacity (kN/m) for <u>Pairs</u> of Tekscrews from Batten to Purlin from Table 6
8. If the roof is subject to snow loading, check the maximum span for the roof sheeting from the Load-Span Tables or Graphs in Appendix A
9. If the roof is not a 4-span continuous sheet:
   a) Given the loading and span, determine the bending, shear, fixing forces and deflection.
   b) Check the bending and shear capacity of the sheet using the Section Properties & Capacities of Roof Sheet Profiles from Table 3 (or Appendix D).
   c) Determine the Fixing capacity (kN/m) for <u>Single</u> Tekscrews from Roof to Batten from Table 5.
   d) Determine the Fixing capacity (kN/m) for <u>Pairs</u> of Tekscrews from Batten to Purlin from Table 6

APPENDIX A: WARM ROOF LOAD/SPAN TABLES & GRAPHS

Load-Span Tables & Graphs are presented in full detail in this Appendix.

The following tables & graphs provide more detailed information and provide the maximum uniform load that can be applied at **serviceability limit state (SLS)** before permanent deformation of the sheet around the fixing occurs, and at **ultimate limit state (ULS)** before sheet failure (or complete detachment).

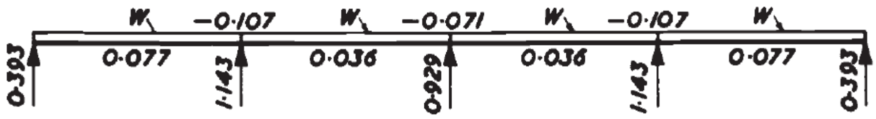
The tables also provide fixing loads for each of the load-span combinations. These figures determine the minimum thicknesses of the supporting steel purlins. Some of the spans are limited by the capacity of the fixings.

When the roof sheet spans over 5 or more supports, values for the End Spans are calculated as a proportion of the Intermediate Span values. For a continuous sheet of equal spans uniformly loaded, the moment and reactions are given by the expressions:

Moment = coefficient x W x L

Reaction = coefficient x W x L

Where W is the UDL on one span and L is the length of one span.



For a 4-span continuous sheet the values for the End Spans are 0.071/0.107 = 0.66 x intermediate span. In other words, if the spans are to be constant, the load on the end spans should be reduced by a factor of 0.66.

For a 4-span continuous sheet loaded with 0.66W on the end spans, the load in each screw is calculated as

T_{uls} = 1.0 x W_{uls} x span x spacing

For a simple supported span, the load in each screw is calculated as T_{uls} = 0.5 x W_{uls} x span x spacing

For other numbers of spans, the fixing load will need to be calculated to allow for continuity of spans.

The ratio between SLS and ULS loads is based on AS/NZS 1170.2: 2011 by comparing the SLS and ULS Regional Wind speeds for Wind Zones A1-A7 for an Importance Level 2 building, i.e.

$$\frac{{V_{R25}}^2}{{V_{R500}}^2} = \frac{37^2}{45^2} = 0.676$$

Note, this ratio varies depending on the region. It is also different in the new code AS/NZS 1170.2: 2021.

The batten thickness for aluminium battens is **3.5mm**. This accommodates a pull-out force of 2.91kN for a 14g screw. Other thicknesses and other grades of aluminium battens give higher loads.

Notes:

1. Where required, a project specific producer statement PS1 can be provided on request.

2. Spans greater than 3m or less than 0.6m, require Specific Engineering Design (SED)

3. Data has been retrieved from test results summarized by JD Consulting Engineers for an Intermediate Span & G550 Steel. Tests were carried out at the MRM Test Facility under Static and Cyclic uplift wind loads.

4. Generally, the same sheets will be used for top and bottom skins. However, with Espan as the top sheet, the bottom sheet can be either Metcom 7 or Kahu. (In either case, the capacity of the warm roof system is governed by the limitation of the top sheet.)

5. Where fixed by screws, the bottom sheeting is fixed to purlins using Tekscrews in timber or steel purlins.

6. Pull-out capacity of fixings can be the limiting factor

7. LSW = Load Spreading Washers

8. Fixing patterns to be:
   A. Metcom 7: Hit one miss one (every other profile crest)
   B. Kahu: Hit one, miss two (every 3rd profile crest)
   C. MC956 - D: Fix every profile crest with LSW
   D. MC930 - B: Fix every profile crest.
   E. Espan 340 – Clips every Standing Seam
   F. Espan 470 – Clips every Standing Seam

APPENDIX A: WARM ROOF LOAD/SPAN TABLES

Client: **INDUSTRIAL INVESTMENT GROUP LTD** Date: **13 Sep '24**

Project: **BATTEN LOAD-SPAN TABLES** Project No. **21154-5**

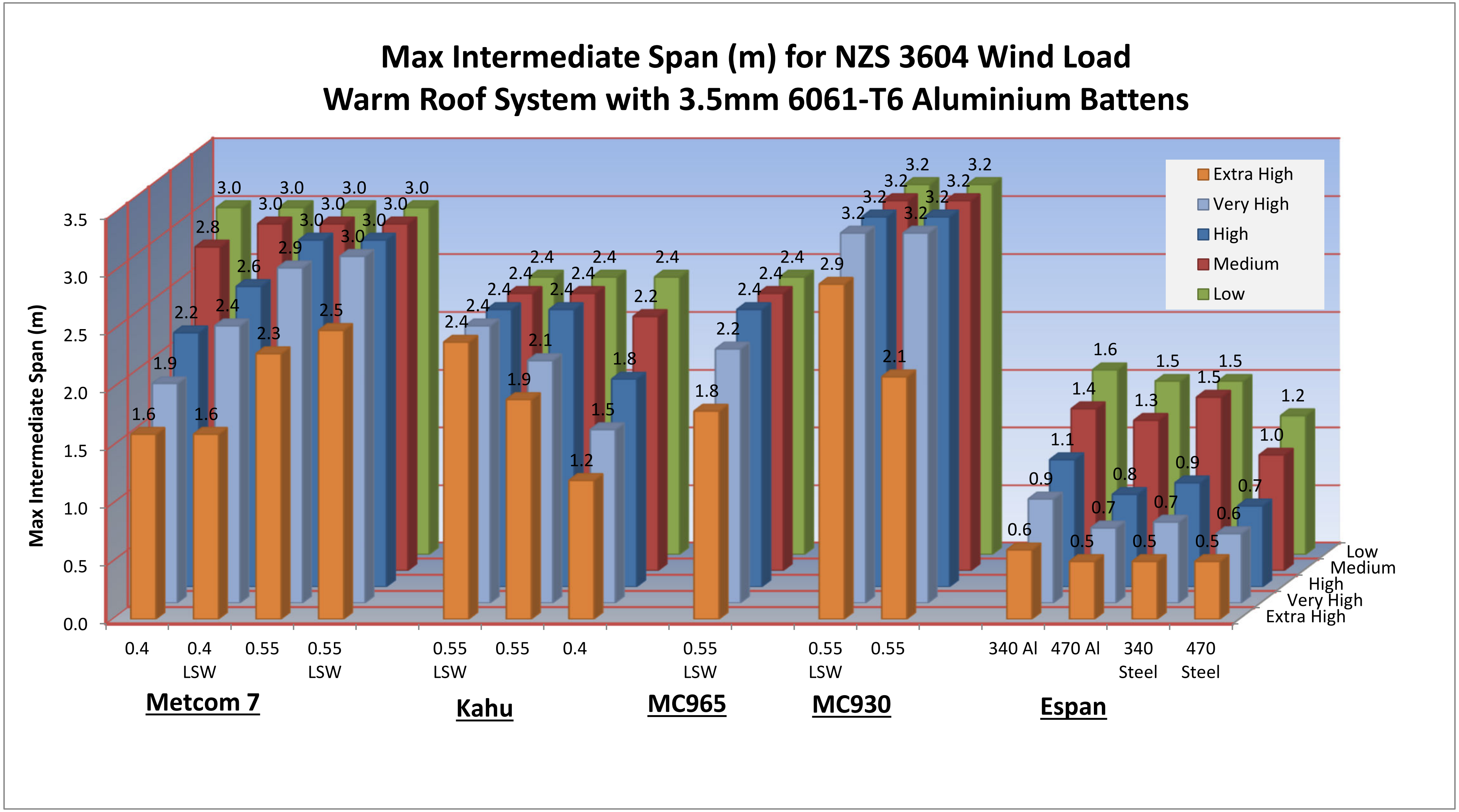
Summary: Maximum Spans for Each Wind Zone

Batten: 3.5mm Aluminium 6061-T6 Aluminium

Warm Roof System		Max Span for NZS 3604 Wind Load (m)									
Family	Type	Low		Medium		High		Very High		Extra High	
		Inner	End	Inner	End	Inner	End	Inner	End	Inner	End
Metcom 7	0.4	3.0	2.0	2.8	2.0	2.2	1.5	1.9	1.3	1.6	1.1
	0.4 LSW	3.0	2.0	3.0	2.0	2.6	1.7	2.4	1.6	1.6	1.1
	0.55	3.0	2.0	3.0	2.0	3.0	2.0	2.9	1.9	2.3	1.5
	0.55 LSW	3.0	2.0	3.0	2.0	3.0	2.0	3.0	2.0	2.5	1.7
Kahu	0.55 LSW	2.4	1.6	2.4	1.6	2.4	1.6	2.4	1.6	2.4	1.6
	0.55	2.4	1.6	2.4	1.6	2.4	1.6	2.1	1.4	1.9	1.3
	0.4	2.4	1.6	2.2	1.5	1.8	1.2	1.5	1.0	1.2	0.8
MC965	0.55 LSW	2.4	1.6	2.4	1.6	2.4	1.6	2.2	1.5	1.8	1.2
MC930	0.55 LSW	3.2	2.1	3.2	2.1	3.2	2.1	3.2	2.1	2.9	1.9
	0.55	3.2	2.1	3.2	2.1	3.2	2.1	3.2	2.1	2.1	1.4
Espan	340 Al	1.6	1.1	1.4	0.9	1.1	0.7	0.9	0.6	0.6	0.4
	470 Al	1.5	1.0	1.3	0.9	0.8	0.5	0.7	0.4	0.5	0.3
	340 Steel	1.5	1.0	1.5	1.0	0.9	0.6	0.7	0.5	0.5	0.3
	470 Steel	1.2	0.8	1.0	0.7	0.7	0.5	0.6	0.4	0.5	0.3

APPENDIX A: WARM ROOF LOAD/SPAN TABLES

Client:	**INDUSTRIAL INVESTMENT GROUP LTD**	Date:	**13 Sep '24**
Project:	**BATTEN LOAD-SPAN TABLES**	Project No.	**21154-5**



APPENDIX A: WARM ROOF LOAD/SPAN TABLES

Client: **INDUSTRIAL INVESTMENT GROUP LTD** Date: **13 Sep '24**

Project: **BATTEN LOAD-SPAN TABLES** Project No. **21154-5**

METCOM 7

Fix Every Other Rib **Based on 3.5mm Aluminium Battens**

	Wind Zone	Sheet Thickness	Fixing Type	Fixing Spacing	SLS Pressure	ULS Pressure	Max Span (m)		Fixing Load (ULS)	Min Purlin Thickness
		(mm)		(mm)	(kPa)	(kPa)	Inner	End	(kN)	(mm)
.40 No	Low	0.4	Regular	254	0.71	1.04	3.0	2.0	0.80	1.00
	Medium	0.4	Regular	254	0.94	1.40	2.8	1.8	0.99	1.00
	High	0.4	Regular	254	1.33	1.97	2.2	1.5	1.10	1.00
	Very High	0.4	Regular	254	1.72	2.55	1.9	1.3	1.23	1.00
	Extra High	0.4	Regular	254	2.09	3.08	1.6	1.1	1.25	1.00
.40 LSW	Low	0.4	LSW	254	0.71	1.04	3.0	2.0	0.80	1.00
	Medium	0.4	LSW	254	0.94	1.40	3.0	2.0	1.06	1.00
	High	0.4	LSW	254	1.33	1.97	2.6	1.7	1.30	1.00
	Very High	0.4	LSW	254	1.72	2.55	2.4	1.6	1.55	1.00
	Extra High	0.4	LSW	254	2.09	3.08	1.6	1.1	1.25	1.00
.55 No	Low	0.55	Regular	254	0.71	1.04	3.0	2.0	0.80	1.00
	Medium	0.55	Regular	254	0.94	1.40	3.0	2.0	1.06	1.00
	High	0.55	Regular	254	1.33	1.97	3.0	2.0	1.50	1.20
	Very High	0.55	Regular	254	1.72	2.55	2.9	1.9	1.88	1.45
	Extra High	0.55	Regular	254	2.09	3.08	2.3	1.5	1.80	1.45
.55 LSW	Low	0.55	LSW	254	0.71	1.04	3.0	2.0	0.80	1.00
	Medium	0.55	LSW	254	0.94	1.40	3.0	2.0	1.06	1.00
	High	0.55	LSW	254	1.33	1.97	3.0	2.0	1.50	1.20
	Very High	0.55	LSW	254	1.72	2.55	3.0	2.0	1.94	1.45
	Extra High	0.55	LSW	254	2.09	3.08	2.5	1.7	1.96	1.45

APPENDIX A: WARM ROOF LOAD/SPAN TABLES

Client: **INDUSTRIAL INVESTMENT GROUP LTD** Date: **13 Sep '24**

Project: **BATTEN LOAD-SPAN TABLES** Project No. **21154-5**

Kahu

Fix Every 3rd Rib

Based on 3.5mm Aluminium Battens

	Wind	Sheet	Fixing	Fixing	SLS	ULS	Max Span (m)		Fixing	Min Purlin
		(mm)		(mm)	(kPa)	(kPa)	Inner	End	(kN)	(mm)
Kahu (0.55mm) LSW	Low	0.55	LSW	293	0.71	1.04	2.4	1.6	0.73	1.00
	Medium	0.55	LSW	293	0.94	1.40	2.4	1.6	0.98	1.00
	High	0.55	LSW	293	1.33	1.97	2.4	1.6	1.39	1.00
	Very High	0.55	LSW	293	1.72	2.55	2.4	1.6	1.79	1.45
	Extra High	0.55	LSW	293	2.09	3.08	2.4	1.6	2.17	1.45
Kahu (0.55mm)	Low	0.55	Regular	293	0.71	1.04	2.4	1.6	0.73	1.00
	Medium	0.55	Regular	293	0.94	1.40	2.4	1.6	0.98	1.00
	High	0.55	Regular	293	1.33	1.97	2.4	1.6	1.39	1.00
	Very High	0.55	Regular	293	1.72	2.55	2.1	1.4	1.57	1.20
	Extra High	0.55	Regular	293	2.09	3.08	1.9	1.3	1.72	1.45
Kahu (0.4mm)	Low	0.4	Regular	293	0.71	1.04	2.4	1.6	0.73	1.00
	Medium	0.4	Regular	293	0.94	1.40	2.2	1.5	0.90	1.00
	High	0.4	Regular	293	1.33	1.97	1.8	1.2	1.04	1.00
	Very High	0.4	Regular	293	1.72	2.55	1.5	1.0	1.12	1.00
	Extra High	0.4	Regular	293	2.09	3.08	1.2	0.8	1.08	1.00

APPENDIX A: WARM ROOF LOAD/SPAN TABLES

Client: **INDUSTRIAL INVESTMENT GROUP LTD** Date: **13 Sep '24**

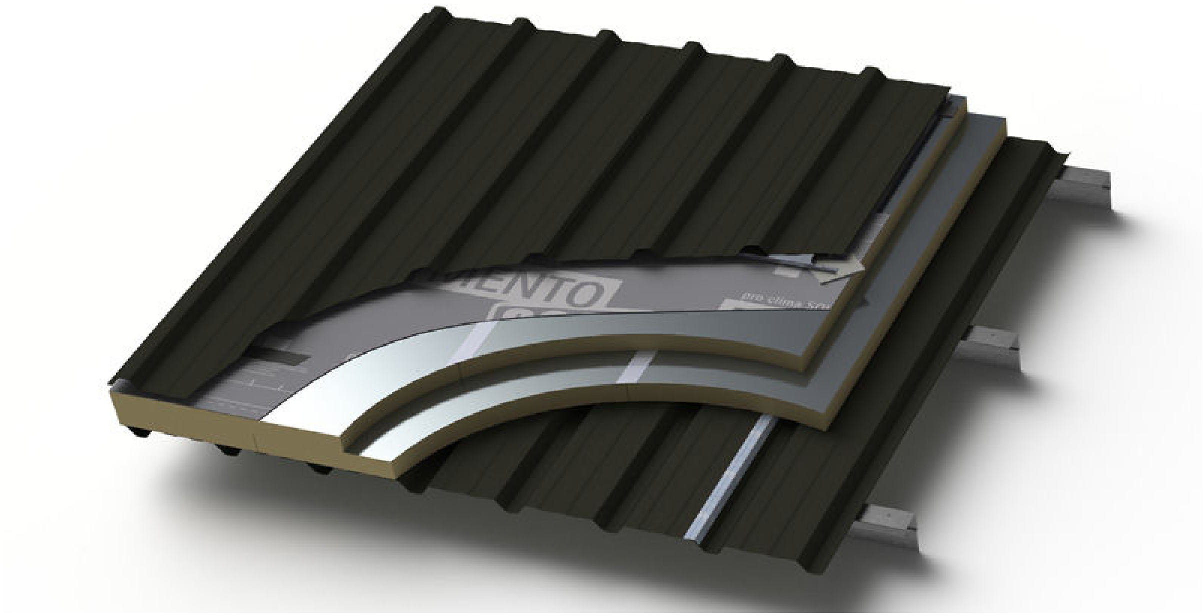
Project: **BATTEN LOAD-SPAN TABLES** Project No. **21154-5**

MC965

Fix Every Rib

Based on 3.5mm Aluminium Battens

	Wind	Sheet	Fixing	Fixing	SLS	ULS	Max Span (m)		Fixing	Min Purlin
		(mm)		(mm)	(kPa)	(kPa)	Inner	End	(kN)	(mm)
MC965 (LSW)	Low	0.55	LSW	322	0.71	1.04	2.4	1.6	0.81	1.00
	Medium	0.55	LSW	322	0.94	1.40	2.4	1.6	1.08	1.00
	High	0.55	LSW	322	1.33	1.97	2.4	1.6	1.53	1.20
	Very High	0.55	LSW	322	1.72	2.55	2.2	1.5	1.81	1.45
	Extra High	0.55	LSW	322	2.09	3.08	1.8	1.2	1.79	1.45



APPENDIX A: WARM ROOF LOAD/SPAN TABLES

Client: **INDUSTRIAL INVESTMENT GROUP LTD** Date: **13 Sep '24**

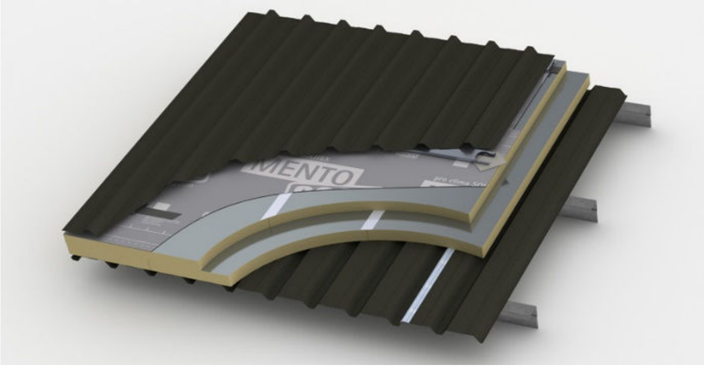
Project: **BATTEN LOAD-SPAN TABLES** Project No. **21154-5**

MC930

Fix Every Rib

Based on 3.5mm Aluminium Battens

	Wind Zone	Sheet Thickness	Fixing Type	Fixing Spacing	SLS Pressure	ULS Pressure	Max Span (m)		Fixing Load (ULS)	Min Purlin Thickness
		(mm)		(mm)	(kPa)	(kPa)	Inner	End	(kN)	(mm)
MC930 (LSW)	Low	0.55	LSW	234	0.71	1.04	3.2	2.1	0.78	1.00
	Medium	0.55	LSW	234	0.94	1.40	3.2	2.1	1.05	1.00
	High	0.55	LSW	234	1.33	1.97	3.2	2.1	1.48	1.00
	Very High	0.55	LSW	234	1.72	2.55	3.2	2.1	1.91	1.00
	Extra High	0.55	LSW	234	2.09	3.08	2.9	1.9	2.09	1.00
MC930	Low	0.55	Regular	234	0.71	1.04	3.2	2.1	0.78	1.00
	Medium	0.55	Regular	234	0.94	1.40	3.2	2.1	1.05	1.00
	High	0.55	Regular	234	1.33	1.97	3.2	2.1	1.48	1.20
	Very High	0.55	Regular	234	1.72	2.55	3.2	2.1	1.91	1.00
	Extra High	0.55	Regular	234	2.09	3.08	2.1	1.4	1.52	1.00



APPENDIX A: WARM ROOF LOAD/SPAN TABLES

Client: **INDUSTRIAL INVESTMENT GROUP LTD** Date: **13 Sep '24**

Project: **BATTEN LOAD-SPAN TABLES** Project No. **21154-5**

Espan

Clipped Every Rib

Based on 3.5mm Aluminium Battens

	Wind Zone	Sheet Thickness	Fixing Type	Fixing Spacing	SLS Pressure	ULS Pressure	Max Span (m)		Fixing Load (ULS)	Min Purlin Thickness
		(mm)		(mm)	(kPa)	(kPa)	Inner	End	(kN)	(mm)
Espan 340 0.9mm Aluminium	Low	0.9	Clip	344	0.71	1.04	1.6	1.1	0.57	1.00
	Medium	0.9	Clip	344	0.94	1.40	1.4	0.9	0.67	1.00
	High	0.9	Clip	344	1.33	1.97	1.1	0.7	0.75	1.00
	Very High	0.9	Clip	344	1.72	2.55	0.9	0.6	0.79	1.00
	Extra High	0.9	Clip	344	2.09	3.08	0.6	0.4	0.64	1.00
Espan 470 0.9mm Aluminium	Low	0.9	Clip	474	0.71	1.04	1.5	1.0	0.74	1.00
	Medium	0.9	Clip	474	0.94	1.40	1.3	0.9	0.86	1.00
	High	0.9	Clip	474	1.33	1.97	0.8	0.5	0.75	1.20
	Very High	0.9	Clip	474	1.72	2.55	0.7	0.4	0.79	1.00
	Extra High	0.9	Clip	474	2.09	3.08	0.5	0.3	0.73	1.00
Espan 340 0.55mm G300 Steel	Low	0.55	Clip	344	0.71	1.04	1.5	1.0	0.54	1.00
	Medium	0.55	Clip	344	0.94	1.40	1.5	1.0	0.72	1.00
	High	0.55	Clip	344	1.33	1.97	0.9	0.6	0.61	1.20
	Very High	0.55	Clip	344	1.72	2.55	0.7	0.5	0.61	1.45
	Extra High	0.55	Clip	344	2.09	3.08	0.5	0.3	0.53	1.45
Espan 470 0.55mm G300 Steel	Low	0.55	Clip	474	0.71	1.04	1.2	0.8	0.59	1.00
	Medium	0.55	Clip	474	0.94	1.40	1.0	0.7	0.66	1.00
	High	0.55	Clip	474	1.33	1.97	0.7	0.5	0.66	1.20
	Very High	0.55	Clip	474	1.72	2.55	0.6	0.4	0.73	1.45
	Extra High	0.55	Clip	474	2.09	3.08	0.5	0.3	0.73	1.45

APPENDIX A: WARM ROOF LOAD/SPAN TABLES

Client:	INDUSTRIAL INVESTMENT GROUP LTD	Date:	13 Sep '24
Project:	BATTEN LOAD-SPAN TABLES	Project No.	21154-5

Roof Sheet Capacity*: SLS Wind Suction (Uplift) (kPa) on Intermediate Span

Warm Roof System

Family	Type	Span	0.6m	1.2m	1.8m	2.4m	3m
Metcom 7	0.4		7.2	2.8	1.9	1.2	0.9
	0.4 LSW		8.7	3.4	1.8	1.4	1.1
	0.55		12.2	4.0	2.9	2.0	1.7
	0.55 LSW		14.0	6.1	3.9	2.2	1.8

Family	Type	Span	0.6m	0.90 m	1.2 m	1.5 m	1.8 m	2.10 m	2.4 m
Kahu	0.55 LSW		10.2	6.9	5.06	4	3.24	2.7	2.28
	0.55		6.76	4.9	3.15	2.55	2.21	1.85	1.45
	0.4		5.17	3.5	2.23	1.75	1.4	1.1	0.8

Family	Type	Span	0.6m	0.90 m	1.2 m	1.5m	1.80 m	2.1 m	2.4m
MC965	0.55 LSW		11.9	7.0	4.9	3.8	3.0	2.6	2.6

Family	Type	Span	0.8m	1.2m	1.6m	2m	2.4m	2.8m	3.2m
MC930	0.55 LSW		11.1	7.3	5.5	4.2	3.0	2.3	1.8
	0.55		6.8	5.0	3.3	2.3	1.8	1.6	1.5

Family	Type	Span	0.33m	0.45 m	0.6 m	0.9 m	1.2 m	1.35 m	1.5 m	1.6 m
Espan	340 Al		3.1	3.0	2.2	1.7	1.2	1.0	0.9	0.9
	470 Al					1.3	1.1	0.9	0.8	
	340 Steel			3.0	2.0	1.4	1.0	1.0	0.9	
	470 Steel			2.6	1.8	1.1	0.7	0.7	0.7	

* Check Fixing Capacity

APPENDIX A: WARM ROOF LOAD/SPAN TABLES

Client: **INDUSTRIAL INVESTMENT GROUP LTD** — Date: **13 Sep '24**

Project: **BATTEN LOAD-SPAN TABLES** — Project No. **21154-5**

Roof Sheet Capacity*: ULS Wind Suction (Uplift) (kPa) on Intermediate Span

Warm Roof System

Family	Type	Span	0.6m	1.2m	1.8m	2.4m	3.0m
Metcom 7	0.4		7.3	2.7	1.7		
	0.4 LSW		14.0	7.1	4.1	3.1	2.6
	0.55		14.0	4.6	3.2	3.1	
	0.55 LSW		14.0	8.1	5.9	4.4	3.9

Family	Type	Span	0.6m	0.9 m	1.2 m	1.5 m	1.8 m	2.1 m	2.4 m
Kahu	0.55 LSW		14.4	12.2	10.1	8.0	5.8	4.9	4.5
	0.55		12.0	8.0	4.0	3.0	2.6	2.4	2.3
	0.4		8.3	5.4	2.6	2.0	1.9	1.7	1.5

Family	Type	Span	0.6m	0.9 m	1.2 m	1.5 m	1.8 m	2.1 m	2.4 m
MC965	0.55 LSW		16.4	12.5	9.4	7.0	5.1	4.0	3.5

Family	Type	Span	0.8m	1.2 m	1.6 m	2.0 m	2.4 m	2.8 m	3.2 m
MC930	0.55 LSW		12.3	10.0	7.9	6.8	5.9	4.9	3.9
	0.55		8.0	6.0	4.3	3.3	2.9	2.9	2.9

Family	Type	Span	0.33m	0.45 m	0.6 m	0.9 m	1.2 m	1.35 m	1.5 m	1.6 m
Espan	340 Al		4.6	4.4	3.3	2.5	1.7	1.5	1.4	1.3
	470 Al					2.0	1.6	1.4	1.2	
	340 Steel			4.4	3.0	2.0	1.5	1.4	1.4	
	470 Steel			3.9	2.7	1.6	1.1	1.0	1.0	

* Check Fixing Capacity

APPENDIX A: WARM ROOF LOAD/SPAN TABLES

Client: **INDUSTRIAL INVESTMENT GROUP LTD** Date: **13 Sep '24**

Project: **BATTEN LOAD-SPAN TABLES** Project No. **21154-5**

Roof Sheet Capacity*: ULS Pressure (Downward Wind or Snow load) (kPa) on Intermediate Span

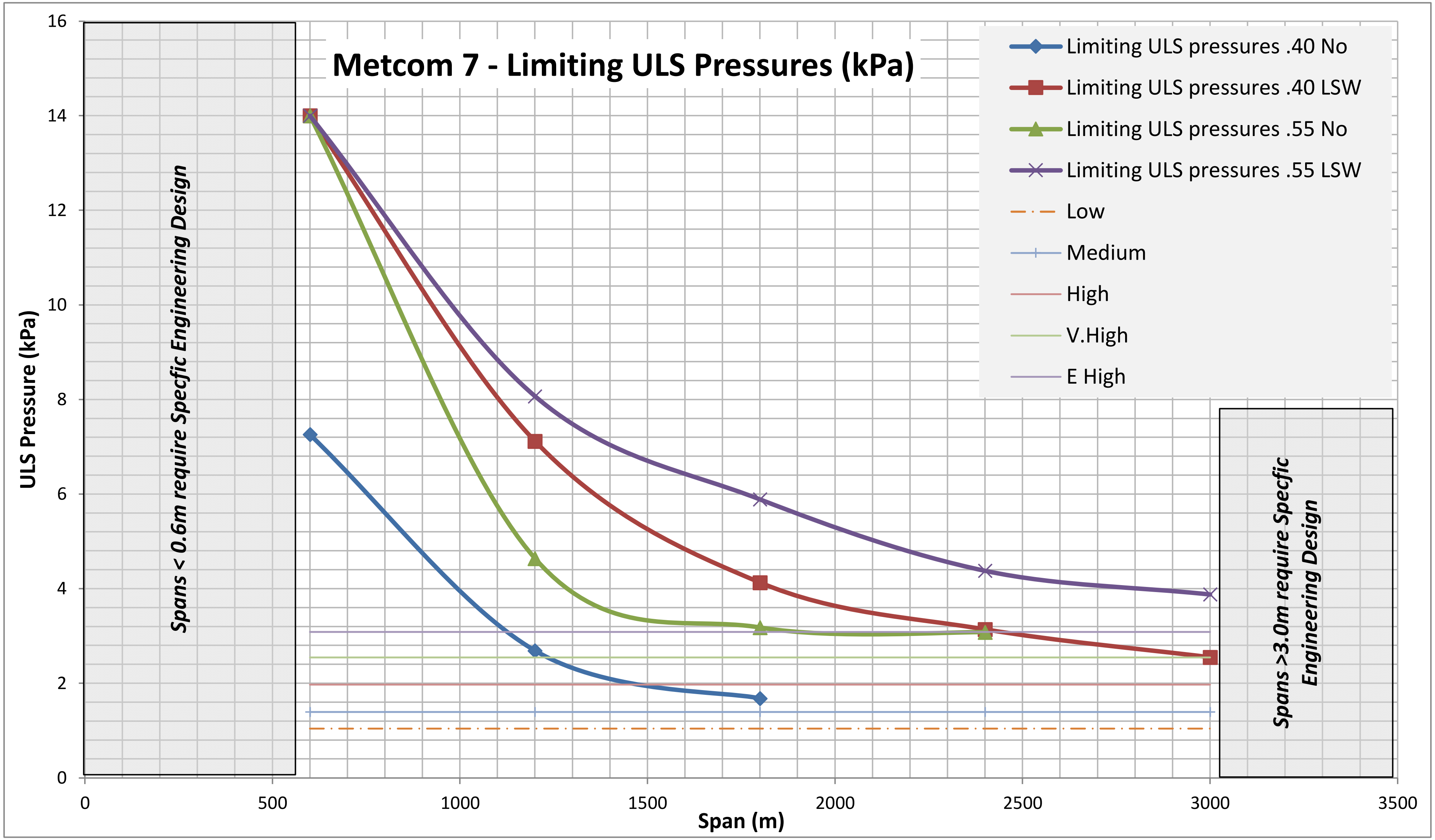
Warm Roof System		Size		Span (m)								
Family	Material	(mm)	Span (m)	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3
Metcom 7	G550	0.4		48.6	21.5	11.9	7.5	5.1	3.1	2.0	1.3	0.9
		0.55		67.0	29.6	16.5	10.5	7.2	4.4	2.9	1.9	1.3
Kahu	G550	0.4		41.7	18.4	10.2	5.9	3.3	2.0	1.2	0.8	0.5
		0.55		57.5	25.4	14.2	8.2	4.6	2.8	1.8	1.2	0.8
Metcom 965	G550	0.55		51.7	23.5	13.1	8.3	5.6	4.1	3.0	2.3	1.7
Metcom 930	G550	0.55		63.3	28.0	15.6	9.9	6.8	4.9	3.7	2.7	1.9
Espan 340	Aluminium	0.9		17.4	7.5	4.1	2.5	1.7	1.1	0.8	0.6	0.4
	G300	0.55		23.4	10.2	5.6	3.5	2.3	1.6	1.2	0.9	0.6
Espan 470	Aluminium	0.9		17.4	7.5	4.1	2.5	1.7	1.1	0.8	0.6	0.4
	G300	0.55		23.4	10.3	5.6	3.5	2.3	1.6	1.2	0.9	0.6

*Nett Max Load based on limits of bending, shear, deflection & PIR insulation compression on an intermediate span for a 4-span continuous roof

APPENDIX A: WARM ROOF LOAD/SPAN GRAPHS

Client: **INDUSTRIAL INVESTMENT GROUP LTD** Date: **13 Sep '24**

Project: **BATTEN LOAD-SPAN TABLES** Project No. **21154-5**



Note: Check pull-out capacity of fixings as this can be the limiting factor

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APPENDIX A: WARM ROOF LOAD/SPAN GRAPHS

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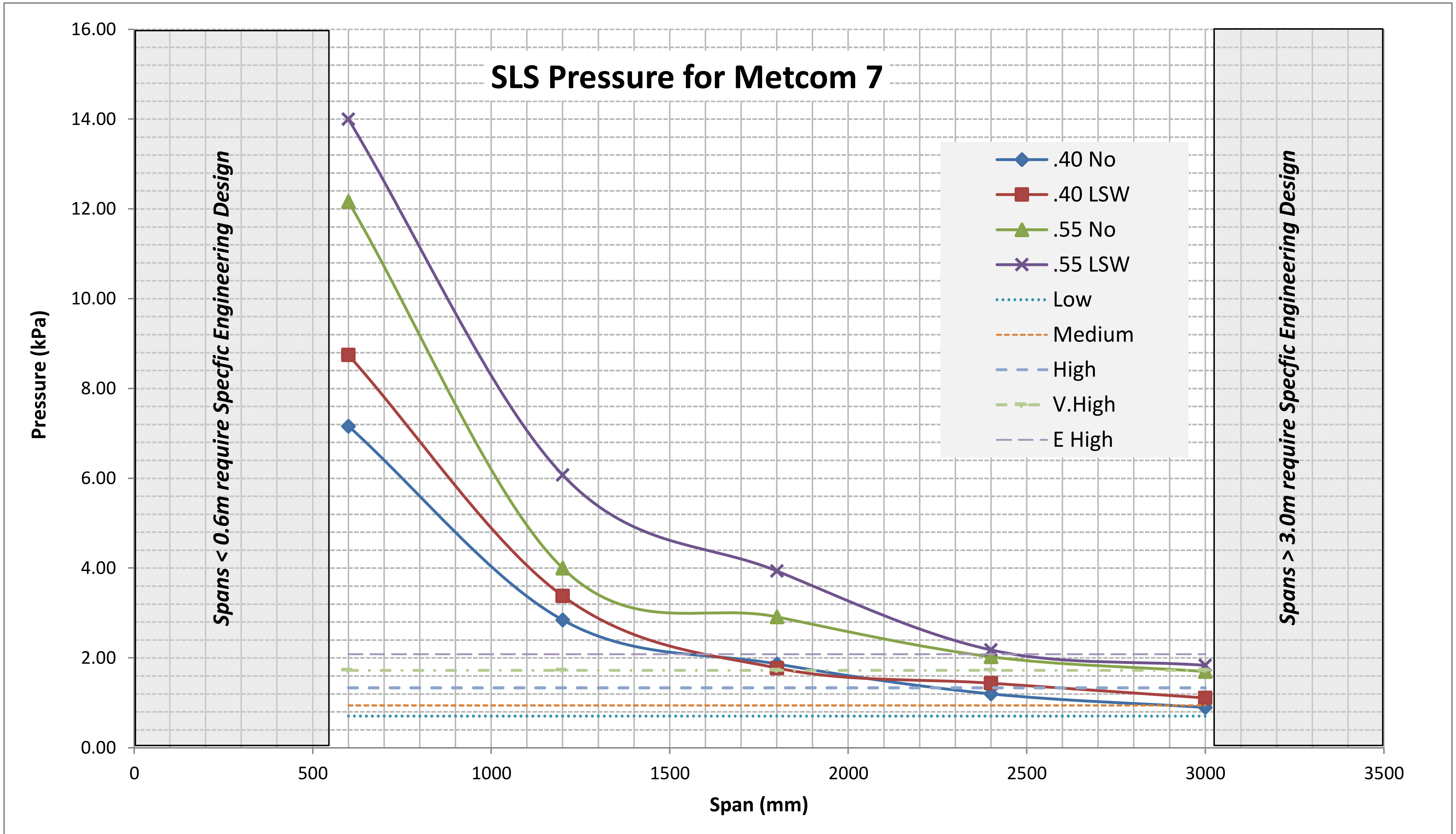

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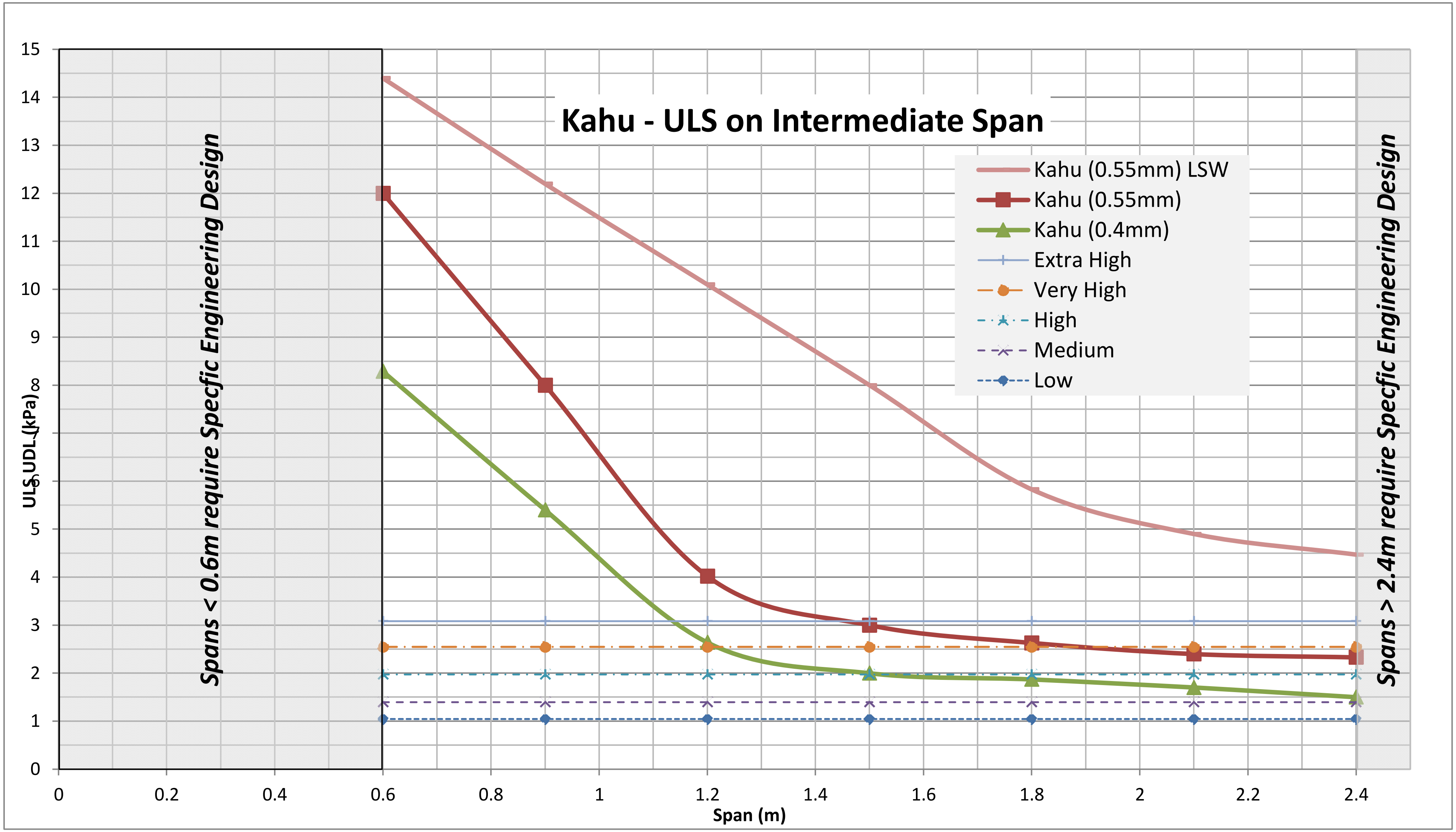

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APPENDIX A: WARM ROOF LOAD/SPAN GRAPHS

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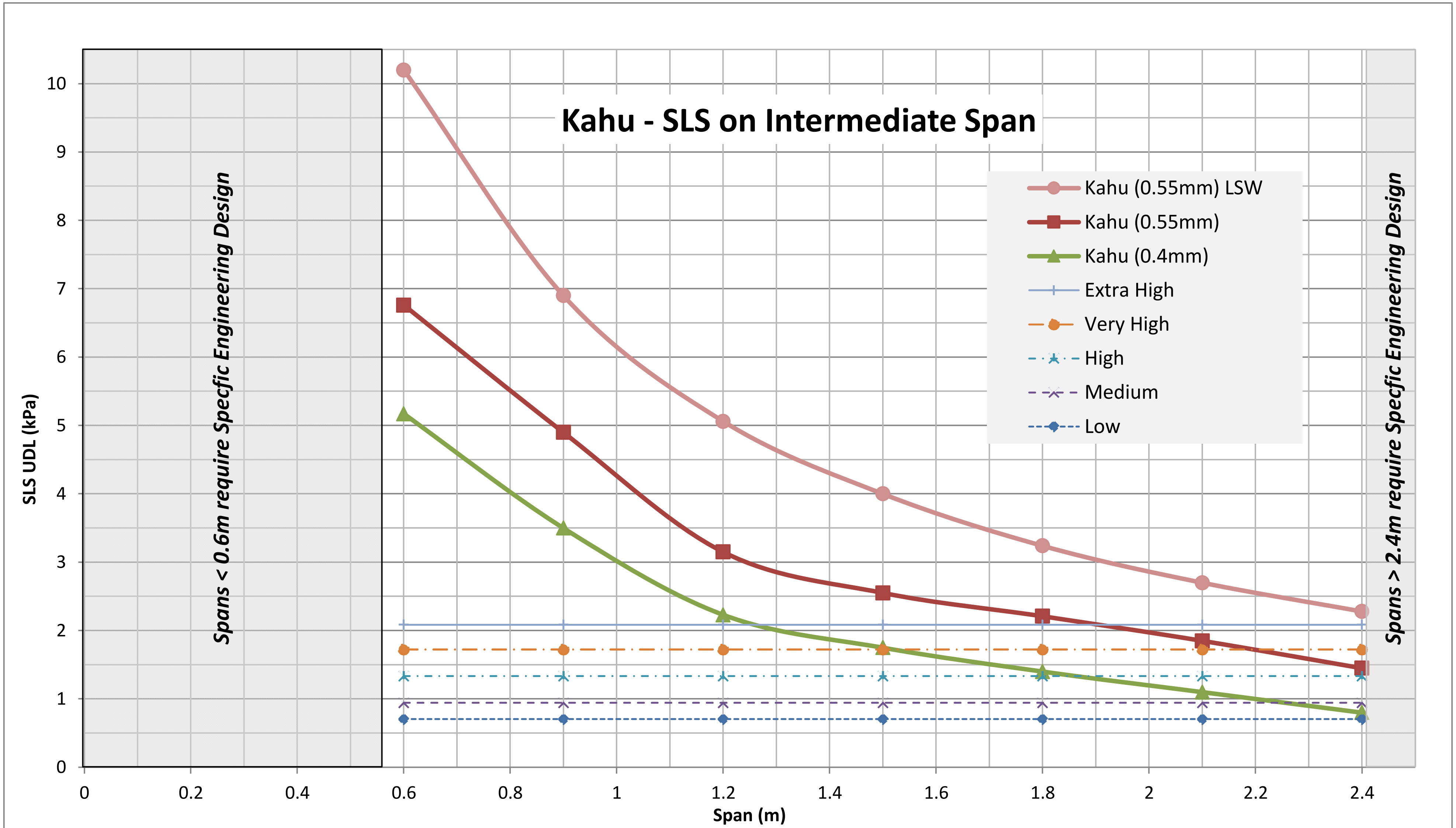

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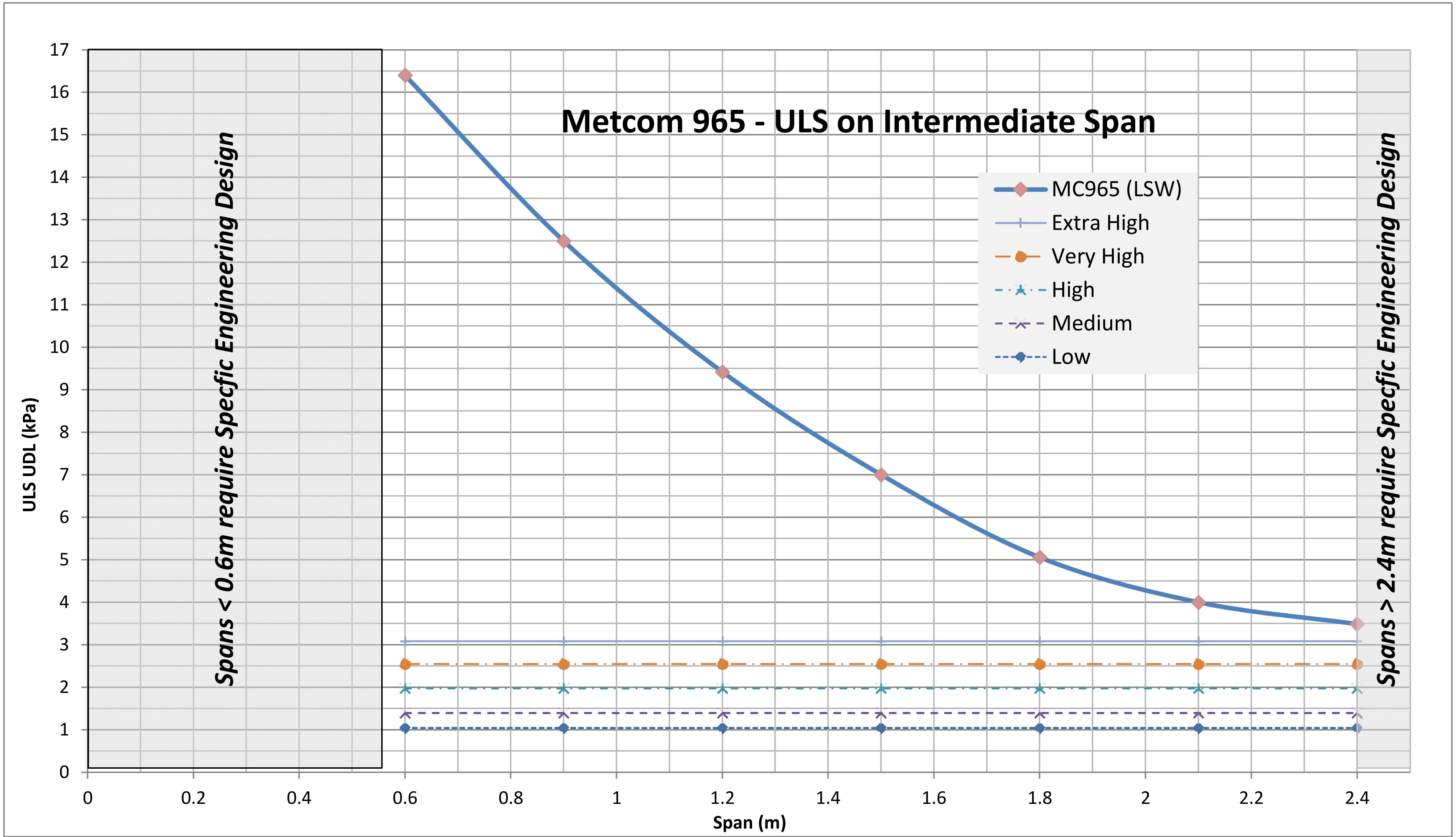

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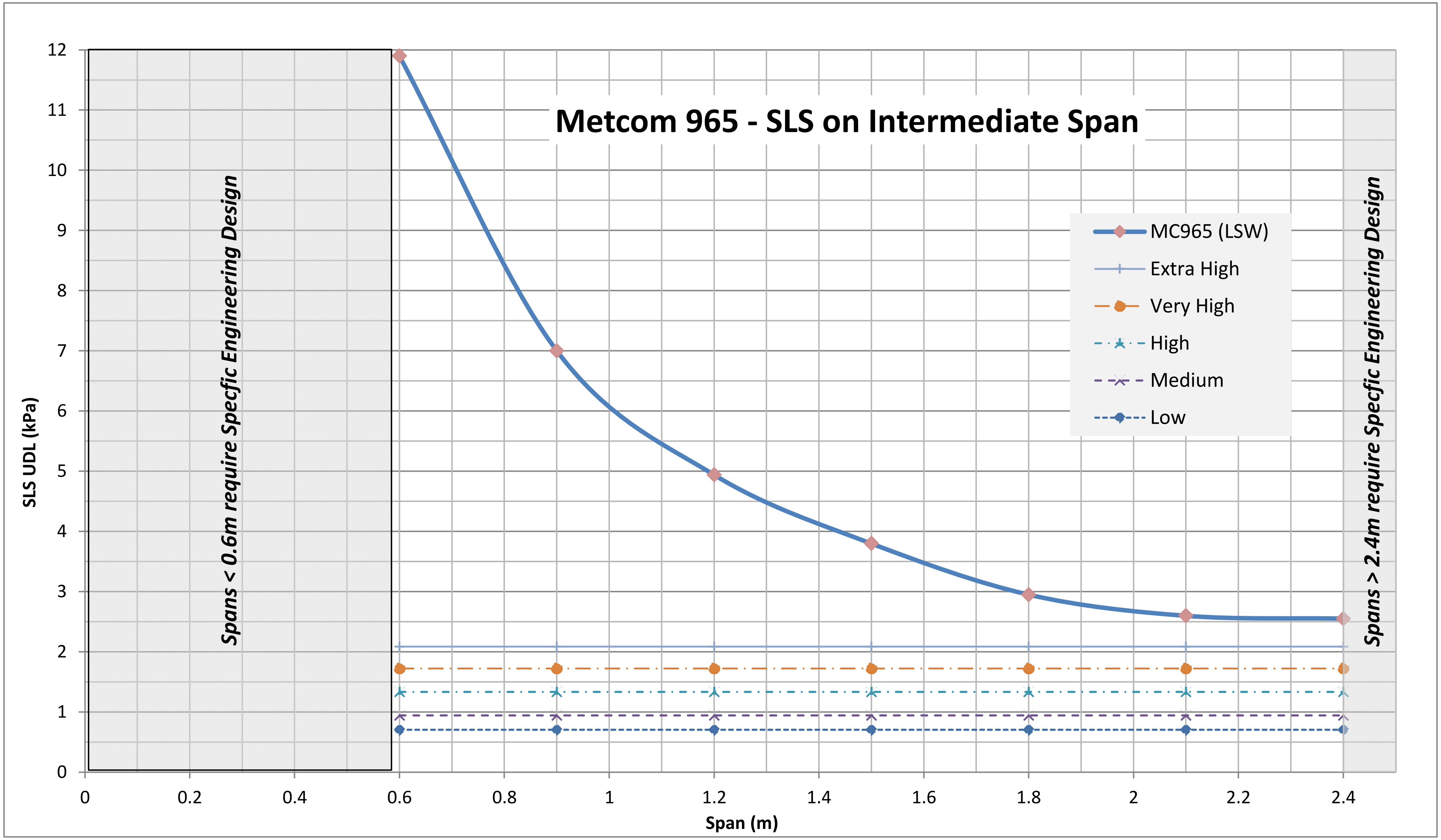

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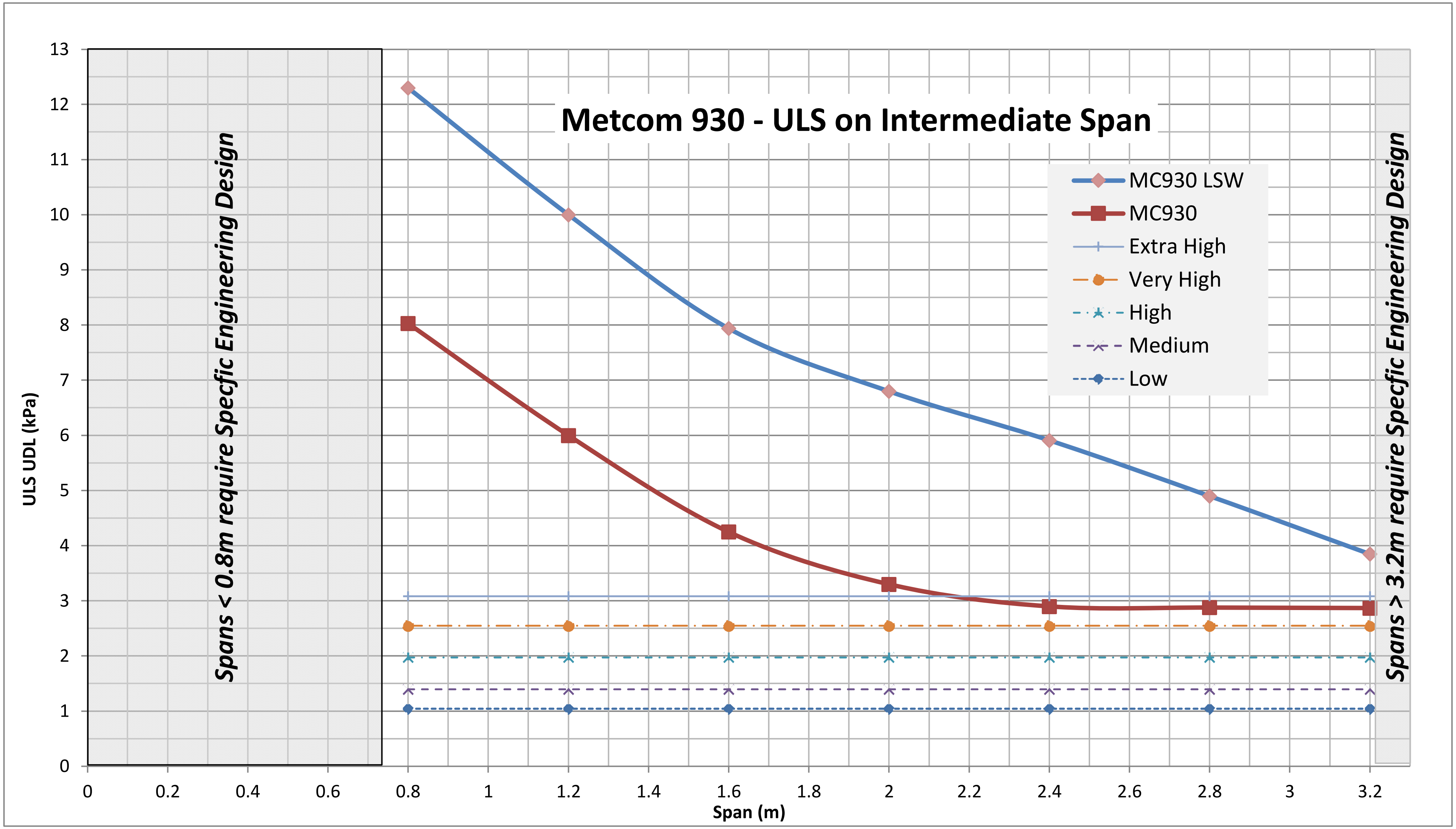

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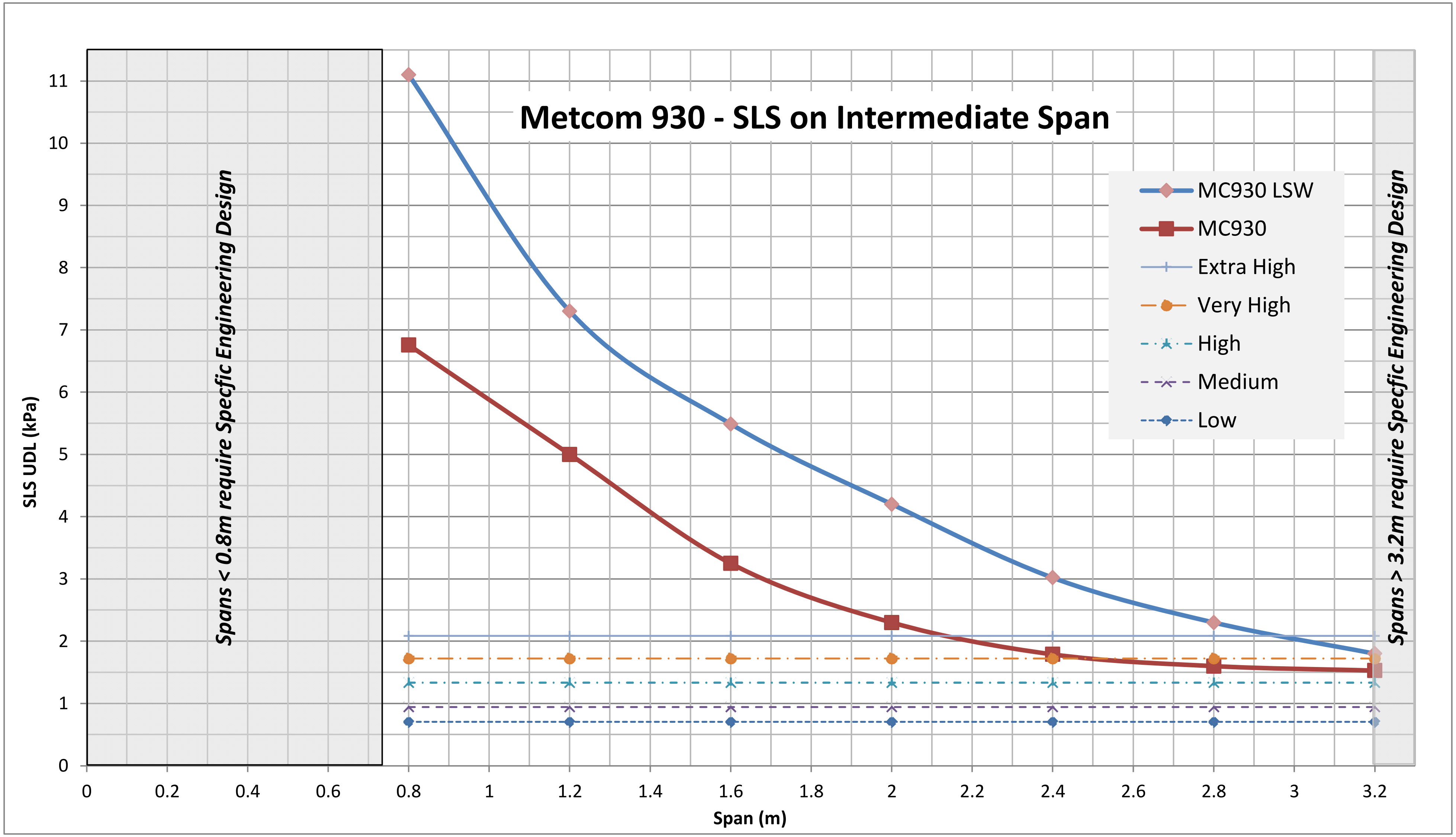

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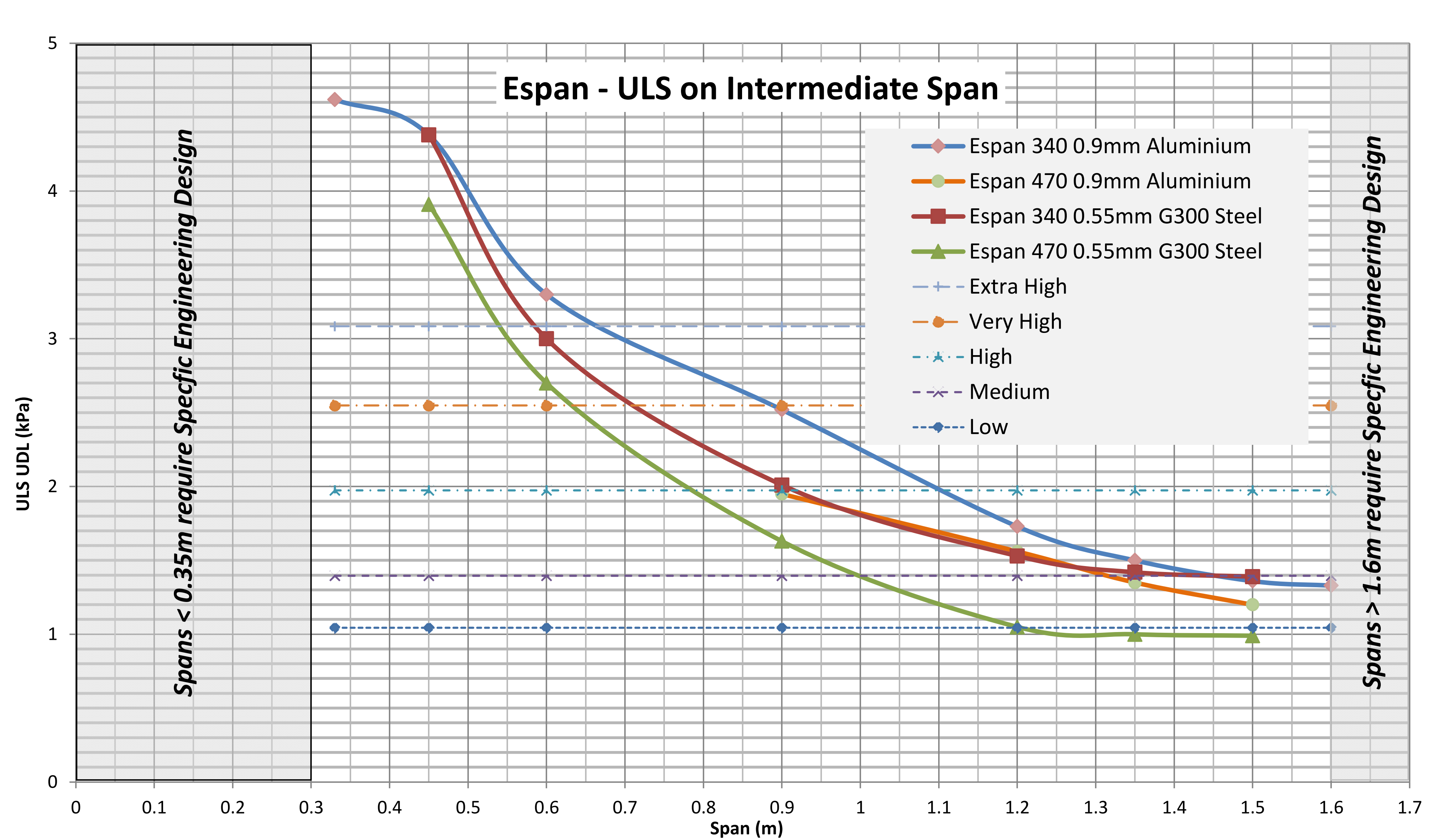

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APPENDIX A: WARM ROOF LOAD/SPAN GRAPHS

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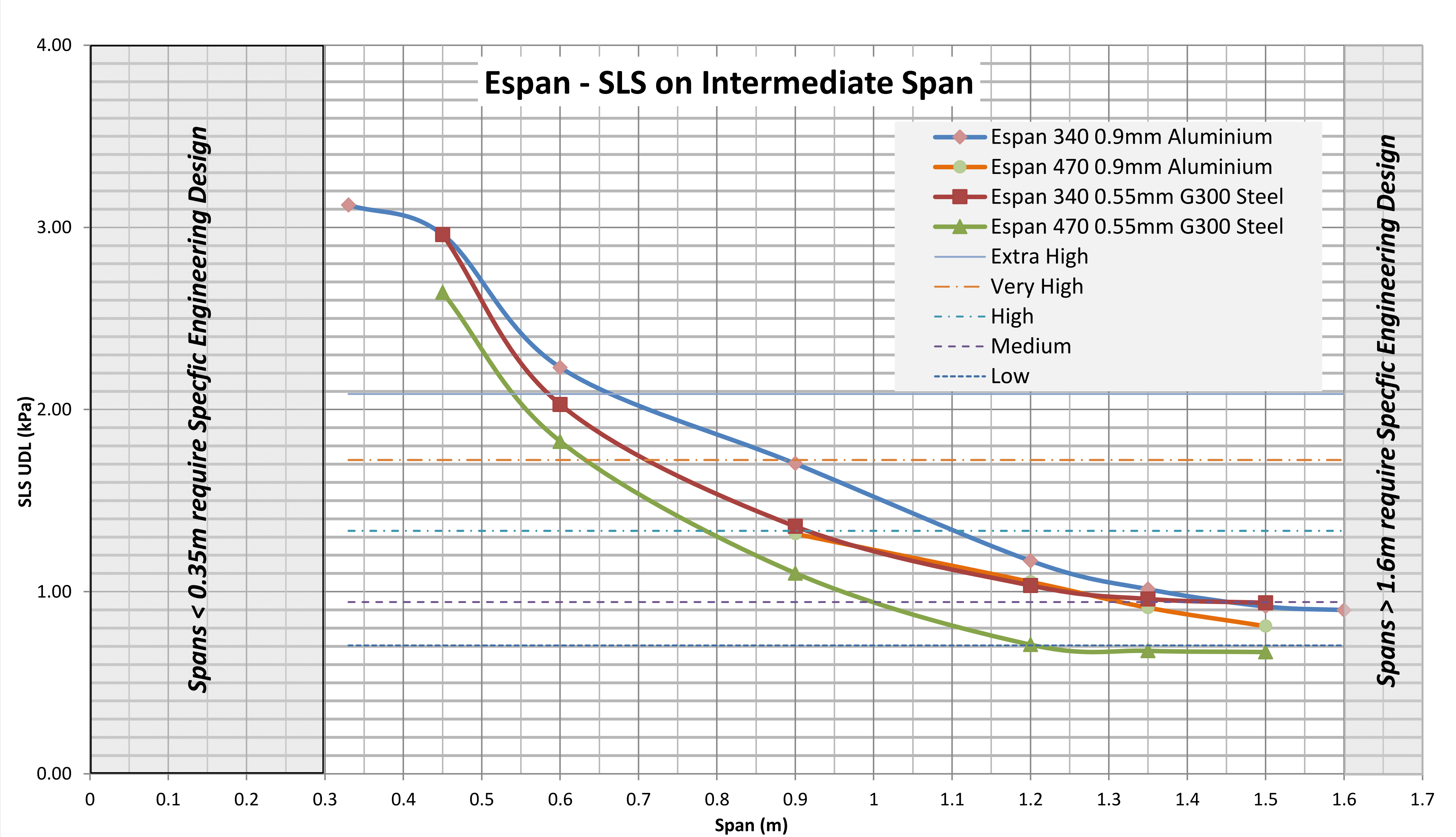

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APPENDIX A: WARM ROOF LOAD/SPAN GRAPHS

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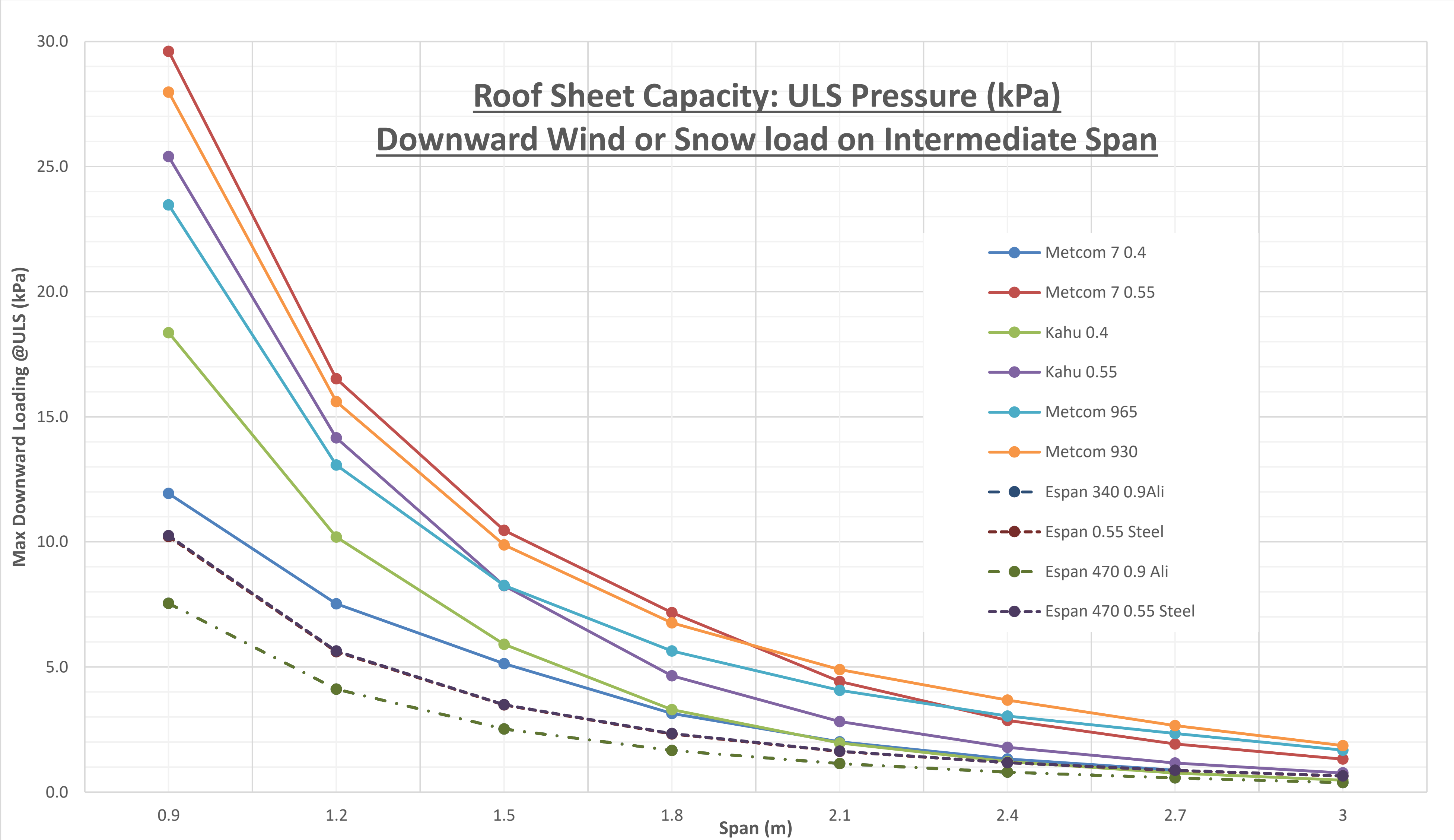


Note: Check pull-out capacity of fixings as this can be the limiting factor

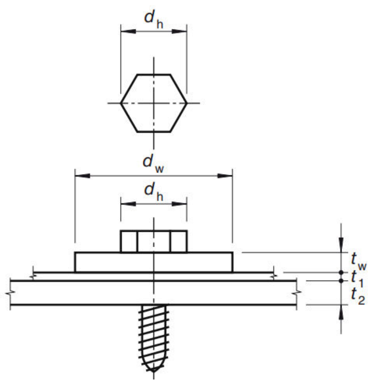
Appendix B: Fixing Design to AS/NZS 4600 & AS/NZS 1664

F1A Steel Sheet (Pull Over)
F1B Aluminium Batten (Pull Out)
F2A Steel Clip on Aluminium Batten
F3A Steel Batten onto Steel Purlin Purlins
F3B Aluminium Batten on Steel Purlin

F1 Roof Sheet to Batten

F1A Tek Screws Through Steel Sheet

Design Capacity of Fasteners **14g Tek Screws in G550 steel roof sheet**



Nominal screw diameter $d_f := 6.3\ mm$

Steel washer diameter $d_w := 16\ mm$ LSW

Steel washer thickness $t_w := 1.27\ mm$ *(Min 1.27mm)*

Screw head diameter $d_h := 2 \cdot d_f = 12.6\ mm$ *(min 8mm)*

Thickness of roof sheet $t_1 := [0.4\ \ 0.55]\ mm$

Tensile strength of roof sheet $f_{u1} := 413\ MPa$

AS/NZS 4600:2018 Clause 5.4.3 - Screwed connections in tension
AS/NZS 4600:2018 Clause 5.4.3.2 - Pull-out and pull-over (pull-through)

Capacity Reduction Factor $\phi := 0.5$ AS/NZS 4600: Tbl 1.6.3

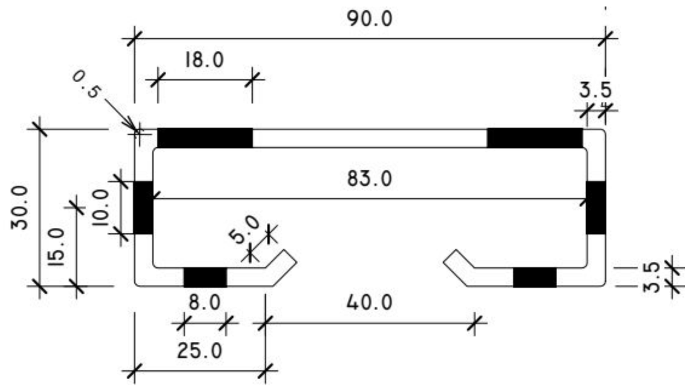
Effective pull-over diameter of washer $d'_w := min\left(d_w, d_h + 2 \cdot t_w + t_1\right) = 15.54\ mm$

Design pull-over capacity $\phi N_{ov} := \overrightarrow{\phi \cdot 1.5 \cdot t_1 \cdot d'_w \cdot f_{u1}} = [1.93\ \ 2.65]\ kN$

F1B) Tek Screws Through Steel Sheet into Aluminium Batten

Element not in contact with fixing head:

Extruded Channel Section
90 x 30 x 3.5



Batten Wall Thicknesses $C' := 3.5\ mm$

AS/NZS 1664:1997 Clause 5.3.3 - Self Tapping Screw Connections in Tension

Material Grade **6061-T6 Aluminium Alloy**

Strength Reduction Factor $\phi_{sc} := 0.5$ Cl 5.3.2

Tensile ultimate $F_{tu2} := 310\ MPa$ (Make It From)

Screw penetration $t_c := C' = 3.5\ mm$

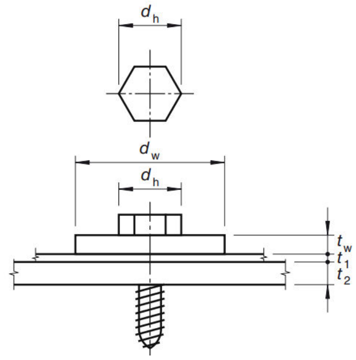
Design Pull out Capacity $\phi P_{ot} := \phi_{sc} \cdot 0.85 \cdot d_f \cdot t_c \cdot F_{tu2} = 2.91\ kN$

F2 Clip to Batten

F2A) Tek Screws through Steel Clip into Aluminium Batten

Design Capacity of Fasteners **10g Tek Screws through G300 clip 1.15mm BMT**

4.1 Pull-over capacity of Steel Clips:
AS/NZS 4600:2018 Clause 5.4.3 - Screwed connections in tension



Nominal screw diameter $d_f := 4.8\ mm$

Steel washer diameter $d_w := 10\ mm$ LSW

Steel washer thickness $t_w := 1.27\ mm$ *(Min 1.27mm)*

Screw head diameter $d_h := 2 \cdot d_f = 9.6\ mm$ *(min 8mm)*

Thickness of clip $t_1 := 1.15\ mm$

Tensile strength of clip $f_{u1} := 340\ MPa$

AS/NZS 4600:2018 Clause 5.4.3.2 - Pull-out and pull-over (pull-through)

Capacity Reduction Factor $\phi := 0.5$ AS/NZS 4600: Tbl 1.6.3

Effective pull-over diameter of washer $d'_w := min\left(d_w, d_h + 2 \cdot t_w + t_1\right) = 10\ mm$

Design pull-over capacity $\phi N_{ov} := \phi \cdot 1.5 \cdot t_1 \cdot d'_w \cdot f_{u1} = 2.93\ kN$

4.2 Pull-out capacity of Aluminium Batten:
AS/NZS 1664:1997 Clause 5.3.3 - Self Tapping Screw Connections in Tension

Strength Reduction Factors $\phi_{sc} := 0.5$ Cl 5.3.2

Element not in contact with fixing head:

Material Grade **6061-T6 Aluminium Alloy**

Tensile ultimate $F_{tu2} = 310\ MPa$

Batten Wall Thicknesses $C' = 3.5\ mm$

Nominal hole diameter $D_h := 7\ mm$

Washer or head diameter $D_{ws} := 13\ mm$ 8.0mm min; 13.0mm max
Washer thickness 1.3mm min

Screw penetration $t_c := C' = 3.5\ mm$

Design Pull out Force $\phi P_{not} := \phi_{sc} \cdot 0.85 \cdot t_c \cdot d_f \cdot F_{tu2} = 2.21\ kN$

$\text{if}\left(min\left(\overrightarrow{\phi P_{not}}\right) < \phi N_{ov}, \text{“Pull out”}, \text{“Pull over”}\right) = \text{“Pull out”}$

Design Tension Capacity $\phi N_{t5} := min\left(\phi N_{ov}, \phi P_{not}\right) = 2.21\ kN$

Thus, aluminium pull out dominates

F3 Batten to Purlin

F3B Tek Screws through Aluminium Batten into Steel Purlin

AS/NZS 1664:1997 Clause 5.3.3 - Self Tapping Screw Connections in Tension

Design Capacity of Fasteners **14g Tek Screws in steel purlin**

Screw / Washer diameter	$d_f := 6.3\ mm$	$d_w := 13\ mm$
Steel washer thickness	$t_w := 1.27\ mm$	*(Min 1.27mm)*
Screw head diameter	$d_h := 2 \cdot d_f = 12.6\ mm$	*(min 8mm)*
Effective pull-over diameter of washer	$d'_w := min\left(d_w, d_h + 2 \cdot t_w + t_1\right) = 13\ mm$	
Batten Wall Thickness	$C' = 3.5\ mm$	
Strength Reduction Factors	$\phi_{sc} = 0.5$	Cl 5.3.2

Pull-over capacity of Aluminium battens:

Element in contact with fixing head:

Material Grade	**6061-T6 Aluminium Alloy**	
Tensile ultimate	$F_{tu2} = 310\ MPa$	
Thickness	$t_1 := C' = 3.5\ mm$	
Nominal hole diameter	$D_h := 7\ mm$	
Washer or head diameter	$D_{ws} := 13\ mm$	8.0mm min; 13.0mm max Washer thickness 1.3mm min
Fixing coefficient	$C := 1.0$	valley fastening
Design Pull over Force	$\phi P_{nov} := \phi_{sc} \cdot C \cdot t_1 \cdot F_{tu2} \cdot \left(D_{ws} - D_h\right) = 3.26\ kN$	

Pull-out capacity of Steel Purlins (as above): **G500 or G450 Steel**

$d_f = 6.3\ mm$

Design capacity (kN)

Pull-out

t_2 (mm)	f_{u2} (MPa)
1.0	520
1.2	520
1.45	520
1.6	480
1.8	480

$$\phi N_{ou} := \overrightarrow{\phi \cdot 0.85 \cdot t_2 \cdot d_f \cdot f_{u2}}$$

$$\phi N_{ou} = \begin{bmatrix} 1.39 \\ 1.67 \\ 2.02 \\ 2.06 \\ 2.31 \end{bmatrix} kN \qquad 2 \cdot \phi N_{ou} = \begin{bmatrix} 2.78 \\ 3.34 \\ 4.04 \\ 4.11 \\ 4.63 \end{bmatrix} kN$$

Design Tension Capacity $\phi N_{t4} := min\left(min\left(\overrightarrow{\phi N_{ou}}\right), \phi P_{nov}\right) = 1.39\ kN$

Thus, aluminium pull over dominates where the purlin thickness exceeds 1.0mm

References

1. AS/NZS 1664.1: 1997- Aluminium Structures, Part 1: Limit state design, Standards New Zealand, 2018
2. AS/NZS 4600: 2018- Cold-formed Steel Structures, Standards New Zealand, 2018

Appendix C: Moments Induced by Downward loading

1) Imposed Point Load

Point Load $P := 1.5 \cdot 1.1\ kN = 1.65\ kN$

2) Max Applied Downward UDL ULS Combinations

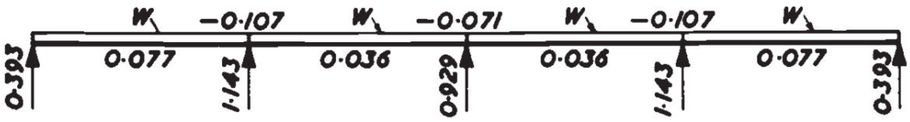
Dead $G := 0.25\ kPa$ Live $Q := 0.25\ kPa$ Wind $W := 0.54\ kPa$

$$ULS1 := 1.35 \cdot G = 0.338\ kPa$$
$$ULS2 := 1.2\ G + 1.5 \cdot Q = 0.675\ kPa$$
$$ULS3 := 1.2\ G + W = 0.84\ kPa$$

UDL $w_d := \max\left(ULS1, ULS2, ULS3\right) = 0.84\ kPa$

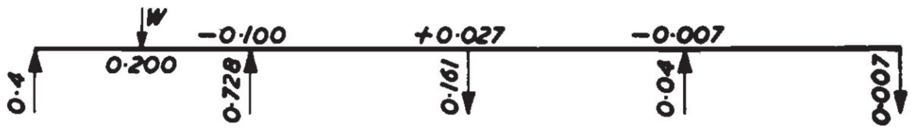
$w_{sls} := G + 0.676 \cdot W = 0.615\ kPa$

Spans Considered $L_D := \begin{bmatrix} 0.6 & 0.9 & 1.2 & 1.5 & 1.8 & 2.1 & 2.4 & 2.7 & 3.0 \end{bmatrix}\ m$ Width $B := 1\ m$



$$M_{dn} := 0.107 \cdot w_d \cdot B \cdot \overrightarrow{\left(L_D\right)^2} = \begin{bmatrix} 0.03 & 0.07 & 0.13 & 0.2 & 0.29 & 0.4 & 0.52 & 0.66 & 0.81 \end{bmatrix}\ kNm$$

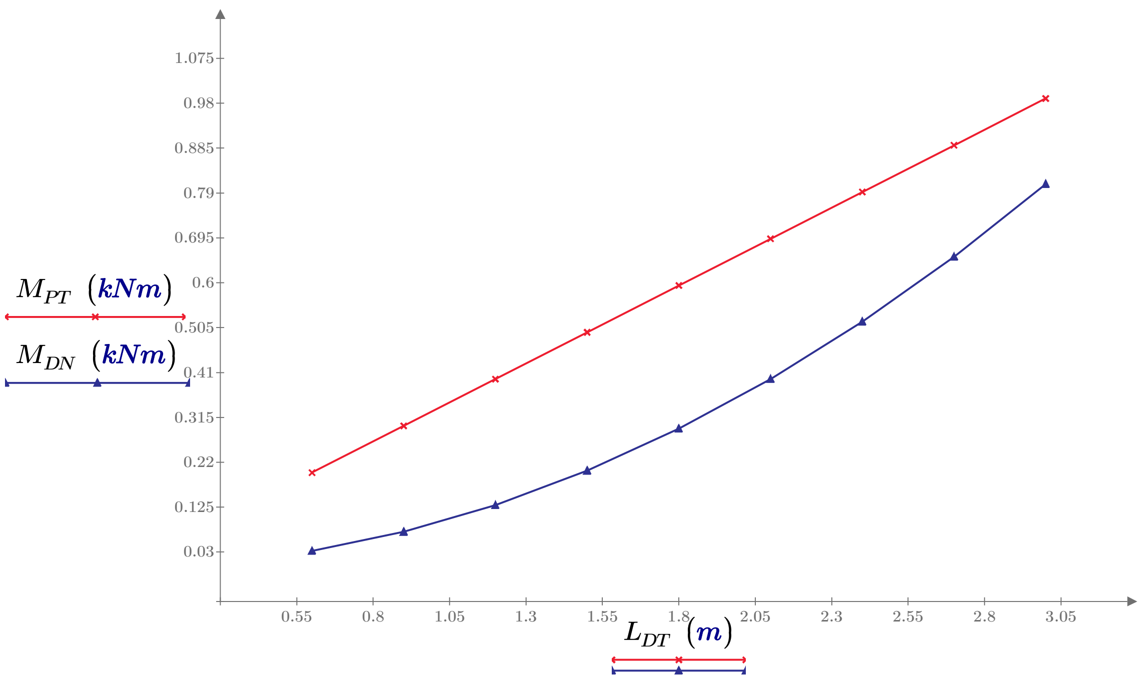
$$V_{dn} := \left(1.143 - 0.5\right)\ w_d \cdot B \cdot L_D = \begin{bmatrix} 0.32 & 0.49 & 0.65 & 0.81 & 0.97 & 1.13 & 1.3 & 1.46 & 1.62 \end{bmatrix}\ kN$$



$$M_{pt} := 0.2 \cdot P \cdot L_D = \begin{bmatrix} 0.2 & 0.3 & 0.4 & 0.5 & 0.59 & 0.69 & 0.79 & 0.89 & 0.99 \end{bmatrix}\ kNm$$

$$V_{pt} := 0.4 \cdot P = 0.66\ kN$$

These are compared with sheet capacities in Appendix F



Appendix D: Properties & Capacities of Roof Sheets

1) Capacities of Steel Roof Sheet Profiles

Capacity Reduction Factor $\phi_b := 0.9$ $\phi_v := 0.9$ AS/NZS 4600 Table 1.6.3

Tensile strength of roof sheet $f_{u1} := 413\ MPa$ $f_{y1} := 413\ MPa$ **G550 steel roof sheet**

$Profile$	D_{rp} (mm)	t_{rp} (mm)	b_p (mm)	b_o (mm)	S_{rp} (mm)	n_{rp}	A_g (mm^2)	I_x (cm^4)	Z_x (cm^3)	S_x (cm^3)	L_{low} (m)
"Metcom 7"	36	0.4	50	933	127	8	527.6	10.5	5.07	6.71	3
"Metcom 7"	36	0.55	50	933	127	8	725.4	14.4	6.97	9.23	3
"Kahu"	32	0.4	19	950	97.5	10	513.7	6.9	4.35	5.35	2.4
"Kahu"	32	0.55	19	950	97.5	10	706.3	9.5	5.99	7.35	2.4
"Metcom 965"	45	0.55	216	1065	322	4	630.9	17.6	5.54	7.72	2.4
"Metcom 930"	45	0.55	142	1010	234	5	666.6	19.2	6.59	9.36	3.2
"Espan 340"	47	0.55	320	344	340	1	674.5	10.6	2.46	3.82	1.5
"Espan 470"	47	0.55	450	474	474	1	674.5	10.5	2.46	3.82	1.2

Youngs Modulus $E_s := 200\ GPa$

Bending Capacity $\phi M_e := \overrightarrow{\phi_b \cdot Z_x \cdot f_{y1}}$ AS/NZS 4600 Cl 3.3.2.2

Shear Buckling Coefficient $k_v := 5.34$ AS/NZS 4600 Cl 3.3.4.1

Youngs Modulus $E := 200\ GPa$

$$EK := \sqrt{\left(\frac{E \cdot k_v}{f_{y1}}\right)} = 51 \qquad 1.415 \cdot EK = 71.956$$

Shear Capacity $$\phi V_1 := \frac{\phi_v \cdot 2 \cdot \overrightarrow{D_{rp} \cdot t_{rp}} \cdot 0.64 \cdot f_{y1}}{S_{rp}}$$ For d/t < EK

Shear Buckling Capacity $$\phi V_2 := \frac{\phi_v \cdot 2 \cdot \overrightarrow{t_{rp}^{\ 2}} \cdot 0.64 \cdot \sqrt{E \cdot k_v \cdot f_{y1}}}{S_{rp}}$$ For EK < d/t < 1.415 EK

$$\phi V_3 := \phi_v \cdot 2 \cdot 0.905 \cdot E \cdot k_v \cdot \left(\overrightarrow{\frac{t_{rp}^{\ 3}}{S_{rp} \cdot D_{rp}}}\right)$$ For d/t > 1.415 EK

Shear Capacity ***Shear Buckling Capacity***

$$Profile = \begin{bmatrix} \text{“Metcom 7”} \\ \text{“Metcom 7”} \\ \text{“Kahu”} \\ \text{“Kahu”} \\ \text{“Metcom 965”} \\ \text{“Metcom 930”} \\ \text{“Espan 340”} \\ \text{“Espan 470”} \end{bmatrix} \quad \frac{D_{rp}}{t_{rp}} = \begin{bmatrix} 90 \\ 65 \\ 80 \\ 58 \\ 82 \\ 82 \\ 85 \\ 85 \end{bmatrix} \quad \phi V_1 = \begin{bmatrix} 53.9 \\ 74.2 \\ 62.5 \\ 85.9 \\ 36.6 \\ 50.3 \\ 36.2 \\ 25.9 \end{bmatrix} \frac{kN}{m} \quad \phi V_2 = \begin{bmatrix} 30.5 \\ 57.6 \\ 39.7 \\ 75.1 \\ 22.7 \\ 31.3 \\ 21.5 \\ 15.4 \end{bmatrix} \frac{kN}{m} \quad \phi V_3 = \begin{bmatrix} 24.4 \\ 63.3 \\ 35.7 \\ 92.8 \\ 20 \\ 27.5 \\ 18.1 \\ 13 \end{bmatrix} \frac{kN}{m}$$

Max Applied Shear $\max\left(V_{dn}, V_{pt}\right) = 1.62\ kN$ Min Shear Capacity $min\left(\phi V_2, \phi V_3\right) = 13\ kN \cdot m^{-1}$

Bending Capacity

$$Profile = \begin{bmatrix} \text{“Metcom 7”} \\ \text{“Metcom 7”} \\ \text{“Kahu”} \\ \text{“Kahu”} \\ \text{“Metcom 965”} \\ \text{“Metcom 930”} \\ \text{“Espan 340”} \\ \text{“Espan 470”} \end{bmatrix} \qquad \phi M_e = \begin{bmatrix} 1.88 \\ 2.59 \\ 1.62 \\ 2.23 \\ 2.06 \\ 2.45 \\ 0.91 \\ 0.91 \end{bmatrix} \, kNm$$

Spans $L_D = \begin{bmatrix} 600 & 900 & 1200 & 1500 & 1800 & 2100 & 2400 & 2700 & 3000 \end{bmatrix} \, mm$

Applied Bending $M_{pt} = \begin{bmatrix} 0.2 & 0.3 & 0.4 & 0.5 & 0.59 & 0.69 & 0.79 & 0.89 & 0.99 \end{bmatrix} \, kNm$

$M_{dn} = \begin{bmatrix} 0.03 & 0.07 & 0.13 & 0.2 & 0.29 & 0.4 & 0.52 & 0.66 & 0.81 \end{bmatrix} \, kNm$

Espan Steel Profile OK up to 2.1m (Max Span 0.9m)
Other Steel Profiles OK up to 3.0m Span

Serviceability Check

Applied Point Load $P_{sls} := 1.1 \, kN$ Applied UDL $w_{sls} = 0.615 \, kPa$ $B = 1 \, m$

Spans Considered $L_D = \begin{bmatrix} 0.6 & 0.9 & 1.2 & 1.5 & 1.8 & 2.1 & 2.4 & 2.7 & 3 \end{bmatrix} \, m$

$PL := \overrightarrow{(L_D)^3} = \begin{bmatrix} 0.22 & 0.73 & 1.73 & 3.38 & 5.83 & 9.26 & 13.82 & 19.68 & 27 \end{bmatrix} \, m^3$

$PLL := \overrightarrow{(L_D)^4} = \begin{bmatrix} 0.13 & 0.66 & 2.07 & 5.06 & 10.5 & 19.45 & 33.18 & 53.14 & 81 \end{bmatrix} \, m^4$

1/Flexural Stiffness

$$PP := \frac{1}{E \cdot I_x} = \begin{bmatrix} 0.048 \\ 0.035 \\ 0.072 \\ 0.053 \\ 0.028 \\ 0.026 \\ 0.047 \\ 0.048 \end{bmatrix} \frac{1}{kN} \cdot \frac{1}{m^2}$$

Permissible deflection

$$L_{DD} := \frac{QQ \cdot L_D}{150} = \begin{bmatrix} 4 & 6 & 8 & 10 & 12 & 14 & 16 & 18 & 20 \\ 4 & 6 & 8 & 10 & 12 & 14 & 16 & 18 & 20 \\ 4 & 6 & 8 & 10 & 12 & 14 & 16 & 18 & 20 \\ 4 & 6 & 8 & 10 & 12 & 14 & 16 & 18 & 20 \\ 4 & 6 & 8 & 10 & 12 & 14 & 16 & 18 & 20 \\ 4 & 6 & 8 & 10 & 12 & 14 & 16 & 18 & 20 \\ 4 & 6 & 8 & 10 & 12 & 14 & 16 & 18 & 20 \\ 4 & 6 & 8 & 10 & 12 & 14 & 16 & 18 & 20 \end{bmatrix} \, mm$$

Midspan Deflection due to 1.1kN point load assuming simply 2-span continuous

$L_D = \begin{bmatrix} 0.6 & 0.9 & 1.2 & 1.5 & 1.8 & 2.1 & 2.4 & 2.7 & 3 \end{bmatrix} \, m$

$$Profile = \begin{bmatrix} \text{“Metcom 7”} \\ \text{“Metcom 7”} \\ \text{“Kahu”} \\ \text{“Kahu”} \\ \text{“Metcom 965”} \\ \text{“Metcom 930”} \\ \text{“Espan 340”} \\ \text{“Espan 470”} \end{bmatrix} \qquad \delta_{pt} := \frac{P_{sls} \cdot PP \cdot PL}{66.89} = \begin{bmatrix} 0.2 & 0.6 & 1.4 & 2.6 & 4.6 & 7.3 & 10.8 & 15.4 & 21.1 \\ 0.1 & 0.4 & 1 & 1.9 & 3.3 & 5.3 & 7.9 & 11.2 & 15.4 \\ 0.3 & 0.9 & 2.1 & 4 & 6.9 & 11 & 16.5 & 23.5 & 32.2 \\ 0.2 & 0.6 & 1.5 & 2.9 & 5 & 8 & 12 & 17 & 23.4 \\ 0.1 & 0.3 & 0.8 & 1.6 & 2.7 & 4.3 & 6.5 & 9.2 & 12.6 \\ 0.1 & 0.3 & 0.7 & 1.4 & 2.5 & 4 & 5.9 & 8.4 & 11.6 \\ 0.2 & 0.6 & 1.3 & 2.6 & 4.5 & 7.2 & 10.7 & 15.3 & 20.9 \\ 0.2 & 0.6 & 1.4 & 2.6 & 4.6 & 7.3 & 10.8 & 15.4 & 21.1 \end{bmatrix} \, mm$$

Utilization Ratio

$$UR_{pt} := \overrightarrow{\frac{\delta_{pt}}{L_{DD}}} = \begin{bmatrix} 4\% & 10\% & 17\% & 26\% & 38\% & 52\% & 68\% & 86\% & 106\% \\ 3\% & 7\% & 12\% & 19\% & 28\% & 38\% & 49\% & 62\% & 77\% \\ 6\% & 14\% & 26\% & 40\% & 58\% & 79\% & 103\% & 130\% & 161\% \\ 5\% & 11\% & 19\% & 29\% & 42\% & 57\% & 75\% & 95\% & 117\% \\ 3\% & 6\% & 10\% & 16\% & 23\% & 31\% & 40\% & 51\% & 63\% \\ 2\% & 5\% & 9\% & 14\% & 21\% & 28\% & 37\% & 47\% & 58\% \\ 4\% & 9\% & 17\% & 26\% & 38\% & 51\% & 67\% & 85\% & 105\% \\ 4\% & 10\% & 17\% & 26\% & 38\% & 52\% & 68\% & 86\% & 106\% \end{bmatrix}$$

All profiles OK for spans up to 2.1m
All profiles 0.55mm thick OK for spans up to 2.7m

Midspan Deflection due to SLS UDL (Down)
assuming 4-span continuous

$$L_D = \begin{bmatrix} 0.6 & 0.9 & 1.2 & 1.5 & 1.8 & 2.1 & 2.4 & 2.7 & 3 \end{bmatrix} \, m$$

$$Profile = \begin{bmatrix} \text{“Metcom 7”} \\ \text{“Metcom 7”} \\ \text{“Kahu”} \\ \text{“Kahu”} \\ \text{“Metcom 965”} \\ \text{“Metcom 930”} \\ \text{“Espan 340”} \\ \text{“Espan 470”} \end{bmatrix}$$

$$\delta_{udl2} := \frac{B \cdot w_{sls} \cdot PP \cdot PLL}{154} = \begin{bmatrix} 0 & 0.1 & 0.4 & 1 & 2 & 3.7 & 6.3 & 10.1 & 15.4 \\ 0 & 0.1 & 0.3 & 0.7 & 1.5 & 2.7 & 4.6 & 7.4 & 11.2 \\ 0 & 0.2 & 0.6 & 1.5 & 3 & 5.6 & 9.6 & 15.4 & 23.4 \\ 0 & 0.1 & 0.4 & 1.1 & 2.2 & 4.1 & 7 & 11.2 & 17 \\ 0 & 0.1 & 0.2 & 0.6 & 1.2 & 2.2 & 3.8 & 6 & 9.2 \\ 0 & 0.1 & 0.2 & 0.5 & 1.1 & 2 & 3.5 & 5.5 & 8.4 \\ 0 & 0.1 & 0.4 & 1 & 2 & 3.7 & 6.3 & 10 & 15.3 \\ 0 & 0.1 & 0.4 & 1 & 2 & 3.7 & 6.3 & 10.1 & 15.4 \end{bmatrix} \, mm$$

Utilization Ratio

$$UR_{udl} := \frac{\overrightarrow{\delta_{udl2}}}{L_{DD}} = \begin{bmatrix} 1\% & 2\% & 5\% & 10\% & 17\% & 26\% & 39\% & 56\% & 77\% \\ 0 & 2\% & 4\% & 7\% & 12\% & 19\% & 29\% & 41\% & 56\% \\ 1\% & 3\% & 8\% & 15\% & 25\% & 40\% & 60\% & 85\% & 117\% \\ 1\% & 2\% & 5\% & 11\% & 18\% & 29\% & 44\% & 62\% & 85\% \\ 0 & 1\% & 3\% & 6\% & 10\% & 16\% & 24\% & 33\% & 46\% \\ 0 & 1\% & 3\% & 5\% & 9\% & 14\% & 22\% & 31\% & 42\% \\ 1\% & 2\% & 5\% & 10\% & 16\% & 26\% & 39\% & 56\% & 76\% \\ 1\% & 2\% & 5\% & 10\% & 17\% & 26\% & 39\% & 56\% & 77\% \end{bmatrix}$$

All profiles OK for spans up to 2.7m (if continuous)
All profiles 0.55mm thick OK for spans up to 3m

2) Capacities of Aluminium Roof Sheet Profiles

$Profile2$	D_{rp} (mm)	t_{rp} (mm)	S_{rp} (mm)	I_x (cm^4)	Z_x (cm^3)	S_x (cm^3)	L_{low} (m)
“Espan 340 Al”	47	0.9	340	17.3	4.02	6.30	0.9
“Espan 470 Al”	47	0.9	470	17.3	4.02	6.30	0.9

Material Grade **0.9mm 5052 H36 BMT Aluminium Alloy** AS/NZS 1664

Strength Reduction Factors $\phi_y := 0.95$ $\phi_b := 0.85$ $\phi_c := 0.85$ $\phi_{cp} := 0.8$ Tbl 3.4(A)

Tensile strength of roof sheet $f_{u1} := 200\ MPa$ Tbl 3.3(A)

Compression strength $F_{cy} := 179\ MPa$ Tbl 3.3(A)

Youngs Modulus $E := 70000\ MPa$ Tbl 3.3(A)

Coefficients $k_t := 1.0$ $k_c := 1.1$ Tbl 3.4(C)

$k_1 := 0.35$ $k_2 := 2.27$ Tbl 3.4(D)

Bending Capacity $\phi M_{e2} := \phi_b \cdot \overrightarrow{Z_x \cdot f_{u1}} = \begin{bmatrix} 0.68 \\ 0.68 \end{bmatrix} kNm$ $f_{u1} = 200\ MPa$

Shear Capacity $\phi V := \frac{\phi_b \cdot 2 \cdot \overrightarrow{D_{rp} \cdot t_{rp}} \cdot 0.6 \cdot f_{u1}}{S_{rp}} = \begin{bmatrix} 25.4 \\ 18.4 \end{bmatrix} kN \cdot m^{-1}$

Buckling constants

Compression in Columns & Beam Flanges

$$B_c := F_{cy} \cdot \left(1 + \sqrt{\frac{F_{cy}}{6900\ MPa}}\right) = 207.83\ MPa$$

$$D_c := \frac{B_c}{20} \cdot \sqrt{\left(\frac{6 \cdot B_c}{E}\right)} \cdot \frac{1}{10} = 0.14\ MPa$$

$$C_c := \frac{2 \cdot B_c}{3 \cdot D_c} = 998.98$$

Compression in Flat Plates Tbl 3.4(C)

$$B_p := F_{cy} \cdot \left(1 + \sqrt{\left(\frac{F_{cy}}{MPa}\right)} \cdot \frac{1}{14.5}\right) = 344\ MPa$$

$$D_p := \frac{B_p}{20} \cdot \sqrt{\frac{6 \cdot B_p}{E}} = 2.96\ MPa$$

$$C_p := \frac{2 \cdot B_p}{3 \cdot D_p} = 77.63$$

AS/NZS 1664:1997 Clause 3.4.16 - Compression in beams (flat plate supported on both edges)

Distance from unsupported edge to toe of fillet $b_b := 14\ mm$ $t_{rp} = \begin{bmatrix} 0.9 \\ 0.9 \end{bmatrix} mm$

Component Thickness $t_{rp} := 0.9\ mm$

Slenderness $S := \frac{b_b}{t_{rp}} = 15.556$

Slenderness Limits $S_1 := \frac{1}{1.6 \cdot D_p} \left(B_p - \left(\frac{\phi_y \cdot F_{cy}}{\phi_b}\right)\right) = 30.473$ $S_2 := \frac{k_1 \cdot B_p}{1.6 \cdot D_p} = 25.472$

Case 1 $S < S_1$ $\phi F_{L1} := \phi_y \cdot F_{cy} = 170.05\ MPa$

Case 2 $S_1 < S < S_2$ $\phi F_{L2} := \phi_b \cdot \left(B_c - 5.1 \cdot D_p \cdot S\right) = -22.6\ MPa$

Case 3 $S > S_2$ $\phi F_{L3} := \frac{\phi_b \cdot k_2 \cdot \sqrt{B_p \cdot E}}{5.1 \cdot S} = 119\ MPa$

Bending Strength $\phi F_{Lpx} := \text{if}\left(S < S_1, \phi F_{L1}, \text{if}\left(S < S_2, \phi F_{L2}, \phi F_{L3}\right)\right) = 170.1\ MPa$

Bending Capacity
Rib Buckling $\phi M := \phi F_{Lpx} \cdot Z_x = \begin{bmatrix} 0.68 \\ 0.68 \end{bmatrix} kNm$ $Profile2 = \begin{bmatrix} \text{“Espan 340 Al”} \\ \text{“Espan 470 Al”} \end{bmatrix}$

$L_D = \begin{bmatrix} 0.6 & 0.9 & 1.2 & 1.5 & 1.8 & 2.1 & 2.4 & 2.7 & 3 \end{bmatrix} m$

$M_{pt} = \begin{bmatrix} 0.2 & 0.3 & 0.4 & 0.5 & 0.59 & 0.69 & 0.79 & 0.89 & 0.99 \end{bmatrix} kNm$

$M_{dn} = \begin{bmatrix} 0.03 & 0.07 & 0.13 & 0.2 & 0.29 & 0.4 & 0.52 & 0.66 & 0.81 \end{bmatrix} kNm$

Aluminium Profiles OK up to 1.8m Span

AS/NZS 1664:1997 Clause 3.4.24 - Shear in webs - unstiffened flat webs

Strength Reduction Factors $\phi_y = 0.95$ $\phi_v := 0.8$ $\phi_{vp} := 0.9$ Tbl 3.4(A)

Min Shear Strength $F_{sy} := 117\ MPa$ $F_{su} := 152\ MPa$ Tbl 3.3(A)

Clear web height $h := min\left(D_{rp} - t_{rp}\right) = 46.1\ mm$

Buckling Constants Tbl 3.3(C)

$$B_s := F_{sy} \cdot \left(1 + \frac{\sqrt[3]{\frac{F_{sy}}{MPa}}}{11.8}\right) = 165.5\ MPa \qquad D_s := \frac{B_s}{20} \cdot \left(\sqrt{\frac{6 \cdot B_s}{E}}\right) = 0.986\ MPa$$

Slenderness Limits $S_1 := \left(B_s - \frac{\phi_y \cdot F_{sy}}{\phi_{vp}}\right) \cdot \frac{1}{1.25 \cdot D_s} = 34.089$ $S_2 := S_1 = 34.089$ Cl 3.1.24

Slenderness $S := \frac{h}{t_{rp}} = 51.222$

$S_2 = 70.936$

Case 1 $S < S_1$ $\phi F_{L1} := \phi_y \cdot F_{sy} = 111.15\ MPa$

Case 2 $S_1 < S < S_2$ $\phi F_{L2} := \phi_{vp} \cdot (B_s - 1.25 \cdot D_s \cdot (S)) = 92.154\ MPa$

Case 3 $S > S_2$ $\phi F_{L3} := \dfrac{\phi_v \cdot \pi^2 \cdot E}{(1.25 \cdot S)^2} = 134.819\ MPa$

Shear Strength $F_s := \text{if}\left(S < S_1, \phi F_{L1}, \text{if}\left(S < S_2, \phi F_{L2}, \phi F_{L3}\right)\right) = 92.2\ MPa$

Shear Capacity $\phi V := \overrightarrow{\dfrac{\phi_v \cdot F_s \cdot 2 \cdot t_{rp} \cdot h}{S_{rp}}} = \begin{bmatrix} 18 \\ 13 \end{bmatrix} \dfrac{kN}{m}$ $Profile2 = \begin{bmatrix} \text{“Espan 340 Al”} \\ \text{“Espan 470 Al”} \end{bmatrix}$

Max Applied Shear $\max\left(V_{dn}, V_{pt}\right) = 1.62\ kN$ Min Shear Capacity $min(\phi V) = 13\ kN \cdot m^{-1}$

Serviceability Check

Applied Point Load $P_{sls} := 1.1\ kN$ Applied UDL $w_{sls} := 0.65\ kPa$ $B = 1\ m$

Spans Considered $L_D := \begin{bmatrix} 0.3 & 0.45 & 0.6 & 0.9 & 1.2 & 1.5 \end{bmatrix} m$

$PL := \overrightarrow{(L_D)^3} = \begin{bmatrix} 0.03 & 0.09 & 0.22 & 0.73 & 1.73 & 3.38 \end{bmatrix} m^3$

$PLL := \overrightarrow{(L_D)^4} = \begin{bmatrix} 8.1 \cdot 10^{-3} & 0.04 & 0.13 & 0.66 & 2.07 & 5.06 \end{bmatrix} m^4$

1/Flexural Stiffness

$$PP := \frac{1}{E \cdot I_x} = \begin{bmatrix} 0.083 \\ 0.083 \end{bmatrix} \frac{1}{kN} \cdot \frac{1}{m^2}$$

Permissible deflection

$$L_{DD} := \frac{QQ \cdot L_D}{150} = \begin{bmatrix} 2 & 3 & 4 & 6 & 8 & 10 \\ 2 & 3 & 4 & 6 & 8 & 10 \end{bmatrix} mm$$

Midspan Deflection due to 1.1kN point load assuming simply 2-span continuous

$L_D = \begin{bmatrix} 0.3 & 0.45 & 0.6 & 0.9 & 1.2 & 1.5 \end{bmatrix} m$

$Profile2 = \begin{bmatrix} \text{“Espan 340 Al”} \\ \text{“Espan 470 Al”} \end{bmatrix}$

$$\delta_{pt} := \frac{P_{sls} \cdot PP \cdot PL}{66.89} = \begin{bmatrix} 0.04 & 0.12 & 0.29 & 0.99 & 2.35 & 4.58 \\ 0.04 & 0.12 & 0.29 & 0.99 & 2.35 & 4.58 \end{bmatrix} mm$$

Utilization Ratio

$$UR_{pt} := \overrightarrow{\frac{\delta_{pt}}{L_{DD}}} = \begin{bmatrix} 2\% & 4\% & 7\% & 16\% & 29\% & 46\% \\ 2\% & 4\% & 7\% & 16\% & 29\% & 46\% \end{bmatrix}$$

Both Espan Aluminium profiles OK for spans up to 1.5m

Midspan Deflection due to SLS UDL (Down) assuming 3-span continuous

$L_D = \begin{bmatrix} 0.3 & 0.45 & 0.6 & 0.9 & 1.2 & 1.5 \end{bmatrix} m$

$Profile2 = \begin{bmatrix} \text{“Espan 340 Al”} \\ \text{“Espan 470 Al”} \end{bmatrix}$

$$\delta_{udl2} := \frac{B \cdot w_{sls} \cdot PP \cdot PLL}{144.93} = \begin{bmatrix} 0 & 0.02 & 0.05 & 0.24 & 0.77 & 1.87 \\ 0 & 0.02 & 0.05 & 0.24 & 0.77 & 1.87 \end{bmatrix} mm$$

Utilization Ratio

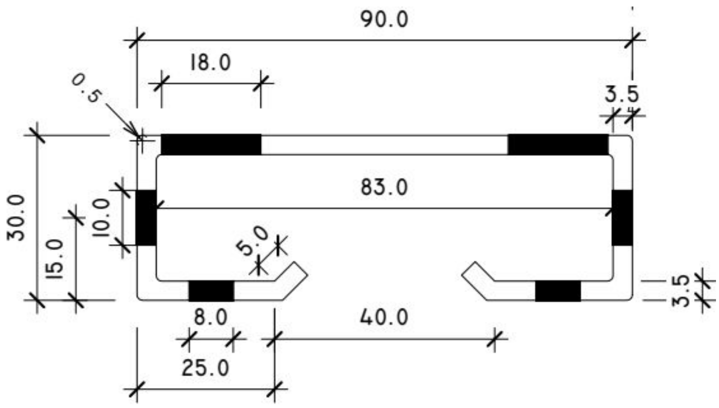
$$UR_{udl} := \overrightarrow{\frac{\delta_{udl2}}{L_{DD}}} = \begin{bmatrix} 0 & 1\% & 1\% & 4\% & 10\% & 19\% \\ 0 & 1\% & 1\% & 4\% & 10\% & 19\% \end{bmatrix}$$

Both Espan Aluminium profiles OK for spans up to 1.5m

Appendix E: Properties & Capacities of Battens

B: 3.5mm Aluminium Channel Battens

1) Section Profile



Material Grade **6061-T6 Aluminium Alloy** AS/NZS 1664

Strength Reduction Factors	$\phi_y := 0.95$	$\phi_u := 0.85$	$\phi_b := 0.85$	$\phi_c := 0.85$	$\phi_{cp} := 0.8$	Tbl 3.4(A)
Tensile strength	$F_{tu} := 310\ MPa$		$F_{ty} := 270\ MPa$	(Make It From)		
Compression strength	$F_{cy} := 241\ MPa$					Tbl 3.3(A)
Shear strength	$F_{sy} := 138\ MPa$		$F_{su} := 165\ MPa$			
Youngs Modulus	$E := 70000\ MPa$					Tbl 3.3(A)
Coefficients	$k_t := 1.0$		$k_c := 1.12$			Tbl 3.4(C)
	$k_1 := 0.35$		$k_2 := 2.27$			Tbl 3.4(D)

Buckling constants

Compression in Columns & Beam Flanges

$$B_c := F_{cy} \cdot \left(1 + \sqrt{\frac{F_{cy}}{15510\ MPa}}\right)$$

$$B_c = 271.041\ MPa$$

$$D_c := B_c \cdot \sqrt{\left(\frac{B_c}{E}\right)} \cdot \frac{1}{10} = 1.69\ MPa$$

$$C_c := 0.41 \cdot \frac{B_c}{D_c} = 65.89$$

Compression in Flat Plates Tbl 3.4(D)

$$B_p := F_{cy} \cdot \left(1 + \left(\sqrt[3]{\frac{F_{cy}}{MPa}} \cdot \frac{1}{21.7}\right)\right)$$

$$B_p = 310.114\ MPa$$

$$D_p := B_p \cdot \sqrt{\left(\frac{B_p}{E}\right)} \cdot \frac{1}{10} = 2.06\ MPa$$

$$C_p := 0.41 \cdot \frac{B_p}{D_p} = 61.6$$

Batten Wall Thicknesses	$C' := 3.5\ mm$
Batten Width	$B_B := 90\ mm$
Batten Depth	$D_B := 30\ mm$
Side Hole Diameter	$D_{HW} := 10\ mm$
Side Hole Spacing	$S_{HW} := 100\ mm$

2) Tension Design Checks

AS/NZS 1664:1997 Clause 3.4.2 - Tension, axial, net section

Material Grade **6061-T6 Aluminium Alloy**

Web Tensile Area $A_{Te} := (S_{HW} - D_{HW}) \cdot C' = 315\ mm^2$

Design Tensile strength $\phi F_t := \phi_y \cdot F_{ty} = 256.5\ MPa$ $\phi F_{tu} := \dfrac{\phi_u \cdot F_{tu}}{k_t} = 263.5\ MPa$

Tensile Capacity $\phi T := 2 \cdot A_{Te} \cdot \phi F_t = 161.6\ kN$ 2 webs

$F_{ty} = 270\ MPa$

Applied Point Load $T' := 2.91\ kN$ $C' = 3.5\ mm$ Max single screw capacity

Utilization $\overrightarrow{\dfrac{T'}{\phi T}} = 1.8\%$

3) Shear Checks

AS/NZS 1664:1997 Clause 3.4.24 - Shear in webs - unstiffened flat webs

Web Shear Area $A_{Ve} := (D_B - D_{HW}) \cdot C' = 70\ mm^2$

Strength Reduction Factors $\phi_y = 0.95$ $\phi_v := 0.8$ $\phi_{vp} := 0.9$ Tbl 3.4(A)

Min Shear Strength $F_{sy} = 138\ MPa$ $F_{su} = 165\ MPa$ Tbl 3.3(A)

Clear web height $h := (D_B - 2 \cdot C') = 23\ mm$

Buckling Constants Tbl 3.3(D)

$$B_s := \overrightarrow{F_{sy} \cdot \left(1 + \frac{\sqrt[3]{\frac{F_{sy}}{MPa}}}{17.7}\right)} \qquad D_s := \overrightarrow{\frac{B_s}{10} \cdot \left(\sqrt{\frac{6 \cdot B_s}{E}}\right)}$$

$B_s = 178.29\ MPa$ $D_s = 1.971\ MPa$

Slenderness Limits $S_1 := \overrightarrow{\left(B_s - \dfrac{\phi_y \cdot F_{sy}}{\phi_{vp}}\right) \cdot \dfrac{1}{1.25 \cdot D_s}} = 13.241$ $S_2 := 14$ Cl 3.4.24

Slenderness $S := \overrightarrow{\dfrac{h}{C'}} = 6.571$

$S_2 = -38.016$

Case 1 $S < S_1$ $\phi F_{L1} := \phi_y \cdot F_{sy} = 131.1\ MPa$

Case 2 $S_1 < S < S_2$ $\phi F_{L2} := \phi_{vp} \cdot (B_s - 1.25 \cdot S \cdot D_s) = 145.9\ MPa$

Case 3 $S > S_2$ $\phi F_{L3} := \dfrac{\phi_v \cdot \pi^2}{(1.25 \cdot S)^2} \cdot E = (8.19 \cdot 10^3)\ MPa$

Shear Strength $F_{s35} := \phi F_{L1} = 131.1\ MPa$ For C' = 3.5mm

Shear Capacity $\phi V_{35} := 2 \cdot A_{Ve} \cdot F_{s35} = 18.354\ kN$ 2 webs

Max Applied Shear $V' := \dfrac{T'}{2} = 1.455\ kN$ Min Shear Capacity $min(\phi V) = 13\ kN \cdot m^{-1}$

Utilization $UR_{shear} := \dfrac{V'}{\phi V_{35}} = 8\%$

Appendix F: Checks on PIR Insulation

Upper limit on downward load depends on compression and bearing capacity of PIR insulation

Strength Reduction Factor $\phi_{cc} := 0.8$

Compressive Strength of core $f_{cc} := 110\ kPa$

Tensile Strength of core $f_{ct} := 100\ kPa$

Downward Load Upper Limit $w_{pir} := \phi_{cc} \cdot f_{cc} = 88\ kPa$

Upward Load Upper Limit $w_{ct} := \phi_{cc} \cdot f_{ct} = 80\ kPa$