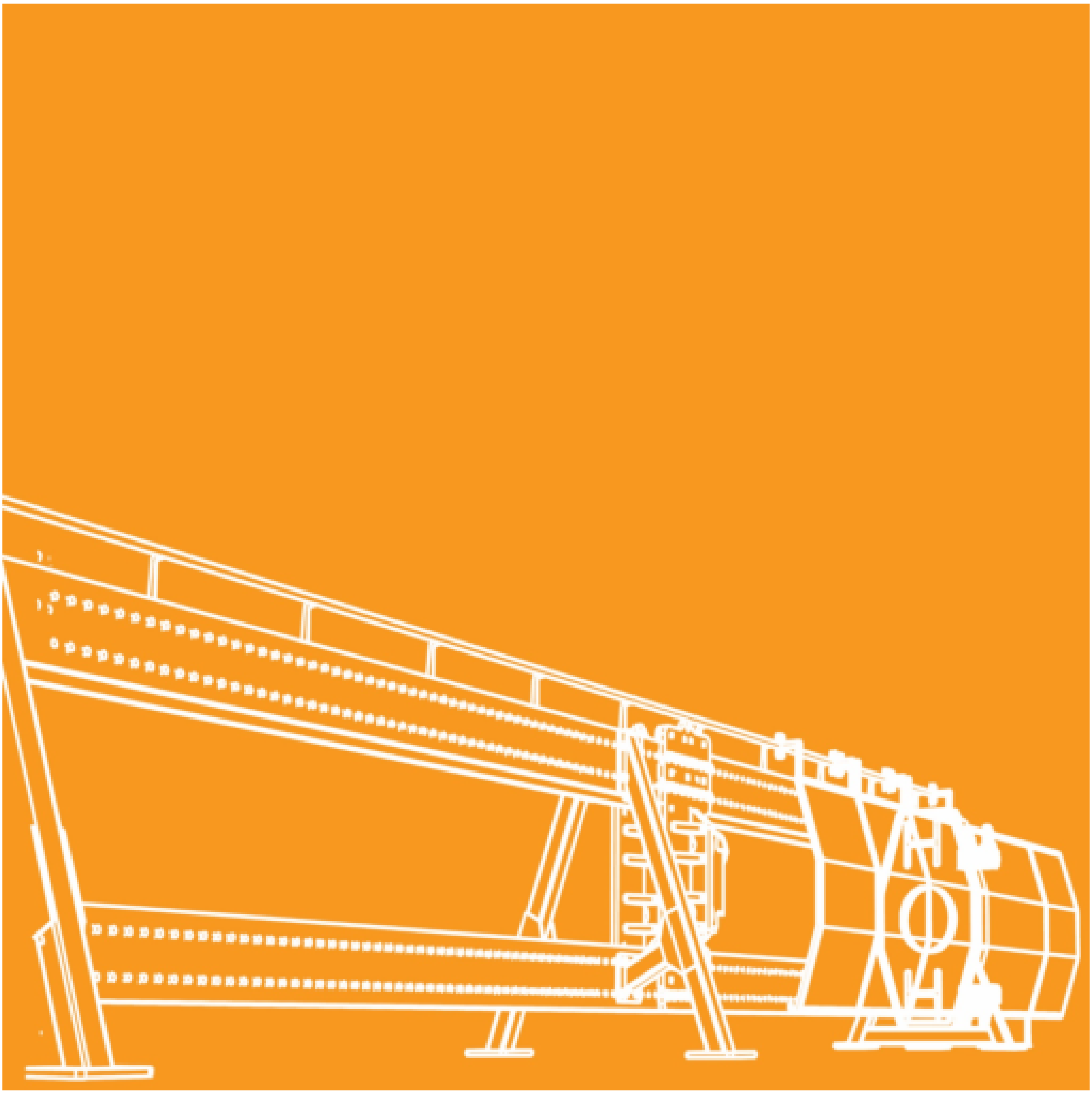

Viking Roofspec WarmSpan²

Structural Testing

Revision: 1.4
16/06/2023
Project: 144942.00

Holmes Solutions

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Revision No:	Date	Revision
1.0	27 February 2023	Final report released
1.1	4 April 2023	Minor correction to section 3.2 reflecting revised roof build up
1.2	13 April 2023	Further correction to section 3.2 regarding roof build up.
1.3	8 June 2023	Inclusion of steel tray substitutes, minor edits
1.4	16 June 2023	Minor edits

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1 EXECUTIVE SUMMARY

Holmes Solutions were commissioned by Viking Roofspec to provide structural testing of the WarmSpan^2 product. Holmes Solutions had previously performed a system analysis of the WarmSpan^2 design on behalf of Viking Roofspec, prior to proceeding to testing.

Viking Roofspec have updated their WarmSpan product to meet the new energy efficiency requirements of the NZBC Clause H1 (H1/AS1, 5th edition, and H1/AS2, 1st edition, amendment 1). The updated product, named WarmSpan^2, consists of a vapour barrier laid on the substrate, and a Polyisocyanurate (PIR) panel, mechanically fixed to the roofing substrate below with plastic plug washers and screws. The system is clad with a DensDeck coverboard, adhered to the PIR, and covered by a roofing membrane (Figure 1-1).

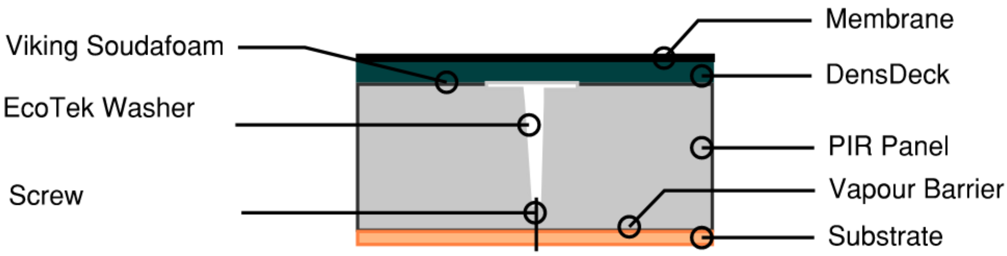


Figure 1-1. Viking RoofSpec Example Build Up

The roofing substrate is designed to resist the full wind loading without composite action. Any wind loads on the surface are transferred by the adhesives to the PIR panel, which then loads the washers and screws in withdrawal.

Testing was carried out to assess structural performance aspects, including fixing capacity, adhesive strength, and simulated wind uplift testing to assess strength and deformation compatibility between the load resisting roof substrate and the loaded WarmSpan^2 roof build up.

Plastic washer pull-through testing was carried out using a 135 mm Conqueror PIR panel and EcoTek 50 mm x 105 mm plastic washers. Using AS NZS 1170.0 the capacity of the washer in PIR was determined to be 1.14 kN. This was less than the withdrawal strength obtained through testing of both the Carlisle HP-X fastener in Steel & Tube 0.55 mm BMT ST900 roof sheeting and the Carlisle HD14-10 fastener from a 26 MPa concrete slab.

Adhesive pull off tests were conducted on a selection of three membranes: Enviroclad, Bitumen Torch-On, and Bitumen Halley P Peel & Stick. The Enviroclad membrane was trialled with two different adhesives: CavGrip and SureWeld. The minimum factored value from the membranes, processed using AS NZS 1170.0 Appendix B1, was 24.8 kPa.

Point load testing of the plywood substrate was carried out on 12 specimens. Each specimen consisted of 17 mm EcoPly plywood on purlins at 900 mm centres. This testing demonstrated the ability of the bare plywood to support loads of 2.41 kN, without the need for additional blocking except at roof edges.

A total of eight WarmSpan^2 systems were tested, with four affixed to 17 mm Ecoply and 4 affixed to Steel & Tube ST900 0.55 mm BMT roofing. Three of each substrate were subjected to pseudo-static serviceability and ultimate limit state loads. This testing determined a Serviceability Limit State (SLS) capacity of 3.08 kPa and an Ultimate Limit State (ULS) capacity of 4.32 kPa with the tested washer arrangement.

The fourth specimen of each substrate was subjected to cyclic loading of 1000 cycles between 40% to 80%, 45% to 90% and 50% to 100% of the factored SLS loading to establish the ability of the system to withstand repeat loading. After inspection, the samples were then loaded to failure. Both substrates achieved the factored capacity of the earlier SLS/ULS tests.

The data obtained through testing was used to generate a suggested fixings chart, which is repeated below.

Table 1-1. Proposed fastener quantity for 2400 mm x 1200 mm PIR fixed to 17 mm Ecoply plywood sheeting or ST900 roofing

NZS 3604 Wind Zone/ wind pressure	Corner [no. off]	Edge 1 [no. off]	Edge 2 [no. off]	Typical [no. off]
Low	8	8	8	8
Medium	9	8	8	8
High	12	10	8	8
Very High	15	13	10	8
Extra High	18	15	12	8
6.5kPa[1]	26			

Note 1: 6.5kPa design wind pressure is outside the scope of NZS 3604, and specific engineering design is required.

2 INTRODUCTION

Viking Roofspec have modified the design of the externally insulated warm roof system, "WarmSpan^{2}" to meet the updated requirements of the New Zealand Building Code (NZBC) Clause H1 – Energy Efficiency (H1/AS1, 5th edition, and H1/AS2, 1st edition, amendment 1). Viking Roofspec have used this opportunity to also modify the construction of the system, including using mechanical fixings to attach the Polyisocyanurate (PIR) insulation panel to the roof structure below.

Subsequently, Holmes Solutions LP were commissioned to provide structural testing to assist in the design process. This testing included component testing of the mechanical fixings and adhesives, the results of which have then been used to inform the design of the system alongside code-derived values. The constructed system was then subjected to simulated wind loading to determine performance under Serviceability Limit State (SLS), Ultimate Limit State (ULS) and cyclic loading.

Point load testing was then carried out on bare plywood samples to demonstrate that a worker could move across the bare sheeting during construction.

3 TECHNICAL DISCUSSION

3.1 Test Location

All testing was completed in the Holmes Solutions LP testing facility, located at 7 Canterbury Street, Hornby, Christchurch.

3.2 Test Articles

3.2.1 Viking Roofspec Build Up

The Viking Roofspec system (Figure 3-1) is built up from a vapour barrier, a Polyisocyanurate (PIR) panel, a DensDeck gypsum coverboard and a waterproofing membrane. The membrane is adhered to the coverboard using an adhesive, and the coverboard is then attached to the PIR using Viking Soudafoam. The PIR panel is then secured using screws in insulated plastic plug washers to clamp the system to the substrate. The substrate may be timber, concrete, roofing sheeting or steel tray.

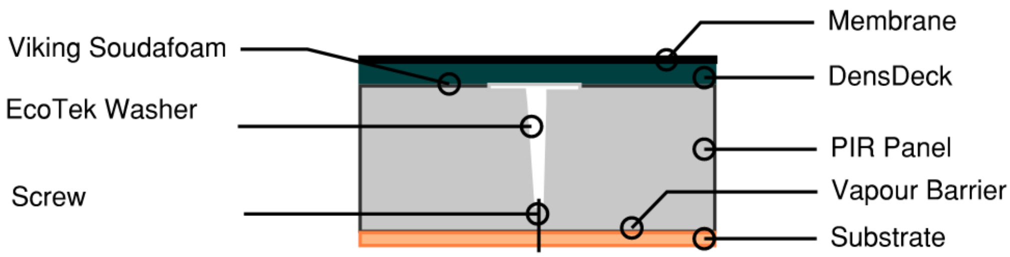


Figure 3-1. Viking RoofSpec Example Build Up

3.2.2 Viking Roofspec Components

Further information on the components referred to in this report is provided below.

- Substrate – the structural roofing material, either:
  - Plywood - 17 mm, 5 ply (17-38-5) Carter Holt Harvey Ecoply F8/F5 with plastic polypropylene tongue and groove edges. Alternatively, structural plywood of greater than or equal to 17mm thickness without a tongue and groove edge, with the same or better mechanical properties, may be adopted, with additional blocking at sheet edges (note this alternative was not tested).
  - Steel – Steel and Tube ST900 (Figure 3-2), a 0.55 mm Base Metal Thickness (BMT) steel roof sheeting. Note that the ST900 profile will be installed inverted as shown in Figure 3-2, to

maximise the area available to install the fixings from the roof build up. Alternative steel substrates are:

- Steel and Tube ST7 0.55mm BMT profile,
- Metalcraft roofing 'Metcom 7' 0.55mm BMT profile,
- Dimond Roofing 'Brownbuilt 900, 0.55mm BMT profile,
- Roofing Industries 'MultiRib 0.55mm BMT profile.

Note that these alternatives were not physically tested, however through calculation have been shown to be suitable alternative substrates for up to 1.8m spans, except the BrownBuilt 900 profile, which is suitable for up to 1.6m spans. Refer to the 'Metal Roof Substrate Substitution' report in 10.4Appendix D for more details.

- Polyisocyanurate (PIR) panels - a 135 mm thick, aluminium foil faced insulated panel manufactured by Conqueror. Additional testing was subsequently completed on 85 mm thick PIR.
- Plastic washers – a EJOT EcoTek 50 mm diameter x 105 mm long plastic roofing washer (EJOT EcoTek 110-180 -105/120).
- Screw fixings, used in combination with the plastic washers, sandwich the PIR to the substrate, and are either a Carlisle HP-X fastener (5.13mm shank diameter) for fixings made to roofing steel or plywood, or a Carlisle HD14-10 fastener for fixings made to concrete. Screws into plywood or steel should penetrate through the substrate a minimum of 10mm to ensure a complete fixing. Screws into concrete should be installed to a minimum depth of 25mm.
- Viking Soudafoam adhesive, used to bond the DensDeck to the PIR panel.
- DensDeck Prime roof board - a 6.4 mm glass mat faced gypsum coverboard, manufactured by Georgia-Pacific Gypsum.
- Membrane – a waterproofing membrane. Multiple variants may be used and are discussed further in 7.2.1 Membrane Specimens.
- The plywood substrate was fixed to the underlying 190x45 SG8 rafters with 10gx50mm wood screws at 150mm o/c on edges, and 200mm o/c through the field
- The steel substrate was fixed to 190x45 SG8 rafters with 12g x 55mm hex head tek screws at each trough.

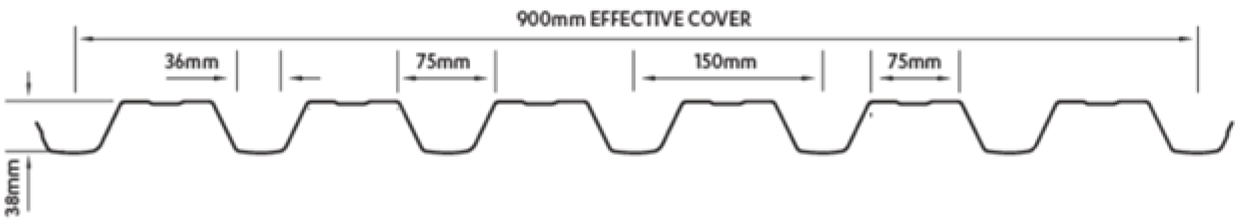


Figure 3-2. ST900 Profile (Note: Installed inverted as shown)

3.3 The Use of Test Data in Design

AS/NZS 1170.0:2005 (including A1, A2, A3, A4, A5) Structural design actions, Part 0: General principles contains *Appendix B: Use of test data in design.*

Appendix B contains provisions for the use of observations and data from testing in design. Section B3 discusses the use of prototype testing to demonstrate the ability of a population of items to satisfy a design limit state. It is not applicable to testing structural models, nor to the establishment of general design criteria or data.

Clause B3.2 covers the use of testing to determine the design capacity of specific products or assemblies. The design capacity should not exceed the minimum value of the testing, divided by the appropriate value, known as k_t. k_t allows for variability of the structural units, and the variability should be established based on the potential variation of the materials and fabrication. The values of k_t are given below in Table 3-1.

Table 3-1. Values of k_t from AS/NZS 1170.0:2005

TABLE B1

VALUES OF k_t TO ALLOW FOR VARIABILITY OF STRUCTURAL UNITS

Number of units to be tested	Coefficient of variation of structural characteristics (V_{sc}), percent						
	5	10	15	20	25	30	40
1	1.20	1.46	1.79	2.21	2.75	3.45	5.2
2	1.17	1.38	1.64	1.96	2.36	2.86	3.9
3	1.15	1.33	1.56	1.83	2.16	2.56	3.3
4	1.15	1.30	1.50	1.74	2.03	2.37	2.9
5	1.13	1.28	1.46	1.67	1.93	2.23	2.7
10	1.10	1.21	1.34	1.49	1.66	1.85	2.1

NOTE: For values between those listed in the Table, interpolation may be used. Extrapolation is not permitted.

Clause B3.4 discusses the test load, which should be applied such that the distribution and duration represent the forces the system is deemed to be subjected.

3.4 Test Programme

A staged testing programme was developed to demonstrate the capacity of the Viking Roofspec WarmSpan[2] warm roof product line. The programme included testing of individual components, such as fasteners, and system testing of portions of a representative roof. The component testing and its associated report section are given in Table 3-2, and the system testing programme and associated report sections are given in Table 3-3.

Table 3-2. Component Test Programme

Report Section	Test Type	Component	Qty
5	Pull out / Withdrawal	Carlisle HP-X fasteners in ST900 roofing	5
5	Pull out / Withdrawal	Carlisle HD-14 fasteners in concrete	7
6	Washer pull-through	EJOT EcoTek 50 mm x 105 mm plastic washer in PIR	5
7	Pull off	Various waterproofing membranes	5 – 6 ea.
7	Pull off	Viking Soudafoam adhesive	5

Table 3-3. System Testing Program

Report Section	Test Type	System	Qty
8	Point loading (various locations)	Plywood sheathing on purlins	3 per location (12 total)

Report Section	Test Type	System	Qty
9	Uniformly Distributed Load (SLS and ULS)	WarmSpan² on plywood substrate	3
9	Uniformly Distributed Load UDL (SLS and ULS)	WarmSpan² on ST900 substrate	3
9	Uniformly Distributed Load UDL (Cyclic and ULS)	WarmSpan² on plywood substrate	1
9	Uniformly Distributed Load UDL (Cyclic and ULS)	WarmSpan² on ST900 substrate	1

4 TEST EQUIPMENT

4.1 Support Frame

System testing was completed on the Holmes Solutions strong floor. A support frame was created from structural steel universal column (UC) sections and rectangular hollow sections. The support frame consisted of a central staple frame and corner posts, which supported two UCs on edge. The staple frame also supported the hydraulic actuator.

A 45 mm x 190 mm timber stringer was bolted to each UC beam, allowing the samples to be fixed to the frame with LumberLok joist hangers and LumberLok multigrips (Figure 4-1).

Figure 4-1. Test Frame

4.2 Shimadzu Universal Test Machine 1 (UTM1)

A Shimadzu UH-600 servo-hydraulic controlled universal test machine (UTM1) was used to perform small scale tests of the screws, washers, and PIR. The UTM1 has a load capacity of 600 kN, a maximum stroke of 250 mm, and a peak table velocity of 150 mm/min. The machine control and data acquisition are handled using the embedded Shimadzu control system.

The UTM1 is calibrated annually in accordance with the requirements of our ISO 17025 accreditation and is deemed to be a Class-1 calibrated test machine capable of applying a given load with an accuracy of ± 1 %.

4.3 Compression Testing Machine 1 (CTM1)

A Laryee JYS2000 compression test machine (CTM1) was used to perform concrete cylinder compressive tests. The CTM1 has a maximum stroke of 20 mm and can apply a maximum force of 2 MN.

The CTM1 is calibrated annually in strict accordance with the requirements of our ISO 17025 accreditation and is deemed to be a Class-1 calibrated test machine capable of applying a given load with an accuracy of ± 1 %.

4.4 Data Acquisition

Raw force and displacement data were sampled and recorded at a rate of 0.5 Hz using the Delta Computer System RMC150 controller.

4.5 Force Measurement

The applied force was measured using a 250 kN PL Ltd load cell placed in line between the hydraulic actuator and an attachment clevis.

Scaling of the load cell and data acquisition, in the complete measurement chain, was conducted using a calibrated universal testing machine, following in-house procedures. The load cell is deemed to be class 2 calibrated in tension and compression.

4.6 Displacement Measurement

Displacement during system testing was measured via string potentiometers, placed at the locations discussed in the relevant test methodology. Each string potentiometer was supported by a rigid support structure and positioned in line with the actuator's line of action.

5 FASTENER PULL OUT TESTING

5.1 Background

5.1.1 Fasteners in Plywood

The pull-out strength of fasteners in plywood can be calculated using *NZS 3603:1993 Timber structures* standard or the newly released *NZS AS 1720.1:2022 Timber structures*. At the time of writing, *NZS 3603:1993* is still cited within the New Zealand Building Code.

Based on calculations to NZS 3603:1997 and NZS AS 1720.1:2022, it was expected that the pull out (withdrawal) strength of the fasteners in plywood would exceed the capacity of the plastic washer in the PIR panel.

Therefore, the fasteners in plywood were not tested in this phase, and instead assessed as part of the system testing using a plywood substrate.

5.1.2 Fasteners in Steel Sheeting

Fastener pull out testing was used to assess the capacity of the fasteners and compare to values calculated using AS/NZS 4600:2018 Cold-formed steel structures. It was desired to accurately determine the pull-out strength of the fasteners to efficiently design the roof system for wind uplift (suction) loads.

A custom fixture was used to support the screw head, and a second fixture used to retain the ST900 steel sheeting. Force and displacement were recorded directly by the test machine.

5.1.3 Fasteners in Concrete

Indicative testing was carried out to investigate the withdrawal strength of the Carlisle HD14-10 fasteners from a concrete slab.

A custom fixture was used to support the screw head, which was contained inside a 100NB pipe. The 100 mm internal diameter of the pipe was selected to allow a shallow, 35° failure cone to form around the without influencing the cone (Figure 5-1).

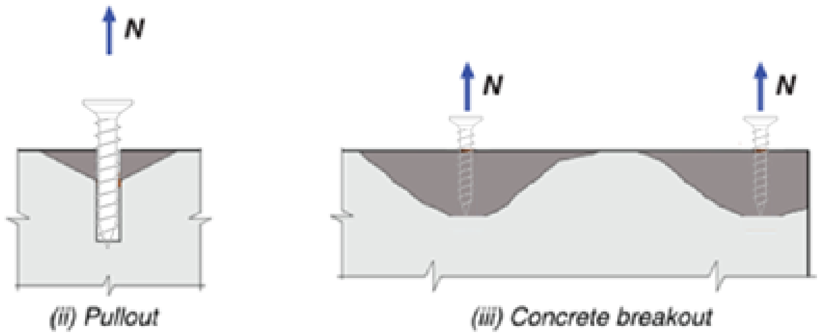


Figure 5-1. Pull Out and Break Out Failure Modes (ACI 318-19)

Load was applied via a hydraulic cylinder atop the pipe. Peak force was recorded through data acquisition hardware attached to the pancake load cell.

5.2 Test Articles

5.2.1 Carlisle HP-X Fastener in Steel & Tube ST900 Metal Roofing

Six samples were prepared by Holmes Solutions. Due to a supply error, each sample consisted of a section of Steel & Tube ST900, with a nominal Base Metal Thickness of 0.40 mm, instead of the specified 0.55 mm BMT. The samples measured 300 mm by 300 mm. A single Carlisle HP-X fastener was fixed through the centre of the sheeting.

5.2.2 Carlisle HD14-10 Fastener in Concrete

A concrete slab of 100 mm thickness was cast. The slab was cast using concrete with the following properties:

- Specified 28-day f'c = 20 MPa
- 19 mm maximum aggregate
- No Supplementary Cementitious Materials (SCMs)

A sheet of SE92 reinforcing mesh was placed 20 mm from the bottom face of the specimen for strength during transport.

The sample set for seven days at the precast yard, before being transported to Holmes Solutions' Canterbury Street facility where it continued to set.

On the day of testing, Carlisle HD 14-10 fasteners were inserted into 5 mm diameter drilled holes, to an embedment of 25 mm in accordance with Carlisle's product documentation.

5.3 Test Methodology

5.4 Test Procedure

5.4.1 Fasteners in Steel Sheeting

- The test article was supported on the reaction frame.
- The crosshead was manually displaced until the steel sheet was supported by the frame fixture.
- The load cell was zeroed.
- Load was applied at a constant velocity of 10 mm per minute.
- The test was continued until failure, defined as when the fastener pulled out of the steel sheeting.

5.4.2 Fasteners in Concrete

- The test article was supported in the custom fixture.
- The hydraulic cylinder was displaced manually until failure.
- Peak load was recorded.

5.5 Results and Observations

5.5.1 Fasteners in Steel Sheeting

Six samples were tested. All six samples failed from the screw pulling out of the hole, leaving an upturned lip (Figure 5-2).

Figure 5-2. Carlisle HP-X fastener pulling out of ST900 sheeting

Figure 5-3. Carlisle HP-X fastener showing upturned lip

The crosshead displacement is plotted against the applied load in Figure 5-4, with the maximum loads achieved summarised in Table 5-1. Note that the crosshead displacement is larger than the displacement of the screw relative to the sheeting, as the sheeting deforms significantly under load (Figure 5-5).

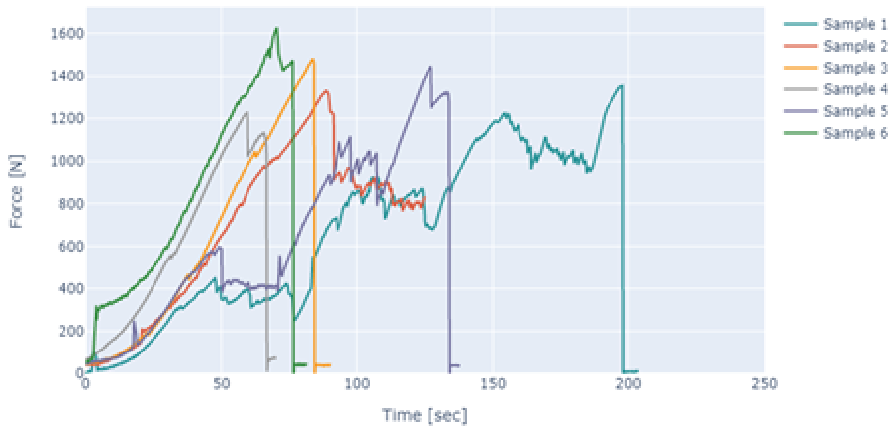


Figure 5-4. Carlisle HP-X fastener in ST900 sheeting force-displacement results

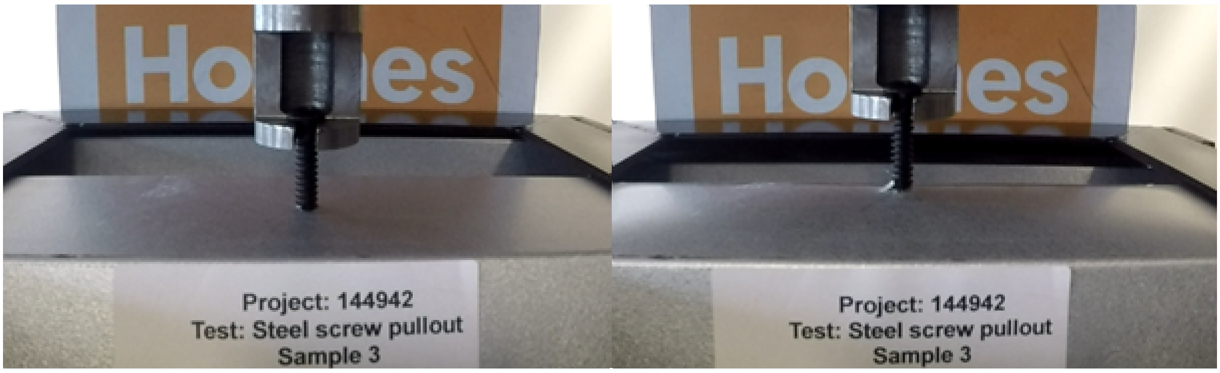


Figure 5-5. ST900 deforming under withdrawal load

Table 5-1. Carlisle HP-X fastener in 0.40 mm BMT ST900 sheeting peak force results

Test	Result (N)
1	1,353
2	1,331
3	1,481
4	1,231
5	1,444
6	1,627

A statistical summary of the test results is provided in Table 5-2. The value determined using AS NZS 1170.0:2002 Table B1 was 0.98 kN, where the coefficient of variation of structural characteristics was determined from the test results alone.

Table 5-2. Carlisle HP-X fastener in 0.40 mm BMT ST900 sheeting summary results

Parameter	Value
Number of Tests	7
Mean	1,411 N
Min	1,230 N
Std. Dev. (Sample)	138 N
CoV (Sample)	9.8%
k_t	1.26
Min/ k_t	977 N

After testing, it was determined that the 0.40 mm BMT variant had incorrectly been delivered to the lab. Therefore, these results are considered conservative as the 0.55 mm BMT variant will be used for system testing.

The calculated value using AS NZS 4600:2018 (for the 0.40 mm BMT variant) was 0.63 kN. Based on the test results shown, it appears AS NZS 4600:2018 provides a conservative estimate of the screw capacity. Due to the unknown characteristics of the metal used (yield strength, location of screw etc.) it was decided that use of the calculated value was appropriate.

5.5.2 Fasteners in Concrete

Testing was conducted 26 days after the concrete was poured. Two 100 mm diameter x 200 mm tall cylinders were tested in the compressive test machine (CTM1) on the day of testing. The cylinders had an average compressive strength of 26.9 MPa.

The tests conducted (Figure 5-6) showed the failure of the concrete around the fastener. The fastener itself did not fail through steel tensile yielding or rupture.

Figure 5-6. Carlisle HD14-10 fasteners after loading in concrete

The raw data is provided in Table 5-3.

Table 5-3. Carlisle HD14-10 fasteners in concrete peak force results

Test	Result (N)
1	9,565
2	8,326
3	8,914
4	7,456
5	8,839
6	10,354
7	8,077

Summary statistical data is provided in Table 5-4. It was observed that the characteristic capacity of 7.3 kN was far larger than the loads achieved with the plastic washer (Section 6.4 of this report), therefore it was unlikely the concrete fixings would control the design.

Table 5-4. Carlisle HD14-10 fasteners in concrete summary results

Parameter	Value
Number of Tests	7
Mean	8,790 N
Min	7,456 N
CoV	10.1%
Characteristic (5%ile)	7,323 N

6 PLASTIC WASHER PULL THROUGH TESTING

6.1 Background

Plastic washer pull-through testing (Figure 6-1) was used to assess the capacity of the plastic plug washer to hold down the PIR substrate during a wind uplift (suction) event. This captured potential failure modes including PIR crushing/bearing failure, washer head bending, and failures at the screw head.

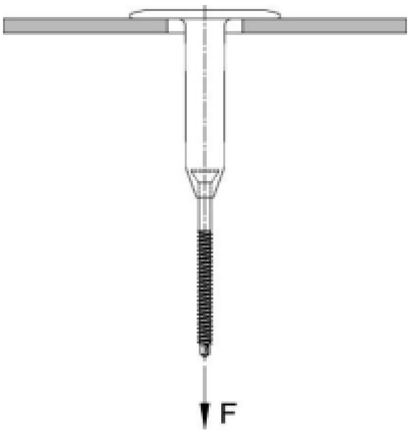


Figure 6-1. Principle of a plastic washer pull through test (EAD 030351-00-0402)

A custom fixture was used to support a PIR sample, and the protruding fastener was supported by the test machine jaws. Force and displacement were recorded directly by the test machine.

6.2 Test Articles

Five specimens were prepared. Each specimen consisted of a 300mm x 300mm sample of PIR panel, with a 16 mm diameter hole through the centre of the panel. An EcoTek 50mm x 105mm washer was installed into the specimen, with a Carlisle HP-X fastener inserted into the washer.

6.3 Test Procedures

- The test article was supported on the reaction frame.
- The crosshead was manually displaced until the specimen was supported by the frame fixture.
- The load cell was zeroed.
- Load was applied at a constant velocity of 10 mm per minute.
- The test was continued until failure (either a drop of at least 20% of ultimate load, or rupture of the specimen).

6.4 Results and Observations

Five samples were tested. It was observed that the washer would crush the PIR and foil together, before breaking the foil and continuing to pull into the PIR panel. In all tests the failure mode was deemed to be washer crushing the PIR.

It was observed that the washer head would flex and deform as it was pulled into the sample, but the washer did not rupture at the washer flange or at the screw head. The force-displacement results from testing are shown in Figure 6-2..

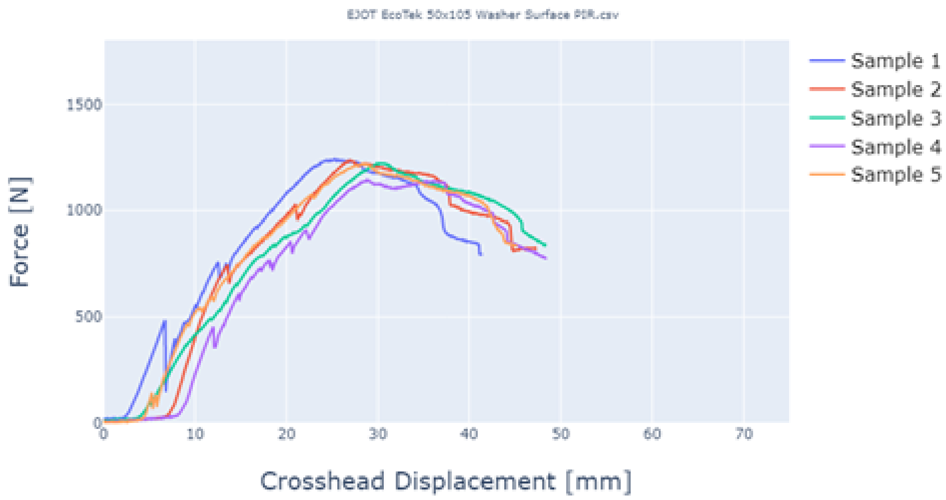


Figure 6-2. EcoTek 50mm x 105 mm plastic washer pull-through force-displacement results

The peak loads are displayed in Table 6-1.

Table 6-1. EcoTek 50 mm x 105 mm plastic washer pull-through peak force results

Test	Result (N)
1	1,242
2	1,236
3	1,224
4	1,142
5	1,220

A statistical summary of the test results is provided in Table 6-2. It is noted that the test results are relatively consistent, with a coefficient of variation of 3.3%.

Table 6-2. EcoTek 50 mm x 105 mm plastic washer pull-through summary results

Parameter	Value
Number of Tests	5
Mean	1213 N
Min	1142 N
Std. Dev. (Sample)	40.4 N
CoV (Sample)	3.3%
k_t	1.13
Min/ k_t	1,146 N

It was noted that the foil provided a membrane action across the face of the PIR sample during loading, before rupturing and allowing the washer to pull through the PIR foam. Therefore, it is recommended that Viking Roofspec provide guidance to installers to ensure the installed condition minimises damage to the PIR facing foil.

6.5 Additional testing

Additional testing of thinner PIR sheets was conducted to ensure that the pull through resistance was not dependant on the thickness of the PIR substrate. For this testing, EcoTek 50mm x 65mm washers were used within 85mm thick foil skinned PIR. The results of this testing are presented in Table 6-3.

Table 6-3 Ecotek 50 mm x 65 mm plastic washer pull-through peak force results

Test	Result (N)
1	1644
2	1566
3	1464
4	1524
5	1413
6	1450
7	1556
8	1427
9	1399
10	1403
11	1420
12	1490

A statisistical summary is provided in Table 6-4.

Table 6-4 Ecotek 50 mm x 65 mm plastic washer pull-through summary results

Parameter	Value
Number of Tests	12
Mean	1462 N
Min	1399 N
Std. Dev. (Sample)	60.3 N
CoV (Sample)	4.1%
k_t	1.10
Min/ k_t	1,272 N

It is noted that there is no detrimental effect of using a shorter plastic washer (65mm) in a thinner (85mm) PIR panel compared to 105mm long washers used in 135mm thick PIR.

7 MEMBRANE AND ADHESIVE PULL OFF TESTING

7.1 Background

Pull off testing was completed to determine the suitability of the adhesion methods, and strength of the bond between:

- DensDeck coverboard and a range of waterproofing membranes used by Viking Roofspec, including:
  - Viking Enviroclad, a scrim-reinforced thermoplastic polyolefin (TPO) membrane.
  - Viking Epiclad, single ply, flexible synthetic EPDM rubber membrane.
  - Viking Torch-on, an APP, SBS or APAO modified bitumen membrane installed as a two-layer external waterproof membrane, applied with heat (blow torch).
- DensDeck and the PIR foil when bonded with Viking Soudafoam.

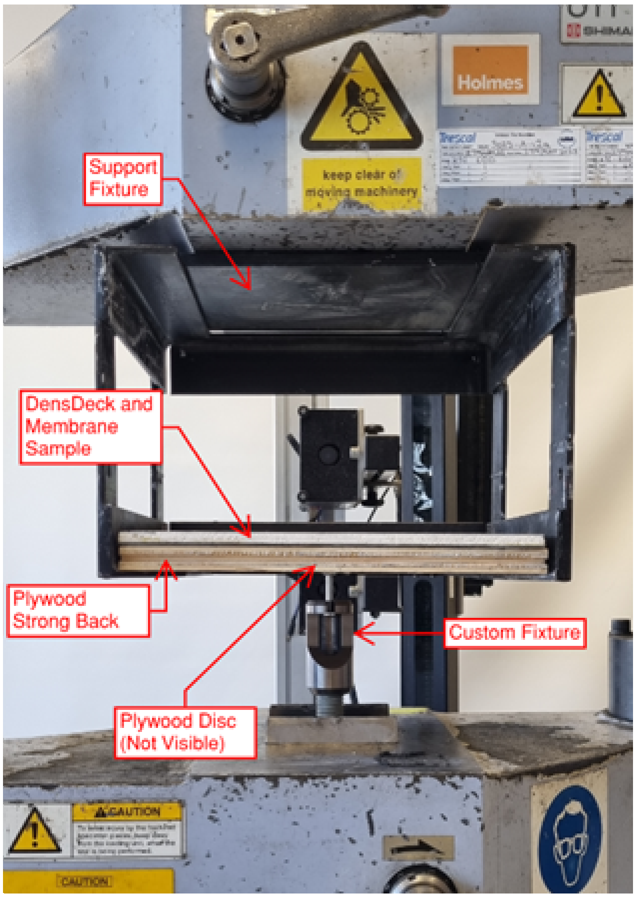


Figure 7-1. Membrane pull off test set up

7.2 Test Articles

7.2.1 Membrane Specimens

Samples we prepared by a qualified installer from Viking Roofspec to replicate the methods utilised on a construction site.

Specimens consisted of a sample of 6.4 mm DensDeck, approximately 300 mm x 300 mm in size, with a circular piece (84mm Ø) membrane applied to the surface. A plywood disk was attached to the membrane using a two-part epoxy and left to cure for a minimum of 2 days.

Figure 7-2: Membrane pull off test matrix

Membrane	Quantity
Enviroclad	6
Bitumen Torch-On	6
Bitumen Halley P Peel & Stick	6
CavGrip	5
SureWeld	6

7.2.2 Viking Soudafoam Adhesive Specimens

Samples were prepared by Holmes which consisted of an 80 mm diameter sample of DensDeck fixed to a 300 mm x 300 mm sample of PIR panel with Viking Soudafoam applied with the Gorilla Click and Fix foam application gun. The plywood disc was attached and left to cure.

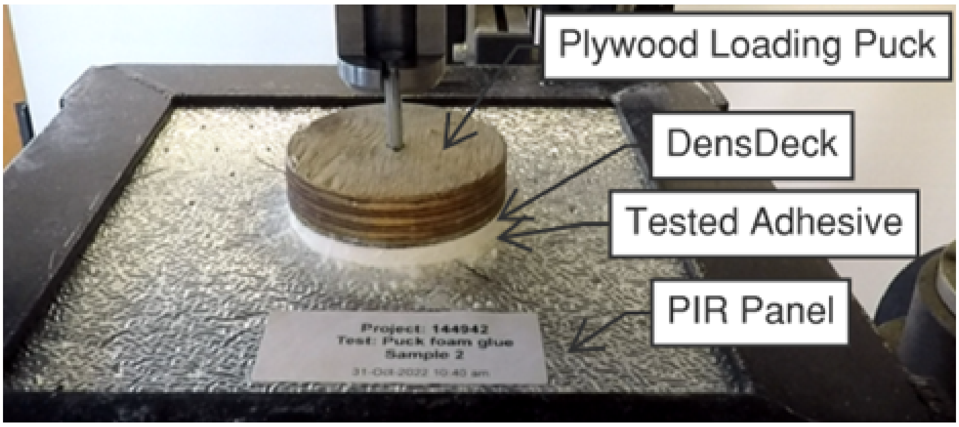


Figure 7-3. Viking Soudafoam adhesive sample

7.3 Test Procedure

- The test article was supported in the custom fixture.
- The threaded rod attached to the plywood was retained in the crosshead jaws.
- The crosshead was displaced at a constant rate of 20 mm per minute.
- The test was continued until failure, which was defined as either:
    a) the plywood disc detached from the membrane or,
    b) the membrane detached from the DensDeck substrate, or
    c) a combination of modes a and b.

7.4 Results and Observations

7.4.1 Membrane Adhesion to DensDeck

The strength results from the membrane adhesion tests are presented in Table 7-1 and processed in Table 7-2.

Table 7-1. Membrane pull off test results

Test	Enviroclad with CavGrip (N)	Enviroclad with SureWeld (N)	Bitumen Torch-On (N)	Bitumen Halley P Peel & Stick (N)
1	770	973	389	562
2	858	1,182	499	397
3	787	1,146	280	480
4	799	1,103	429	700
5	860	1,058	350	267
6	859	1,342	401	606

Table 7-2. Membrane pull off processed results

Parameter	Enviroclad with CavGrip	Enviroclad with SureWeld	Bitumen Torch-On	Bitumen Halley Peel & Stick
Number of Tests	6	6	6	6
Mean	822 N	1,134 N	391 N	502 N
Min	770 N	973 N	280 N	269 N
Std. Dev. (Sample)	41.2 N	125 N	155 N	73.7 N
CoV (Sample)	5.0%	11.1%	30.9%	18.8%
k_t	1.12	1.30	1.59	1.94
Min/ k_t	685 N	747 N	137 N	176 N
Min/ k_t (Expressed as a pressure)	124 kPa	134 kPa	24.8 kPa	31.8 kPa

7.4.2 Viking Soudafoam Adhesive Pull Off Test

It was observed that all samples failed through tearing of the face layer of the DensDeck from the core of the Dens Deck (Figure 7-4, Figure 7-5), rather than through rupture of the Viking Soudafoam adhesive. The aluminium foil layer remained bonded to the PIR in all tests.

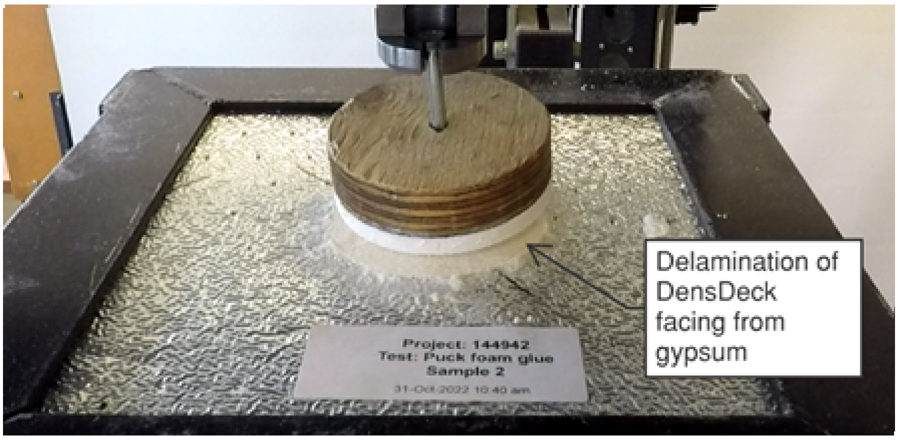


Figure 7-4. Viking Soudafoam pull off test specimen after loading

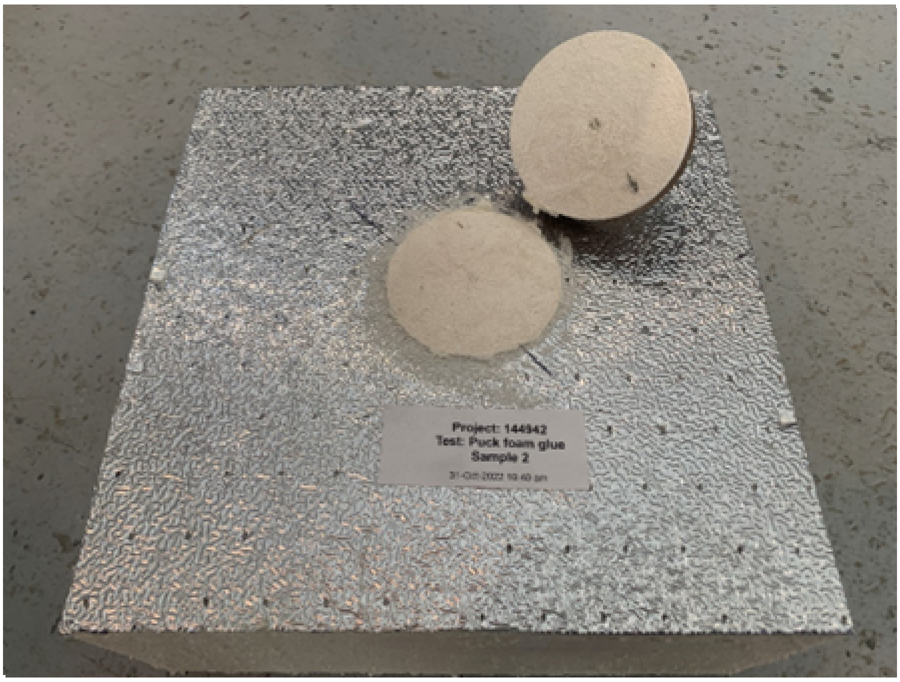


Figure 7-5. Delaminated DensDeck layer

The test results are plotted in Figure 7-6. Viking Soudafoam force-displacement results, and summarised in Table 7-3..

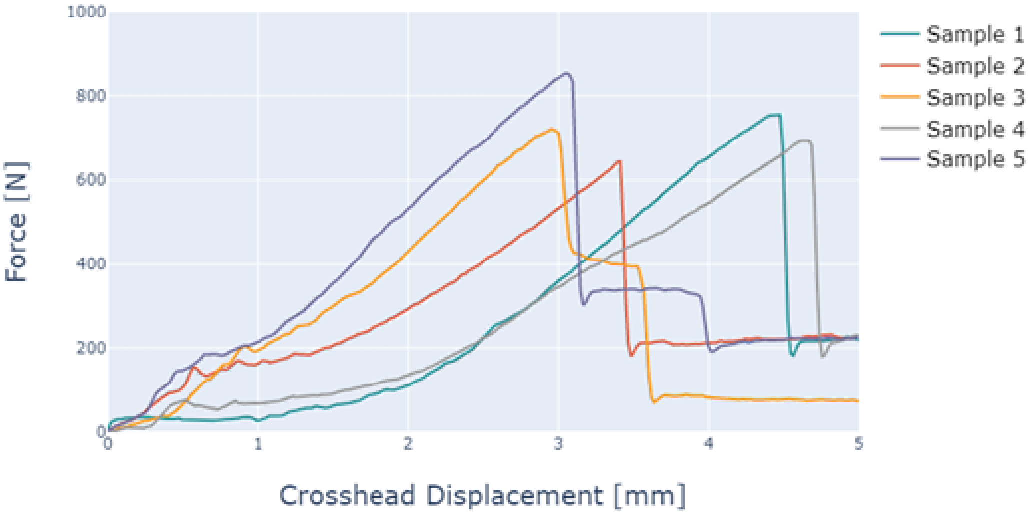


Figure 7-6. Viking Soudafoam force-displacement results

Table 7-3. Viking Soudafoam pull off test results

Test	Load reached (N)
1	756.0
2	644.9
3	721.1
4	695.5
5	854.5

A statistical summary is provided in Table 7-4..

Table 7-4. Viking Soudafoam pull off test - processed results

Parameter	Value
Number of Tests	5
Mean	734 N
Min	644 N
Std. Dev. (Sample)	78 N
CoV (Sample)	10.7%
k_t	1.30
Min/ k_t	493 N
Min/ k_t (Expressed as a pressure)	89 kPa

It was noted that the manufacturer's documentation provided for the Viking Soudafoam states a compressive strength of 15 kPa and a tensile strength of 42 kPa. It is noted that the characteristic force achieved in testing was equivalent to an average surface stress of 89 kPa.

Viking Roofspec have proposed that the foam is applied in 25mm Ø beads, 300mm apart. Based on their experience, the foam is expected to spread to approximately three times the bead size, spreading to an average width of 75 mm. This appeared reasonable based on the deconstruction of a tested sample. Assuming such spread is achieved, the beads on 300 mm centres will spread to cover 28% of the substrate (including connecting beads – refer Figure 9-7). This gives an average stress across the foam of 10.5 kPa before accounting for any other stress raisers.

Holmes Solutions note that adhesive performance can be influenced by a variety of factors, including but not limited to:

- Surface contaminants, e.g., dust or pollen,
- Installation temperature and temperature during the product's lifetime,
- Long-term durability,
- Moisture and humidity,
- Applicator skill,
- Curing conditions including external compression,
- Loading conditions including stress concentrations or prying.

Holmes Solutions acknowledge Viking Roofspec's in-house experience with adhesives for roof products and recommend that Viking Roofspec provide appropriate guidance with the product to ensure consistent insulation and reliable structural behaviour.

8 POINT LOAD TESTING

8.1 Background

During earlier desktop analysis, point loading on the substrate was determined to be a factor governing the plywood thickness, and the distance between supports (rafters). This is primarily a 'during construction' load case, considering a fully laden worker walking around on a roof.

Plywood is an isotropic material, with different strengths and stiffnesses in both the perpendicular and parallel to face grain directions. Analytical modelling indicated that 17mm, 5 ply EcoPly (manufactured by

Carter Holt Harvey) may be able to span up to 900mm between rafters. It was also desired to eliminate blocking, where possible, beneath the plywood at sheet edges by using the capacity of the embedded plastic tongue.

Physical testing was undertaken to prove the analytical model, and to justify assumptions around the strength of the plastic tongue, to determine whether additional blocking was required.

8.2 Test Articles

The point load specimens consisted of 45 mm x 90 mm timber framing at 900 centres. 17 mm CHH Ecoply sheets (17-5-38) were fixed to the timber framing with 10g x 50 mm screws at approximately 150 mm centres. The face grain of the plywood ran perpendicular to the framing. One end of the specimen was fitted with a piece of 45 mm x 90 mm blocking, whilst the other end was left unblocked (Figure 8-4).

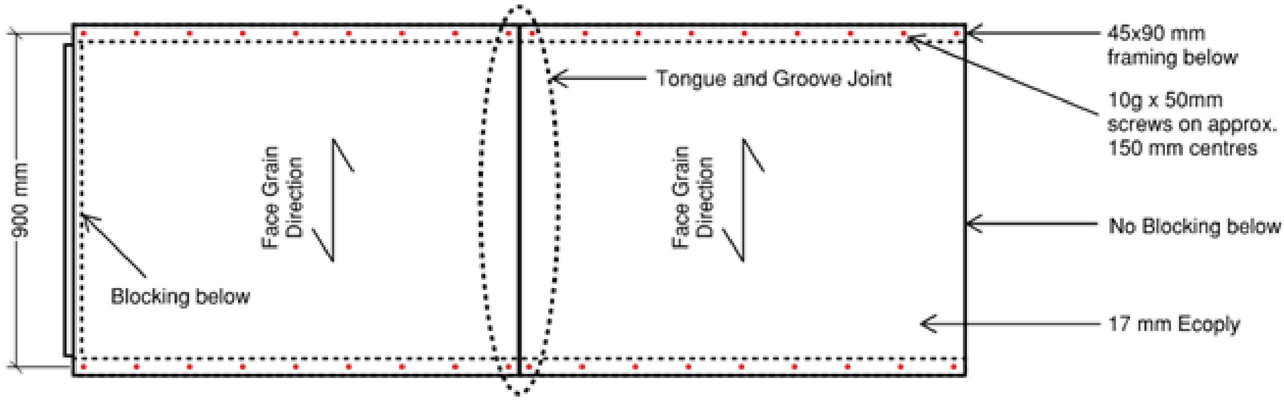


Figure 8-1. Plywood Point Load Testing Specimen

The tongue and groove joint was positioned in the centre, and the two sides of the joint where denoted “Male” and “Female”, referring to the sheet with the tongue preinstalled (Figure 8-2).

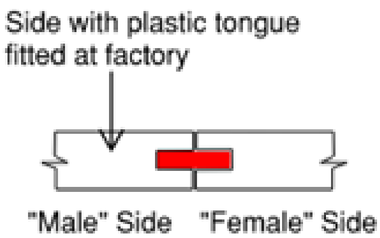


Figure 8-2. Joint naming convention

Point loads were applied during testing at the locations shown below.

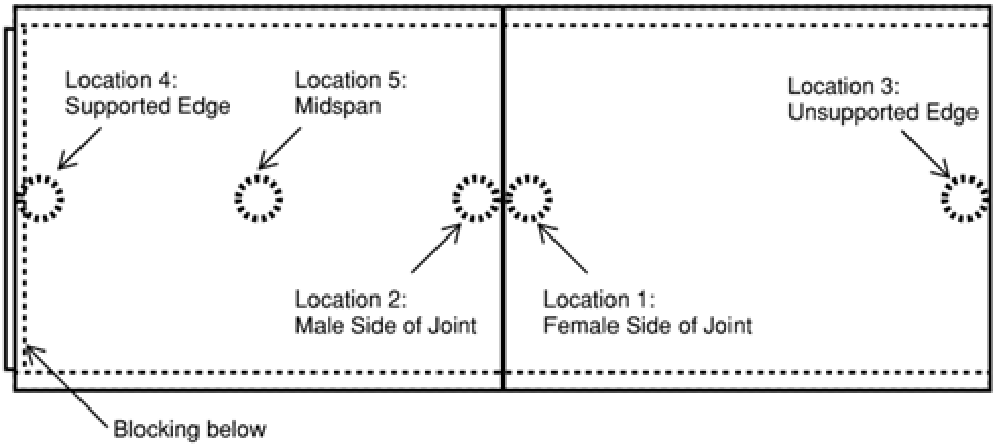


Figure 8-3. Point load application locations

8.3 Test Methodology

8.3.1 Load Application

The point load was applied using a hydraulic actuator fitted with an extended shaft. A steel disc of 100 mm diameter was fitted to the end of the shaft. A 100 mm diameter by 20 mm thick rubber pad was fitted to the end of the disc. All loads were applied in the negative/downward direction to simulate a load under gravity. Application of load was autonomously controlled using a hydraulic servo valve run from Delta computer systems RMC 151 motion controller and RMC tools software.

8.3.2 Load Displacement Measurement

Applied loads were measured using a load cell suspended from the hydraulic actuator. Vertical displacements were measured using linear potentiometers mounted next to the ram contact pad.

8.4 Test Articles

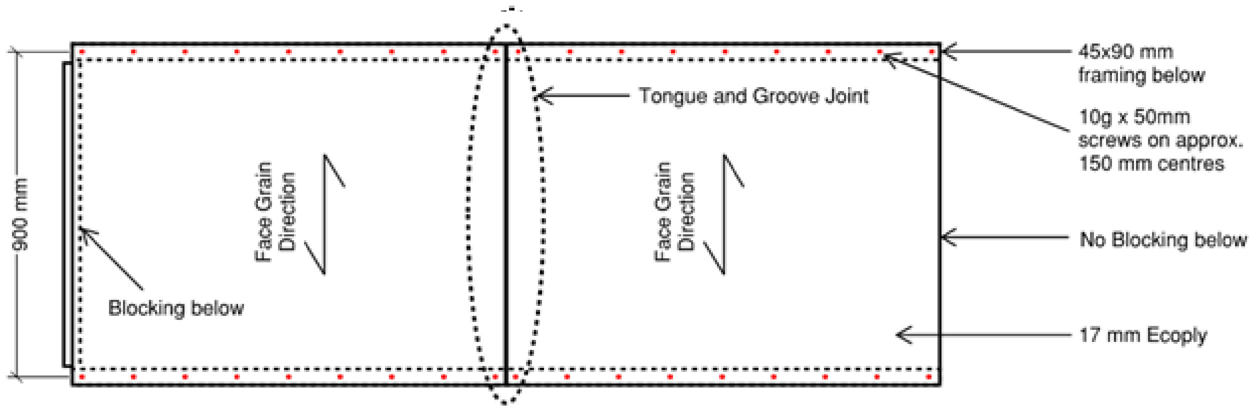


Figure 8-4. Plywood point load testing specimen

8.5 Test Procedure

Testing was carried out to the New Zealand Metal Roofing Manufacturers code of practice (NZMRM CoP) version 3.

- The test article was supported in the reaction frame.
- The ram was manually moved to contact the sample at the specified location.

- The RMC control software was started, ramping the applied force to the SLS target of 1.32 kN.
- Once the SLS target was attained, the load was sustained for 60 seconds.
- The load was then removed to return to 0 kN.
- The sample was allowed to sit unloaded for 60 seconds. Displacements are recorded throughout, along with any perceived deformation.
- The load was ramped to the ULS applied force target of 2.41 kN.
- Once the ULS target was attained, the load was sustained for 60 seconds.
- Any perceived damage or noise was recorded by the test technician.
- After 60 seconds, the load is removed, and the test is complete.

An example force-time trace is provided below (Figure 8-5.). This trace was recorded from a test, therefore there are minor fluctuations in the data as the RMC programme targets and adjusts the forces.

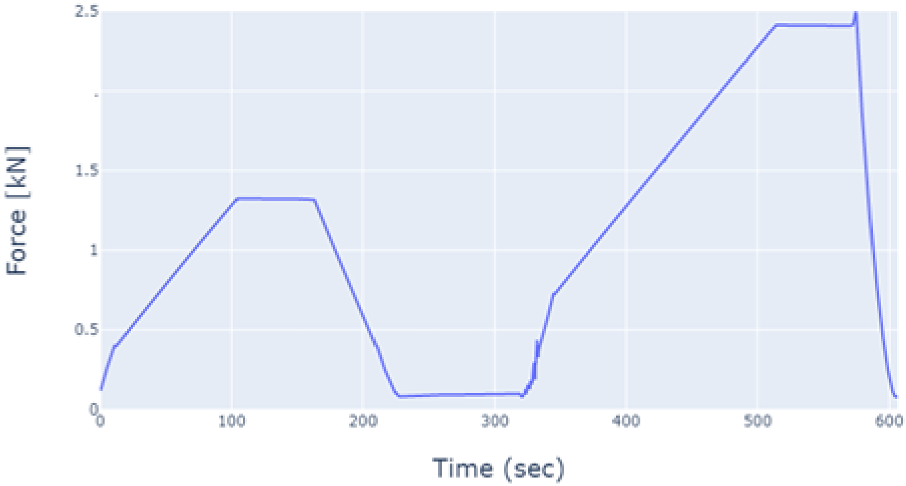


Figure 8-5. Point load testing loading protocol

8.6 Results and Observations

8.6.1 SLS (Displacement) Results

The displacement recordings (measured next to the point of load application) (Figure 8-6.) are presented for the four test conditions (female side of joint, male side of joint, unsupported edge, and midspan) in Appendix A.

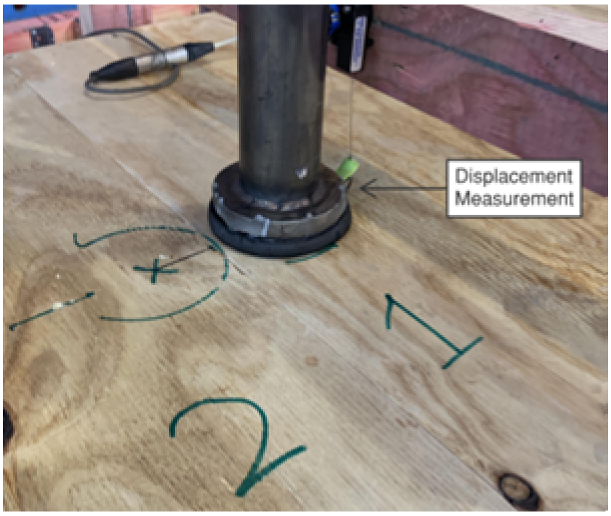


Figure 8-6. Example of point load application and measurement

All samples at all test locations were able to sustain the SLS load of 1.32 kN. The sample sat unloaded for a minimum of 60 seconds after unloading from ULS, allowing residual displacement to be determined. The NZMRM CoP performance criterion is a residual deflection less than the maximum of 1.5 mm or span/1,000 mm (in this case, 0.9 mm). Therefore, the criterion is residual displacement of 1.5 mm or less.

It is observed on the separate figures that the residual displacement after SLS loading (the flat line between the two elevated zones in each plot) is less than 1.5 mm, therefore meeting the suggested criteria in the NZMRM CoP.

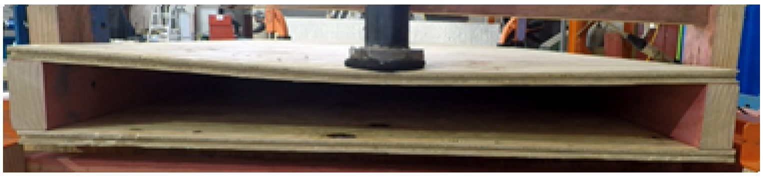


Figure 8-7. SLS deflection (Location 3, Sample 3)

Figure 8-8. SLS residual deflection (Location 3, Sample 3)

It was noted that a control software error resulted in location 2, sample 1 (male side of joint) was subjected to an increase in force prior to unloading after the SLS phase. This is further discussed in the strength results (Section 8.6.2).

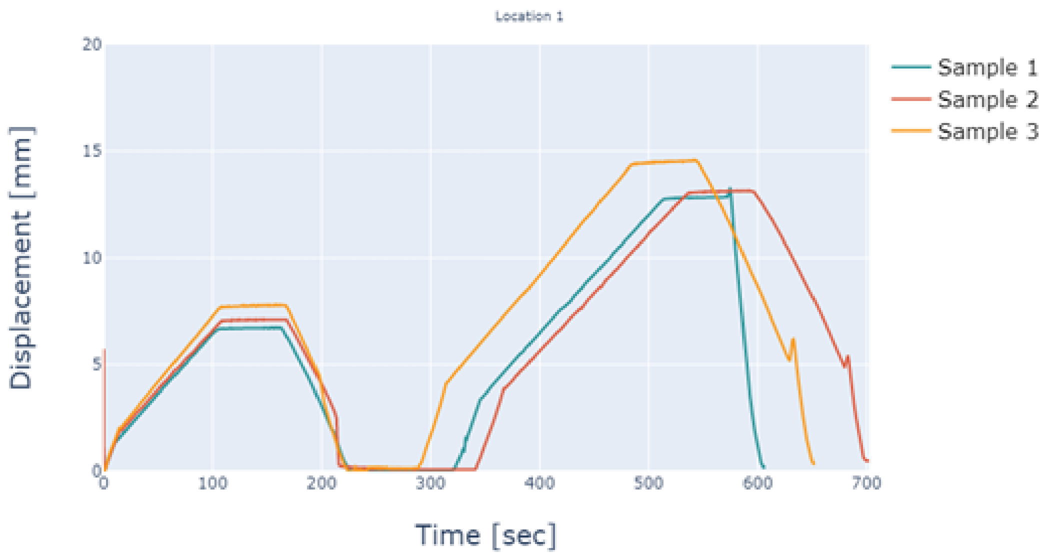


Figure 8-9. Location 1 (female side of joint) displacement results

The load cell force recordings are presented for the four test conditions (female side of joint, male side of joint, unsupported edge, and midspan) in 10.4Appendix A.

All samples at all test locations were able to sustain the SLS load of 1.32 kN. It was noted that a control software error resulted in Location 2, Sample 1 (Male side of joint) being subjected to a load of 2.4 kN at the conclusion of the SLS load. The sample appeared to be undamaged, and the test was completed without incident (Appendix Figure A-1).

All samples reached the ULS load of 2.41 kN. It was observed that Location 3, Sample 3 (unsupported edge) failed 5 seconds after attaining the ULS load. All other samples at all test locations withstood the load for 60 seconds before unloading.

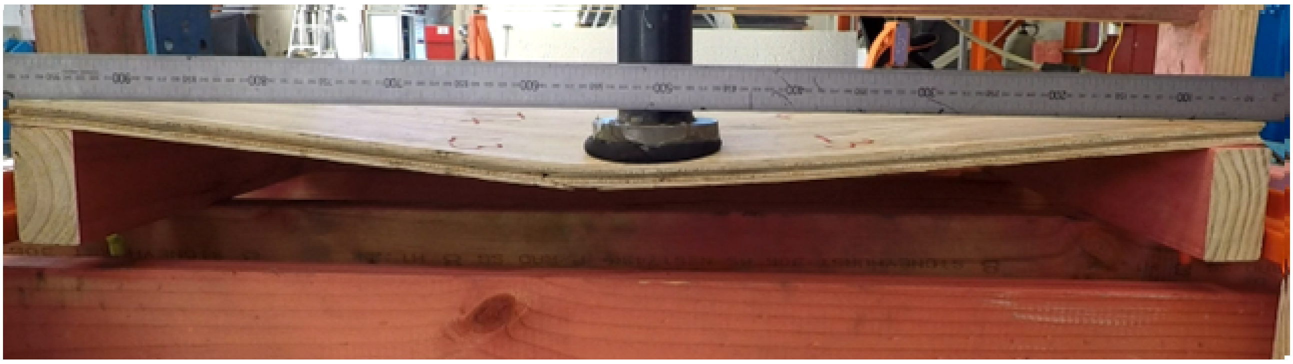


Figure 8-10. Deflection under ULS load (Location 3, Sample 2)

Figure 8-11. Rupture under ULS load (Location 3, Sample 3)

It is noted that the NZMRM CoP, which is being used as the basis for this test programme, does not require the ULS load to be sustained, only achieved. Therefore, this test is not deemed to be a failure.

> *The pressure cell and deflection sensor are positioned above the profile pan or rib at mid-span. For Type A (unrestricted access) and B roofs (restricted access), the load is increased to 1.32 kN, the pressure is released and residual deflection measured after 1 minute. Residual deflection must be less than S/1000 or 1.5 mm, whichever is higher. The pressure is then increased to failure (or at least 2.41 kN) and noted. (NZRMM CoP V3.0 June 2022, Cl. 17.1.3.2).*

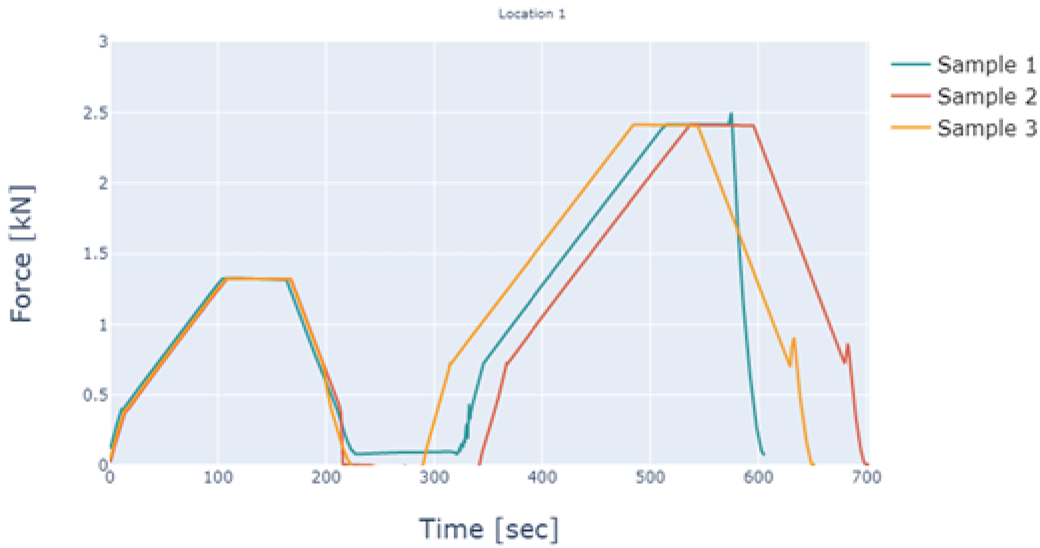


Figure 8-12. Location 1 (female side of joint) force results

8.6.2 Point Load Testing Summary

All samples tested were considered a pass for both SLS and ULS criteria. It was noted that one sample at Location 3 (the unsupported edge) ruptured while loaded to 2.41 kN.

When assessing the result to the NZMRM CoP, this would be considered a pass as the ULS load has been achieved. However, the consequence of a ruptured edge could be a fall from height, therefore it is suggested that blocking is fitted at edge sheets to strengthen the system. Blocking will provide further support to the edge; therefore, the test is considered a conservative representation of the roof edge scenario.

Based on the results summarised below, 17mm, 5 ply EcoPly spanning (face grain perpendicular to rafter direction) up to 900mm is suitable for use as a substrate for the Viking WarmSpan[2] system.

Location 4 was not tested, as it can be demonstrated through calculation that 90x45 SG8 blocking is sufficient to resist the required loads.

Table 8-1. Point load testing summary results

Parameter	Location 1 (Female Side of Joint)	Location 2 (Male Side of Joint)	Location 3 (Unsupported Edge)	Location 5 (Midspan)
Number of Samples	3	3	3	3
Max Loaded SLS Deflection [mm]	7.8 mm	7.6 mm Note 1	17.5 mm	8.2 mm
SLS Residual Deflection [mm]	0.2 mm	0.2 mm	0.4 mm	0.3 mm
SLS Test	Pass	Pass	Pass	Pass
Maximum Load Achieved [kN]	2.41 kN	2.41 kN	2.41 kN	2.41 kN
Deflection at Max Load [mm]	14.6 mm	13.8 mm	31.7 mm	14.4 mm
ULS Test	Pass	Pass	Fractured at ULS load	Pass

Note 1: Reported value does not consider the deflection during the 2.41 kN load spike.

9 UPLIFT TESTING

9.1 Test Methodology

9.1.1 Load Application

All Uniformly Distributed loads (UDL) for SLS, ULS, and cyclic testing were applied in the positive/upward direction to simulate wind uplift conditions. Load was applied using a hydraulic actuator suspended from a staple frame as shown in Figure 9-1. Loading in this direction was considered the worst-case loading direction for the roofing system, as it placed the fasteners connecting the roof build up to the substrate into tension. It also placed the unsupported edge of the purlins into compression, increasing the potential for buckling.

A load equaliser, commonly referred to as a “Whiffle Tree” was fabricated in-house. The whiffle tree was designed to provide equal load to each of up to 32 evenly spaced load points independent of the deflected shape of the roof, allowing close approximation of a Uniformly Distributed Load. The whiffle tree was attached to the roof system by 70 mm steel discs below the PIR panel. The attachment was made by M6 lifting eyes and threaded rods to ensure the steel disc could pivot freely as the roof flexed.

Figure 9-1. Whiffle tree attached to specimen

Application of load was autonomously controlled using a hydraulic servo valve run from Delta computer systems RMC 151 motion controller and RMC tools software.

9.1.2 Load and Displacement Measurement

Applied loads were measured using a load cell suspended from the hydraulic actuator. Vertical displacements were measured using linear potentiometers mounted beneath the specimen, The arrangement of the potentiometers is shown in Figure 9-2, Figure 9-3, and Figure 9-4.

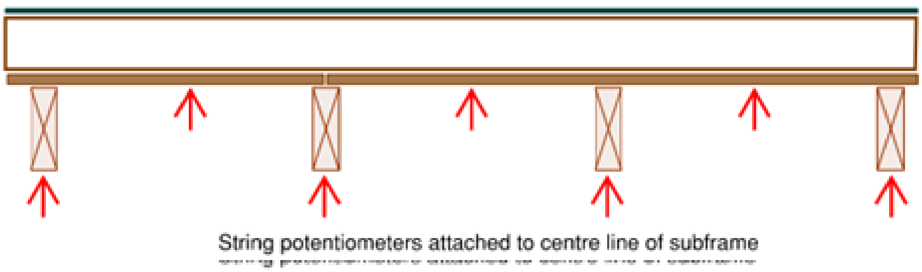


Figure 9-2. String potentiometer locations on plywood subframe during SLS tests

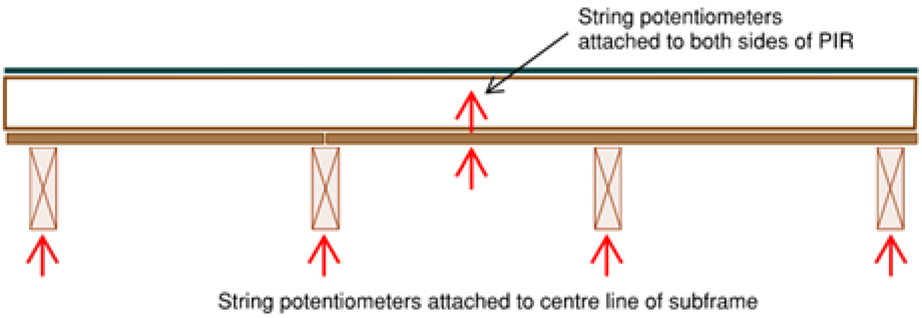


Figure 9-3. String potentiometer locations on plywood subframe during SLS tests

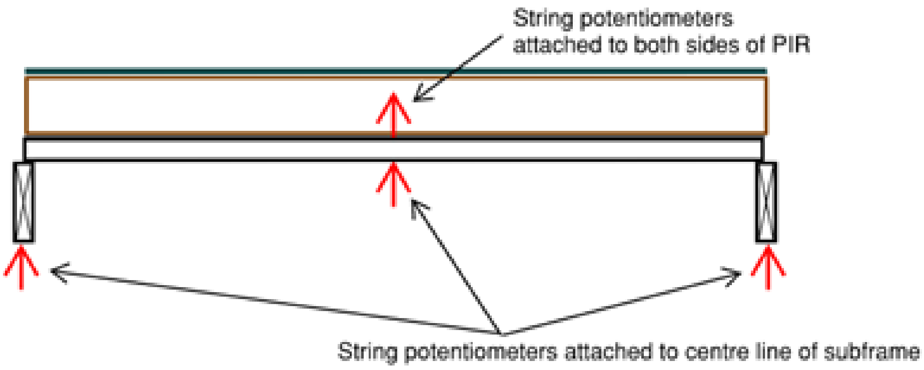


Figure 9-4. String potentiometer locations on ST900 subframe during SLS and Cyclic tests

9.2 Test Articles

9.2.1 17 mm Ecoply Plywood Substrate

The plywood specimens consisted of a timber subframe, and Viking Roofspec roof build up.

The timber subframe (Figure 9-5) was constructed from 45 mm x 190 mm SG8 purlins at 900 mm centres, and two sheets of 17 mm Ecoply plywood. One sheet was 1800 mm x 1200 mm (i.e., spanned two bays) and the other sheet was 900 mm x 1200 mm (i.e. spanned one bay). The plywood was fixed to the purlins with 10g x 50 mm screws at 150 mm centres on edges, and 10g x 50 mm screws at 200 mm centres in the "field" zone. The subframe represented a stiff roof support structure and was not considered to be part of the tested system.

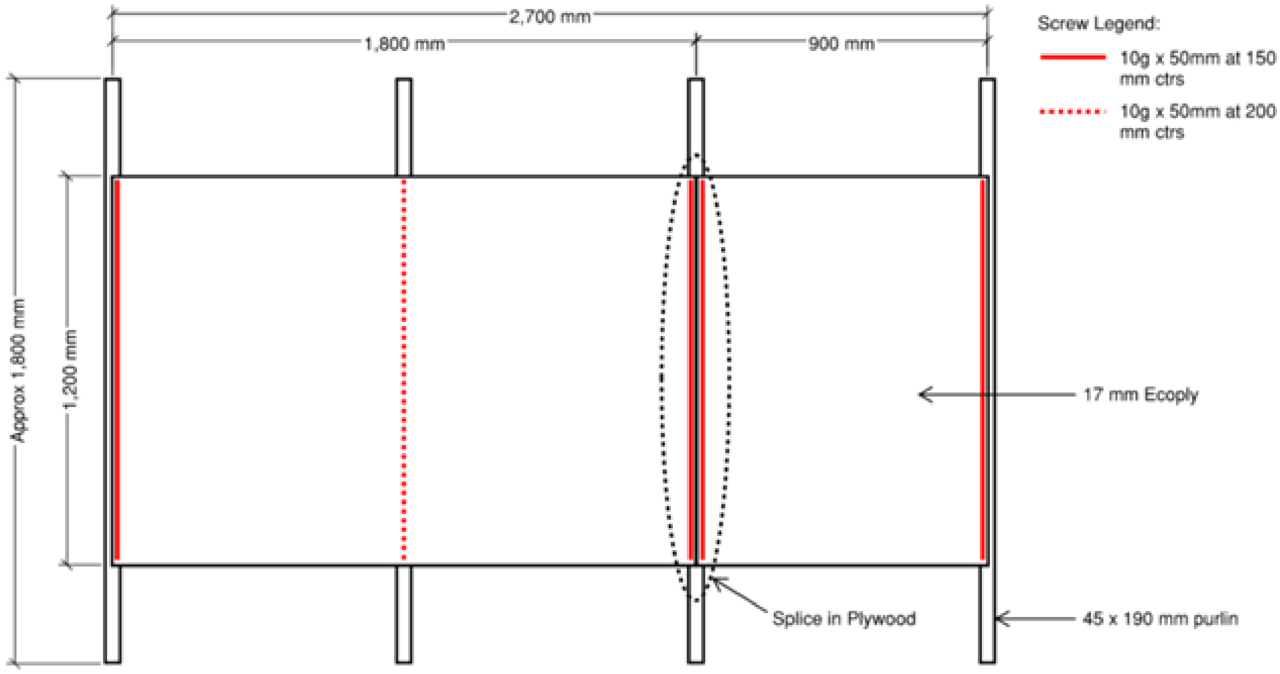


Figure 9-5. Plywood subframe drawing

Affixed to the timber subframe was the Viking Roofspec roof build up, consisting of a vapor barrier sheet, a 135 mm Conqueror PIR panel, and a 6.4 mm DensDeck sheet. Due to the provided sizes of PIR panel and DensDeck sheeting, two PIR panels and two sheets of DensDeck were used to construct each specimen.

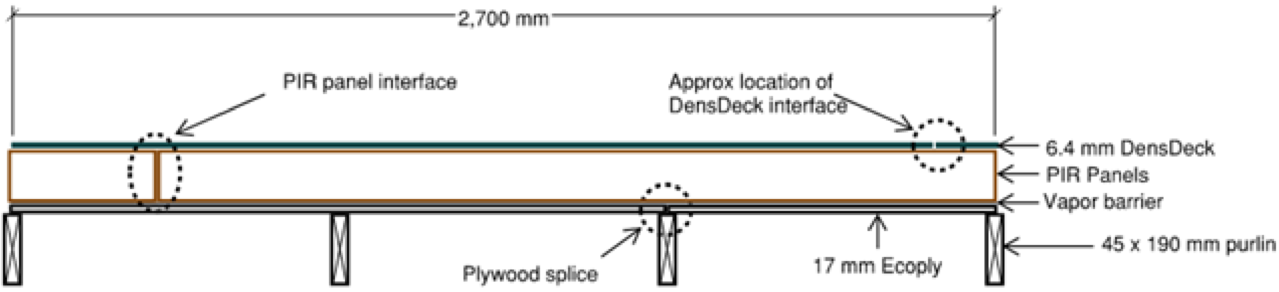


Figure 9-6. Viking Roofspec roof build up on timber subframe

The roof build up was constructed in the following sequence:

- The plastic washers and screws were inserted into the PIR at the specified locations.
- A strip of adhesive, approximately 25 mm in width (Figure 9-8), was applied using the supplied application device. The adhesive was applied in continuous line, approximately 300 mm apart (Figure 9-9).
- The DensDeck coverboard was applied, and steel weights added to provide compression to the sample (Figure 9-10).
- The adhesive was allowed to cure for a minimum of one hour.
- 6mm diameter holes (32 total) were drilled through the PIR and DensDeck. The load washers were inserted, with the washer face in contact under the PIR panel.

- The roof build up sample was then placed on the plywood subframe, and the screws (pre-inserted in the washers) were fixed to the plywood.

Figure 9-7. Applying Viking Soudafoam

Figure 9-8. Viking Soudafoam bead size

Figure 9-9. Viking Soudafoam applied to PIR panel

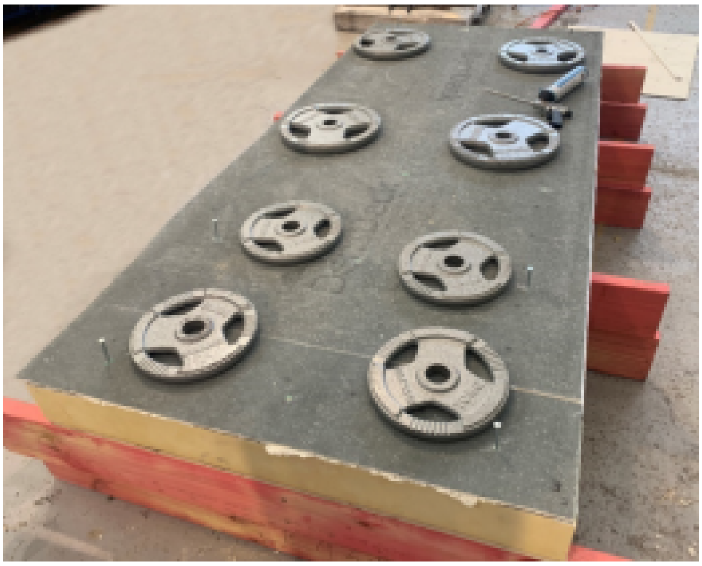


Figure 9-10. Weighted sample

9.2.2 Steel & Tube ST900 Substrate

The steel substrate system tests were similar to the plywood substrate tests, but with the ST900 steel profile instead spanning a single 1,800mm span. Screws were fixed through the top of the profile, in accordance with Viking Roofspec's installation instructions.

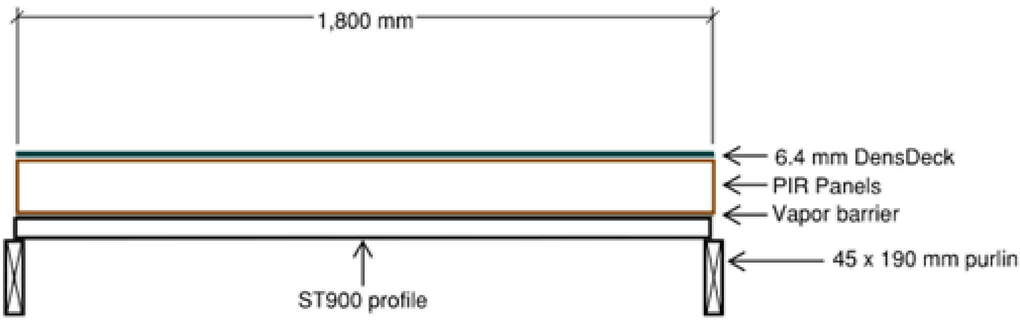


Figure 9-11. Viking Roofspec roof build up on ST900 steel roofing

9.3 Test Procedure

9.3.1 SLS and ULS Testing

- The specimen was loaded into the test frame and secured.
- A 2 kN load was applied to allow the sample to bed in and remove slack from the whiffle tree.
- The string potentiometers were zeroed. Any manual measurements were made using callipers at marked locations.
- The SLS load protocol was applied. This consisted of:
  - For the first plywood sample, a target displacement.
  - For all other samples, a target force equivalent to 3 kPa.
- The SLS load was then sustained for 60 seconds.
- The sample was then allowed to relax for a minimum of 60 seconds.
- Manual measurements were made, as required.
- The ULS load protocol was then applied, in which the actuator travelled at a constant rate of displacement. Peak force was then recorded.

9.3.2 Cyclic Testing

- The specimen was loaded into the test frame and secured.
- A 2 kN load was applied to allow the sample to bed in and remove slack from the whiffle tree.
- The string potentiometers were zeroed. Any manual measurements were made using callipers at marked locations.
- The cyclic load protocol is applied. This consists of groups of 1,000 cycles at a rate of 0.3 Hz to 1.0 Hz.
  - The first group is at a range of 40% to 80% of the factored SLS force.
  - The second group is at a range of 45% to 90% of the factored SLS force.
  - The third group is at a range of 50% to 100% of the factored SLS force.
- Between groups, the sample is unloaded and inspected, with any required measurements taken.
- After the final inspection, the ULS load protocol is then applied.

9.4 Results and Observations

9.4.1 17 mm Ecoply Plywood Substrate

9.4.1.1 SLS and ULS Results

The SLS results are presented in Table 9-1. The SLS loading protocol varied during testing as greater understanding of the system behaviour was developed.

The first test was conducted using a displacement-based protocol. As the displacement target was utilising displacement at the underside of the plywood, the target deflection of L/300 was reached at a lower-than-expected load. The PIR panel was observed to span across the plywood, and the curvature of the plywood was discernible by eye.

The second test targeted a load equivilent to 3 kPa, which was achieved without any noticeable damage to the system.

The third test target a load equivilent to 3.70 kPa, which was selected to exceed the desired design value by a factor of more than 1.20.

Table 9-1. Summarised SLS results

Specimen	Peak Load [kN]	Equivilent Pressure [kPa]	Notes
1	9.16	2.82	Test driven by ply displacement
2	9.72	3.00	No damaged observed
3	12.00	3.70	Higher limit set, no damage observed.

All three samples were observed to be undamaged after the SLS loading. Therefore, Holmes Solutions believe it is appropriate to use the last specimen which was subjected to the greatest load, applying a sample size of n = 1 and a coefficient of variation of 5% based on the results of the ULS testing (discussed below) and the small scale washer testing discussed in Table 6-2. This gives a k_t value of 1.20 and therefore SLS capacity of 3.08 kPa.

The ULS test results are summarised in Table 9-2. Summarised ULS test results. All ULS tests were observed to fail due to crushing of the PIR under the washer head.

Table 9-2. Summarised ULS test results

Specimen	Peak Load [kN]	Equivilent Pressure [kPa]
1	16.00	4.94
2	16.48	5.09
3	17.11	5.28

The ULS results in Table 9-2 are processed using AS NZS 1170.0 Appendix B and presented in Table 9-3.

Table 9-3. Processed ULS test results

Parameter	Value
Number of Tests	3
Mean	16.53 kN
Min	16.00 kN

Parameter	Value
Std. Dev. (Sample)	0.56 kN
CoV (Sample)	3.4%
k_t	1.15
Min/ k_t	13.91 kN
Min/ k_t (Expressed as a pressure)	4.29 kPa

The force-time traces are displayed in Appendix B.1. Note that for specimen 1 the programme was halted at 14.0 kN and the load removed to allow for inspection.

9.4.1.2 Cyclic Test Results

One sample was tested using the cyclic loading protocol. Due to the inertia of the system, the actuator control software was manually tuned during testing to achieve the target force.

For the 40% to 80% cycles, and 45% to 90% cycles, this resulted in loads which exceeded the upper force target and exceeded the range (Figure 9-12).

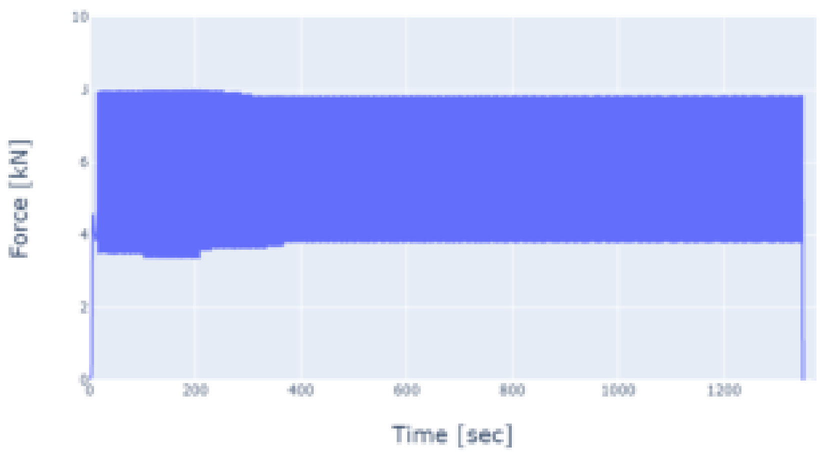


Figure 9-12. Example of the Cyclic Loading Protocol (40% to 80% Range)

The load rate was within the NZMRM CoP recommendation of 0.3 Hz to 1.0 Hz. The frequency decreased at higher load ranges due to the additional travel. An example from the 40% to 80% testing is shown in Figure 9-13, and is approximately 0.75 Hz.

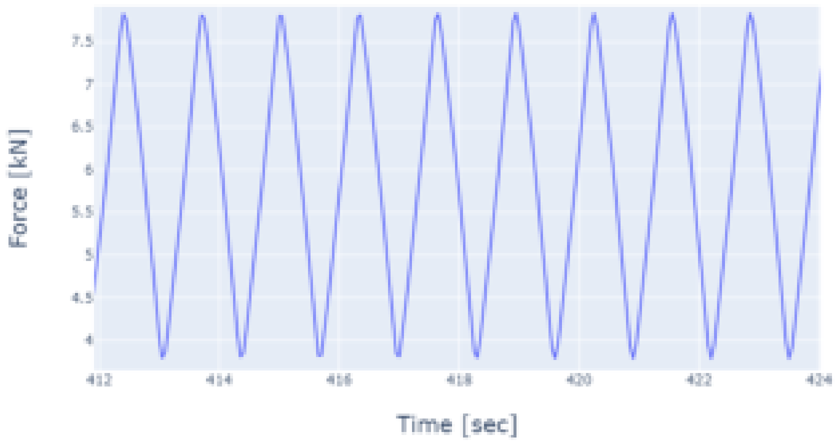


Figure 9-13. Cyclic loading protocol at approximately 0.75 Hz

For the 50% to 100% cycles, the actuator force target was intentionally set lower before building towards the target over the first 100 cycles. An additional 100 cycles were added to the programme to compensate for the initial force reduction.

No observable damage was detected during the three cyclic tests.

A Mitutoyo DTI was used to measure the displacement of the washer head under the DensDeck at a marked location (Figure 9-14). The observations are reported in Table 9-4. The recorded deformation was 0.145 mm, which was approximately 0.01% of the PIR panel's thickness. This indicates that the washer-PIR interface had not undergone significant inelastic deformation. It was also noted that most of the deformation occurred on the first loading increment, suggesting the washer was "bedding in" to the PIR.

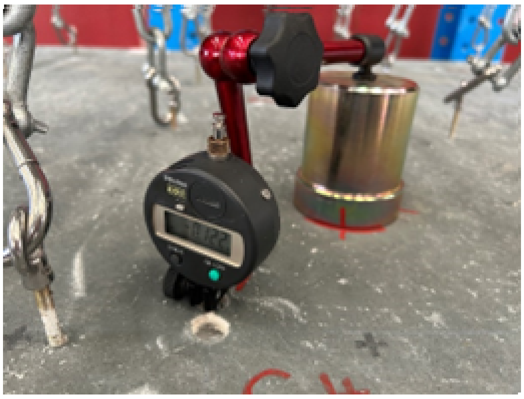


Figure 9-14. DTI measuring washer head movement during a test

Table 9-4. DTI measurement during cyclic tests

Sample	DTI Reading [mm]
Prior to testing	-0.007
After 40% to 80% cycles	-0.112
After 45% to 90% cycles	-0.128
After 50% to 100% cycles	-0.145

Figure 9-15 presents the difference between the string potentiometer at the midspan of the plywood sheet and the average of the string potentiometers attached to the centre of the PIR on either side of the sample (refer to the earlier Figure 9-3). This is essentially the "gap" that opens between the PIR and the plywood roof below.

This plot shows that the maximum gap during cyclic testing was 0.84 mm with a range of approximately 0.50 mm. The gap was observed to increase over time. At the conclusion of each test the gap returned to less than 0.1 mm, indicating no significant permanent deformation occurred during the test.

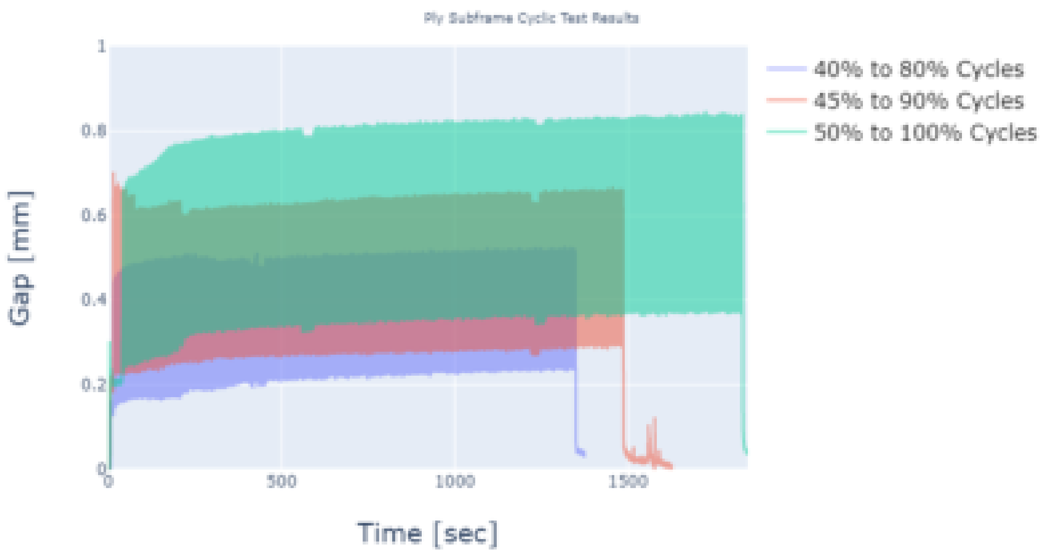


Figure 9-15. Cyclic test gap opening (plywood subframe)

After cyclic testing, the specimen was subjected to the ULS loading protocol. A peak load of 20.7 kN was achieved, equivalent to 6.39 kPa. It was noted that this load exceeded the results achieved in the earlier pseudo-static tests.

9.4.2 Steel & Tube ST900 Substrate

9.4.2.1 SLS and ULS Results

The SLS and ULS test results are provided in plots in 10.4Appendix C. The SLS and ULS results are summarised below in Table 9-5 and Table 9-7, with a statistical summary in Table 9-6 and Table 9-8.

Three sets of plots are provided in 10.4Appendix C. These show the applied load with time, the displacement of the ST900 profile (measured at midspan) with time, and the average relative displacement between of the PIR edges and the midspan of the ST900 below. An example of each graph is reproduced below.

Figure 9-17 demonstrates that after both levels of SLS loading, the substrate had a permanent deformation of less than 2 mm (over an 1,800 mm span), a change of approximately span/900.

Figure 9-18 demonstrates that the PIR and substrate are remaining in position, with less than 1.5 mm of relative movement during the SLS testing. The peak on the plot is the PIR pulling away from the substrate during ULS testing.

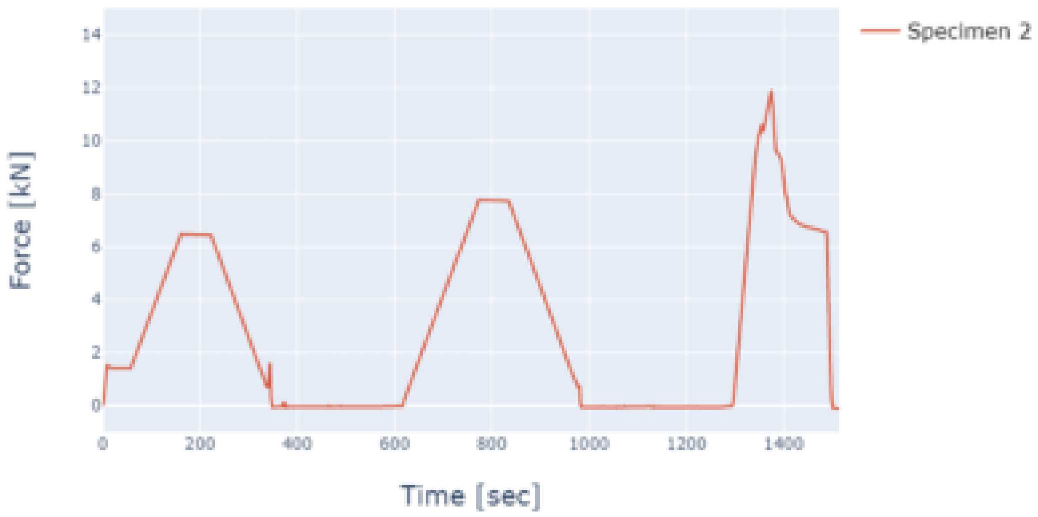


Figure 9-16. ST900 specimen 2 force results

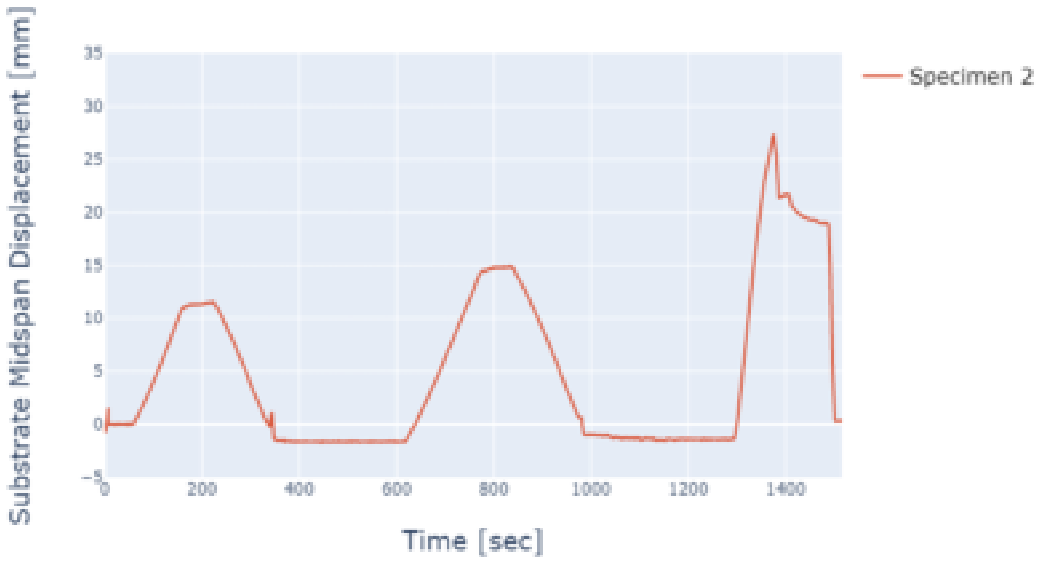


Figure 9-17. ST900 specimen 2 substrate midspan displacement results

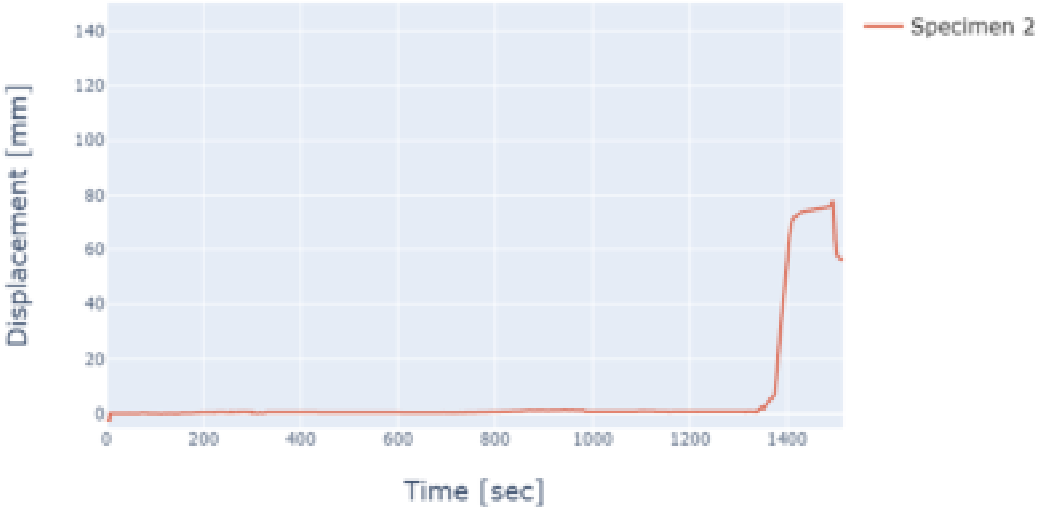


Figure 9-18. ST900 specimen 2 PIR-substrate relative midspan displacement results

Table 9-5. Summarised SLS test results

Specimen	Peak Load [kN]	Equivilent Pressure [kPa]
1	7.78	3.60
2	7.78	3.60
3	7.78	3.60

Table 9-6. Processed SLS results

Parameter	Value
Number of Tests	3
Mean	7.78 kN
Min	7.78 kN
Std. Dev. (Sample)	n/a
CoV	<5.0%
k_t	1.15
Min/ k_t	6.77 kN
Min/ k_t (Expressed as a pressure)	3.13 kPa

Table 9-7. Summarised ULS test results

Specimen	Peak Load [kN]	Equivilent Pressure [kPa]
1	12.28	5.69
2	11.87	5.50
3	13.16	6.09

Table 9-8. Processed ULS test results

Parameter	Value
Number of Tests	3
Mean	12.44 kN
Min	11.87 kN
Std. Dev. (Sample)	0.66 kN
CoV	5.3%
k_t	1.16
Min/ k_t	10.23 kN
Min/ k_t (Expressed as a pressure)	4.73 kPa

All samples were observed to fail by crushing of the PIR below the head of the washer. No screw withdrawal failures were observed during testing (Figure 9-19). At the conclusion of testing, the operator used the actuator to pull the PIR panel from the substrate for disposal, and it was observed that the washer continued to displace into the PIR sample, exceeding 50 mm displacement (Figure 9-20) demonstrating the deformation capacity of the PIR-washer interface.

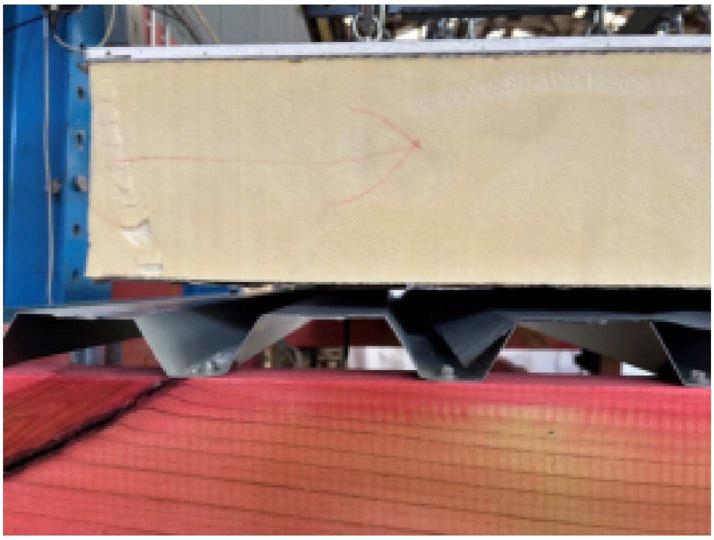


Figure 9-19. Washer pulling through PIR affixed to ST900

Figure 9-20. Washer pulling through PIR (during post-test removal)

9.4.2.2 Cyclic Test Results

Figure 9-21 presents the difference between the string potentiometer at the midspan of the ST900 sheet and the average of the string potentiometers attached to the centre of the PIR on either side of the sample (refer to the earlier Figure 9-4). This is essentially the "gap" that opens between the PIR and the ST900 below, at the specified location.

This plot shows that the maximum gap during cyclic testing was 1.34 mm with a range of approximately 1.0 mm.

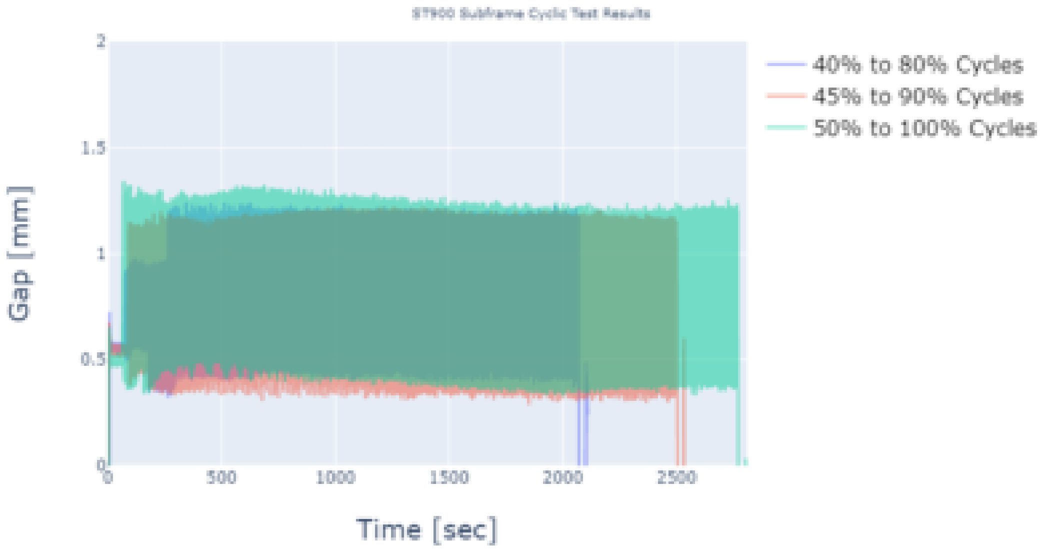


Figure 9-21. Cyclic test gap opening (ST900 subframe)

After cyclic testing, the specimen was subjected to the ULS loading protocol. A peak load of 12.1 kN was achieved, equivalent to 5.60 kPa.

10 CONCLUSIONS

10.1 Component Test Results

The component level testing discussed in Sections 5 and 6 demonstrated that the EcoTek 50 mm x 105 mm achieved a minimum factored strength of 1.14 kN, irrespective of whether the PIR was 85mm or 135mm thick. The Carlisle HP-X fasteners into ST900 roofing and HD14-10 fasteners into a 26 MPa concrete slab were demonstrated to have a higher withdrawal strength than the EcoTek washer's pull-through strength, therefore were not considered to govern the system.

The membrane pull-off testing, discussed in Section 7, demonstrated that the static capacity of the five membranes proposed by Viking Roofspec was at least 24.8 kPa. This exceeds the likely wind pressures in service of up to 6.5 kPa.

The adhesive pull-off testing, also discussed in Section 7, showed a tensile stress of 89 kPa. Holmes Solutions note the variability of adhesive products, and recommend Viking Roofspec create installation guidance and procedures to ensure a repeatable value is achieved.

10.2 System Test Results

The system testing discussed in Section 9 demonstrated the performance of the system at SLS and ULS levels. It was noted that damage was not observed during SLS testing.

Both ST900 and plywood substrate specimens failed in the same manner at ULS, with the EcoTek washer pulling through the PIR sample.

10.3 Representative Wind Loading

Representative site wind speeds are determined using the wind zones in *NZS 3604:2011 Timber framed buildings*. The suction pressure is then determined using *NZS 1170.2:2021 Structural Design Actions, Part 2:*

Wind actions. The resultant pressure is calculated at four locations across the roof structure and is summarised in Table 10-1 with reference to the locations in Figure 10-1.

Table 10-1. NZS 3604:2011 wind zones and calculated roof wind pressure

NZS 3604 Wind Zone	Wind Speed [m/s]	Corner [kPa]	Edge 1 [kPa]	Edge 2 [kPa]	Typical [kPa]
Low	32	1.53	1.28	0.96	0.64
Medium	37	2.05	1.71	1.28	0.85
High	44	2.90	2.42	1.81	1.21
Very High	50	3.74	3.12	2.34	1.56
Extra High	55	4.53	3.78	2.83	1.89

A schematic diagram of different wind locations on roof is shown below:

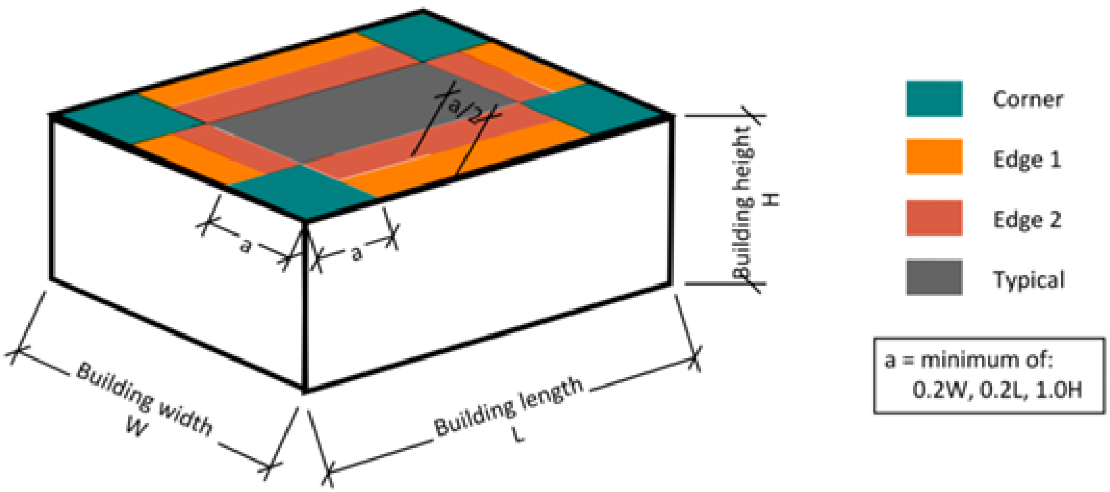


Figure 10-1. Roof regions for determination of fixing quantity

10.4 Fastener Spacing Tables

A factored capacity of 4.30 kPa was determined through processing of the system test results as summarised in Table 9-3. The tested specimens had three rows of six fixings for a total of 18 fixings. The wind pressures provided in Table 10-1 are then factored by the test values to give a recommended number of fixings for the various wind zones and panel locations. The recommended values are provided in Table 10-2. Consultation with Viking Roofspec indicated at least 8 fixings should be provided per PIR panel, which is reflected in Table 10-2.

It was noted that the test data using an ST900 substrate (Table 9-7 and Table 9-8) exceeded the values achieved using the 17 mm Ecoply. Therefore, they provide a conservative value.

The table below applies to roofs with a slope of up to 10°, and does not apply to cantilever roofs, or roofs that are considered 'open under' per AS NZS 1170.2.

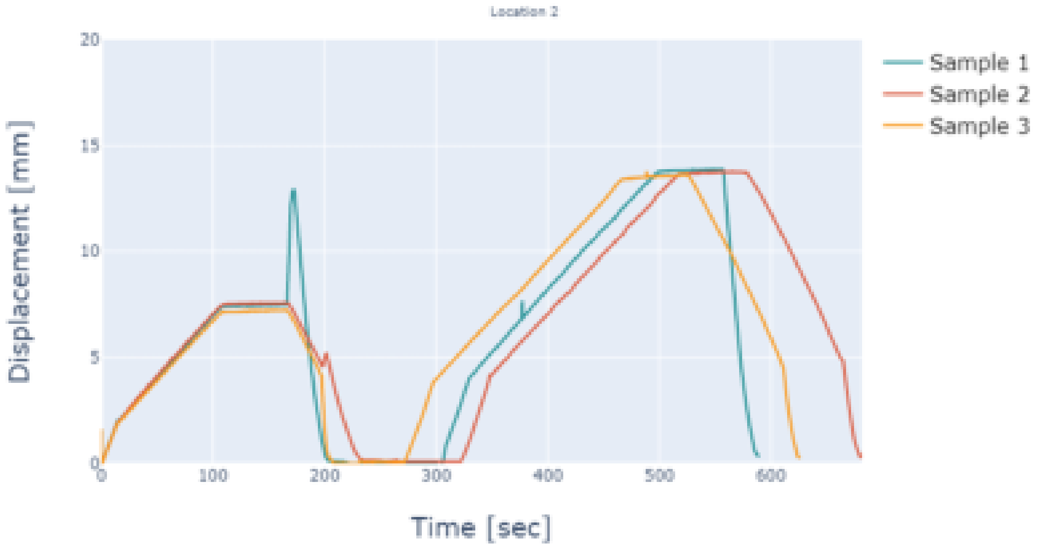
Table 10-2. Proposed fastener quantity for 2400 mm x 1200 mm PIR fixed to 17 mm Ecoply plywood sheeting or ST900 roofing

NZS 3604 Wind Zone/ wind pressure	Corner [no. off]	Edge 1 [no. off]	Edge 2 [no. off]	Typical [no. off]
Low	8	8	8	8
Medium	9	8	8	8
High	12	10	8	8
Very High	15	13	10	8
Extra High	18	15	12	8
6.5kPa[1]	26			

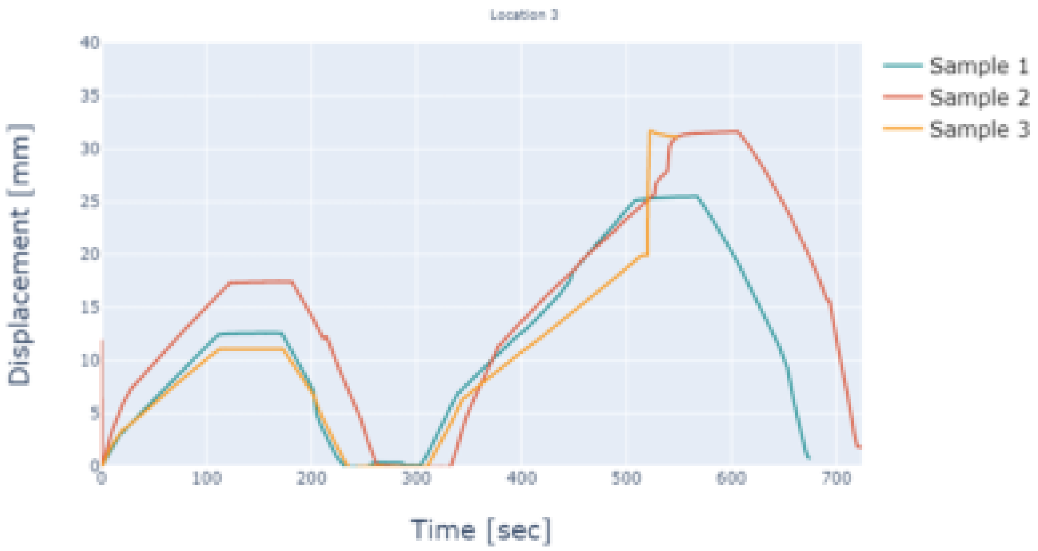
Note 1: 6.5kPa design wind pressure is outside the scope of NZS 3604, and Specific Engineering Design (SED) is required.

Appendix A Point Load Test Data

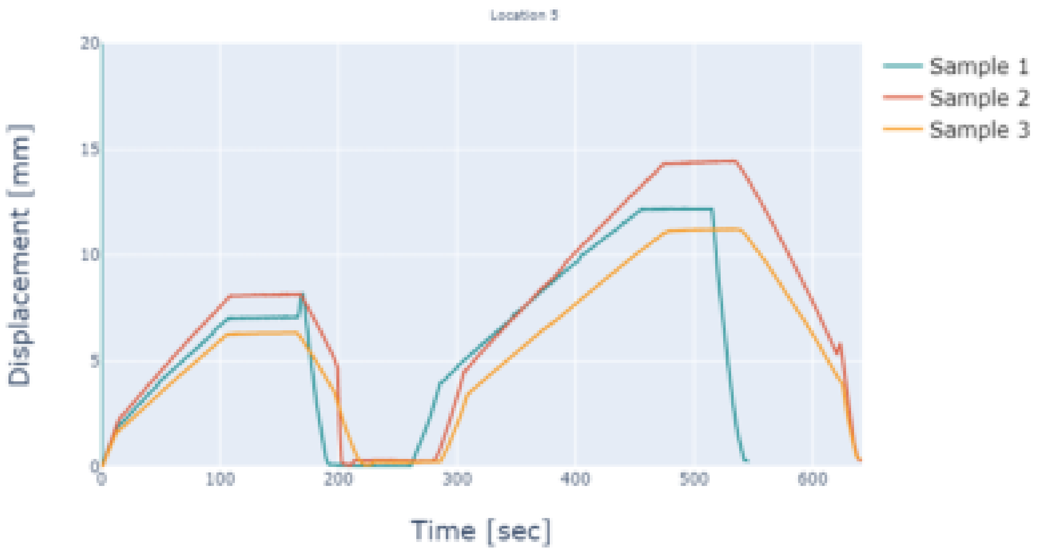
A.1 SLS Point Load Results



Appendix Figure A-1. Location 2 (male side of joint) displacement results

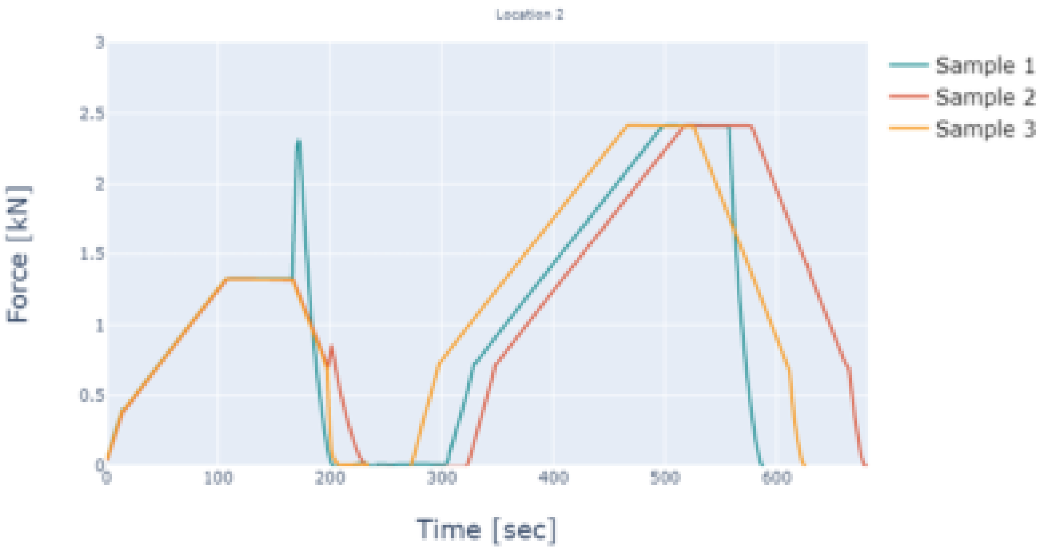


Appendix Figure A-2. Location 3 (unsupported edge) displacement results

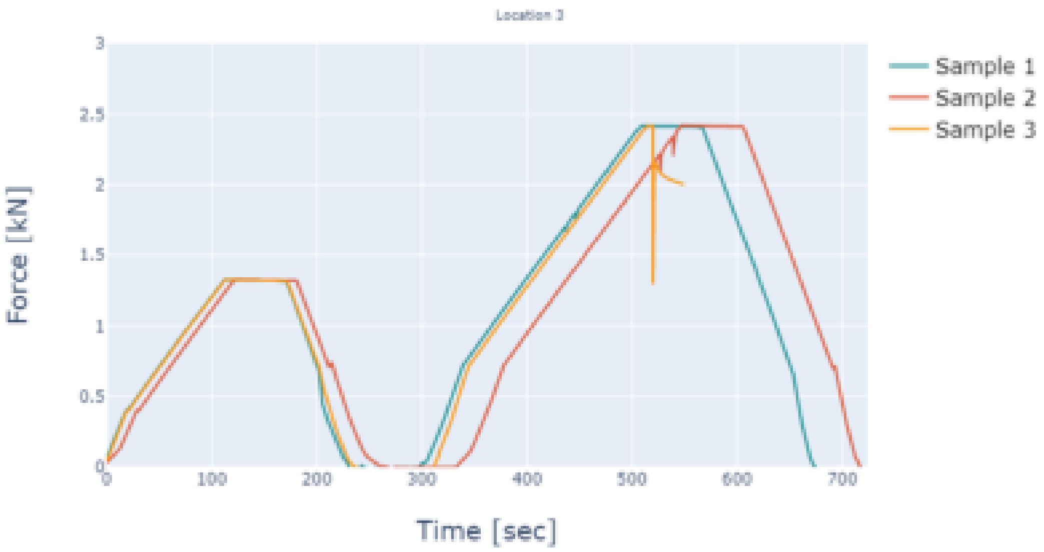


Appendix Figure A-3. Location 5 (midspan) displacement results

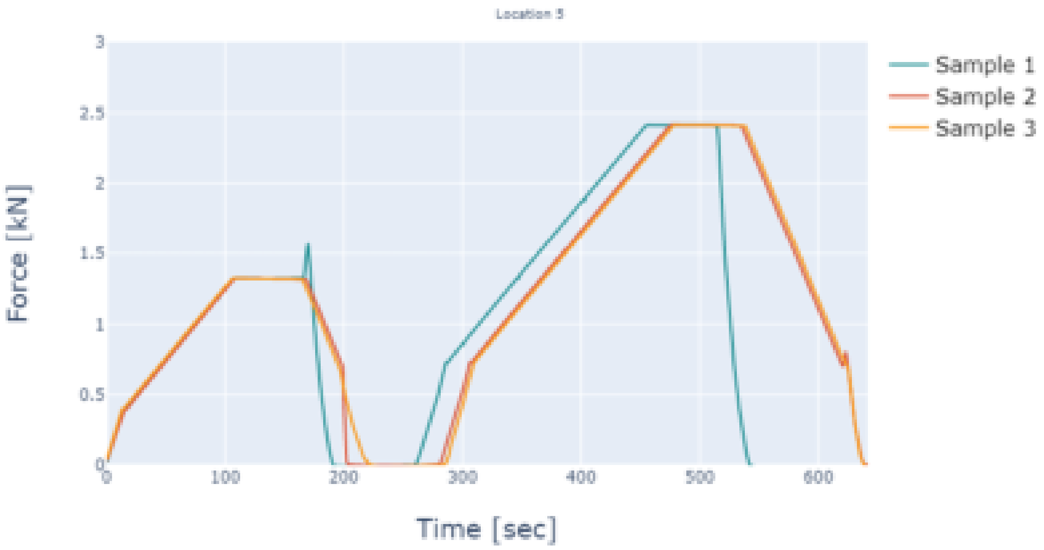
A.2 ULS Point Load Results



Appendix Figure A-4. Location 2 (male side of joint) force results



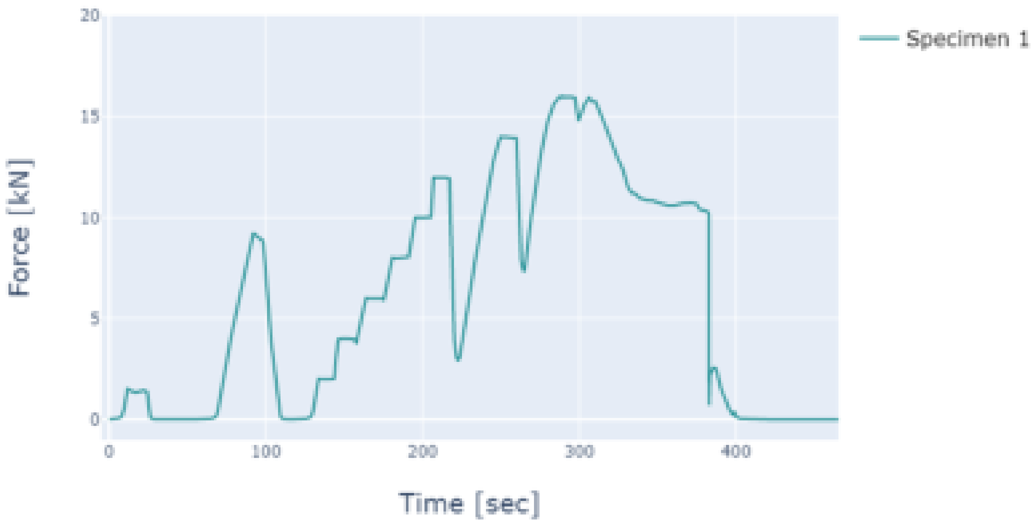
Appendix Figure A-5. Location 3 (unsupported edge) force results



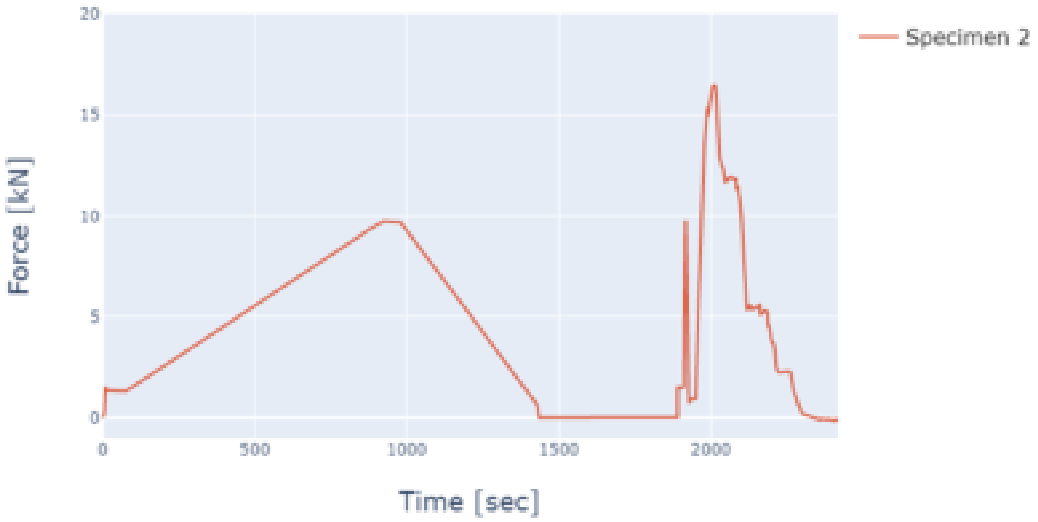
Appendix Figure A-6. Location 5 (midspan) force results

Appendix B 17mm Ecoply Wind Uplift Test Results

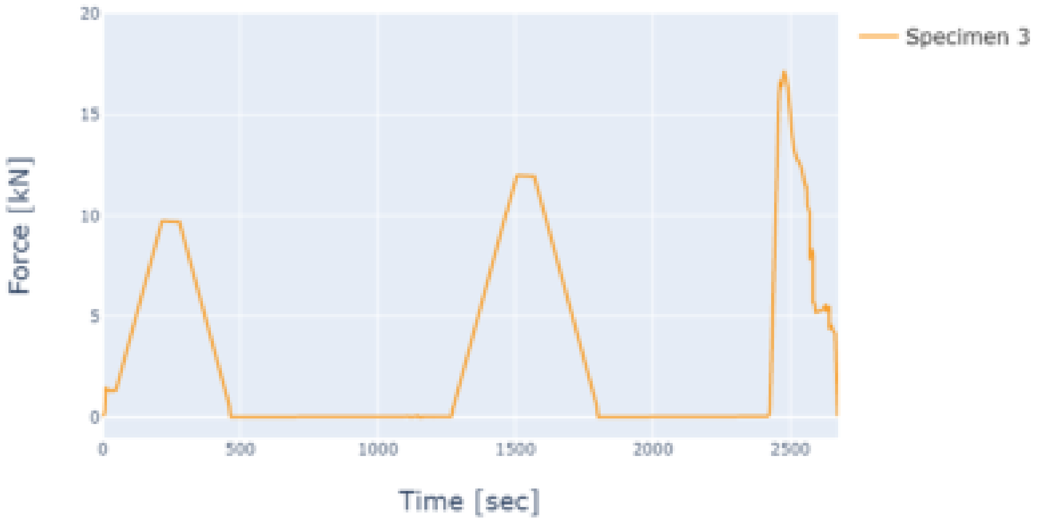
B.1 Force Results



Appendix Figure B-1. Ecoply specimen 1 force results

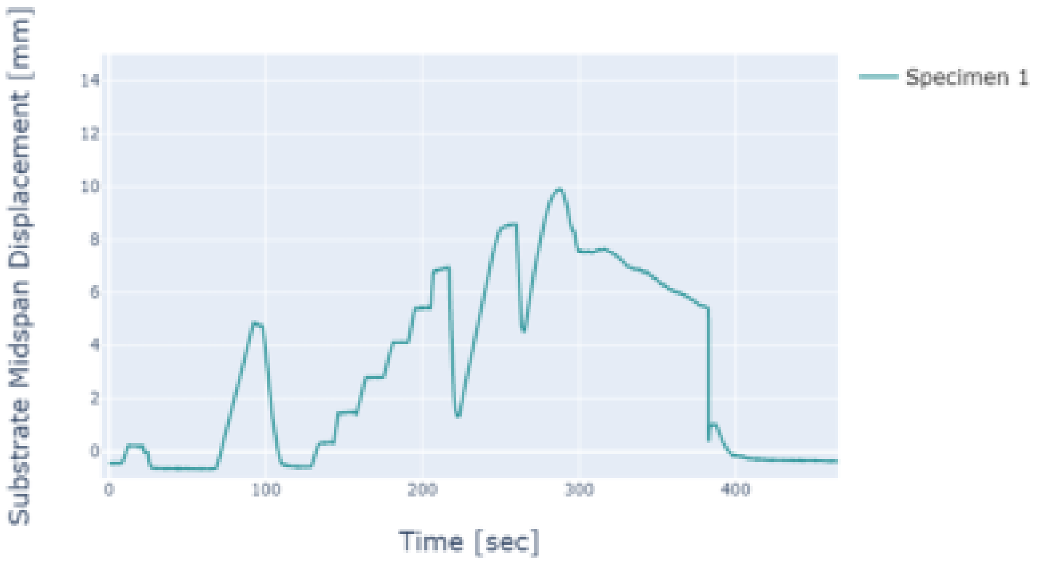


Appendix Figure B-2. Ecoply specimen 2 force results

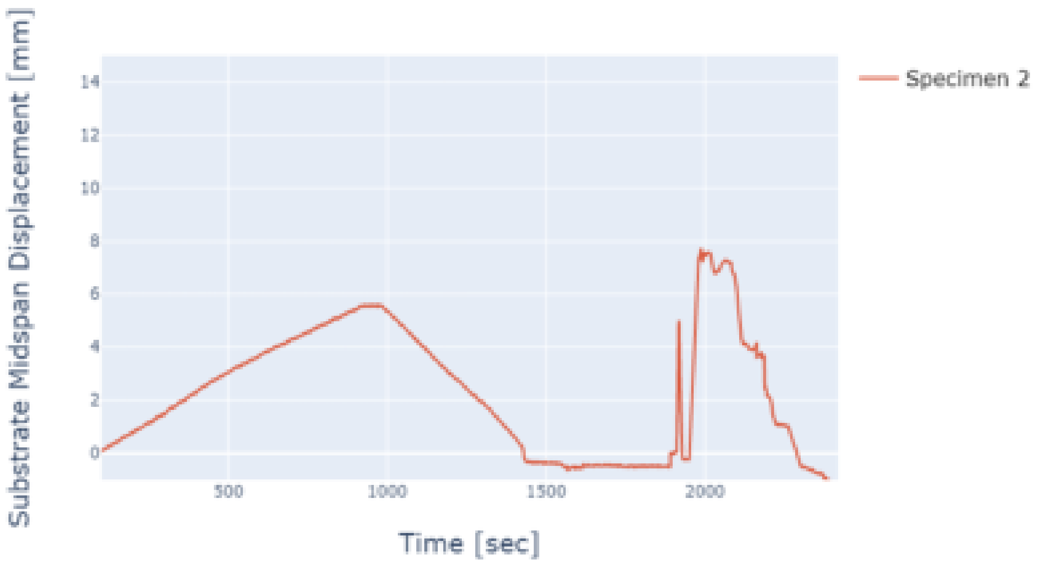


Appendix Figure B-3. Ecoply specimen 3 force results

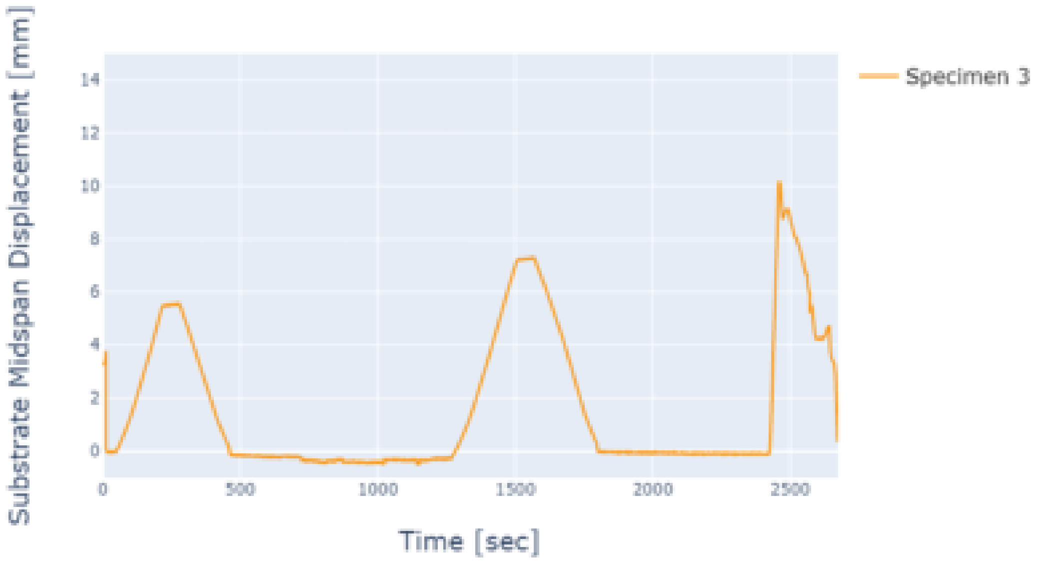
B.2 Substrate Midspan Displacement Results



Appendix Figure B-4. Ecoply specimen 1 substrate midspan displacement results



Appendix Figure B-5. Ecoply specimen 2 substrate midspan displacement results

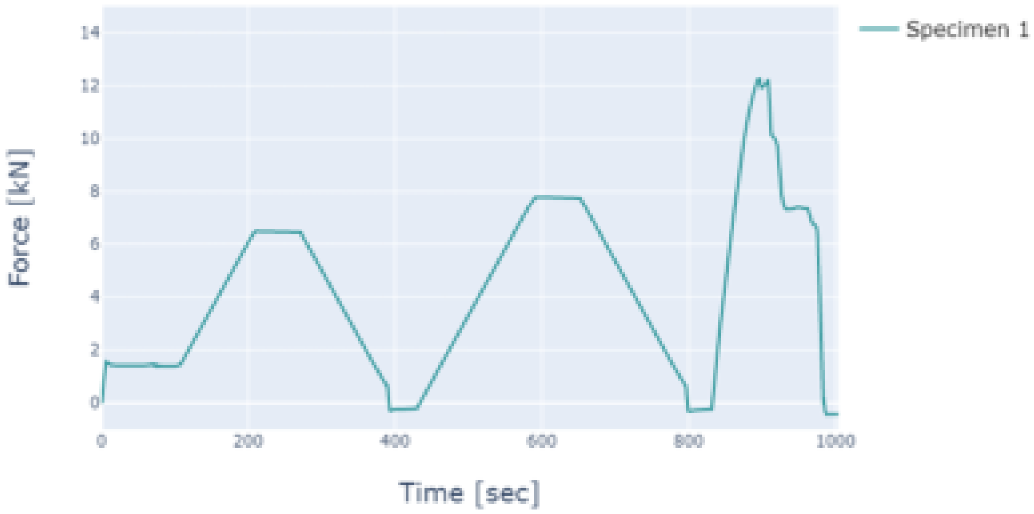


Appendix Figure B-6. Ecoply specimen 3 substrate midspan displacement results

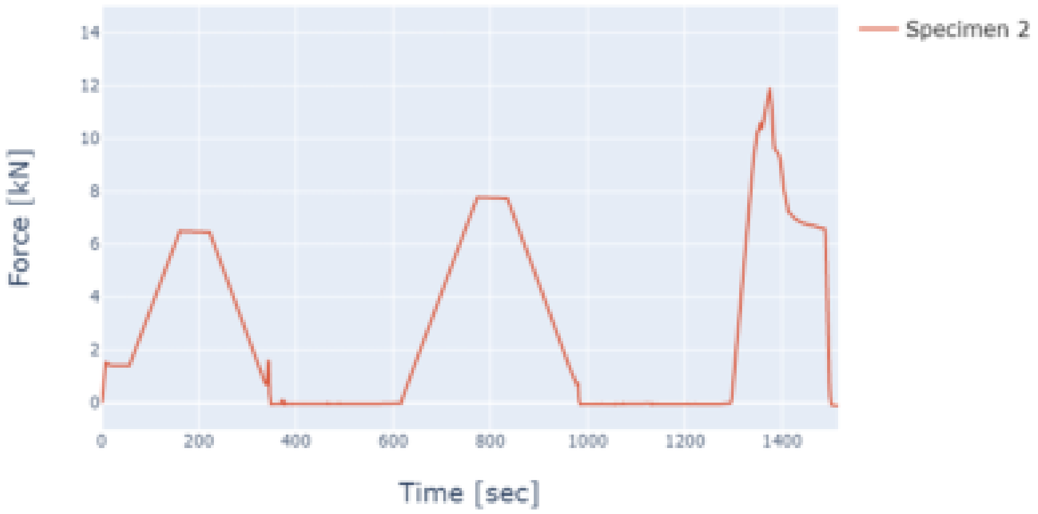
Appendix C ST900 Wind Uplift Test Results

C.1 Force Results

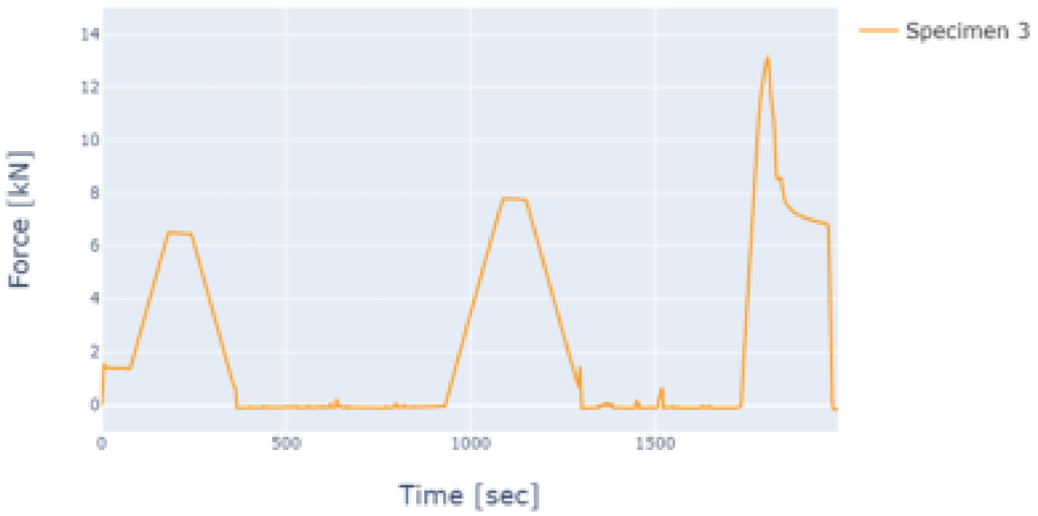
The force results from the three SLS/ULS tests are presented below. Note that the time scales differ as the unloaded condition was held for differing durations to allow for inspection.



Appendix Figure C-1. ST900 specimen 1 force results

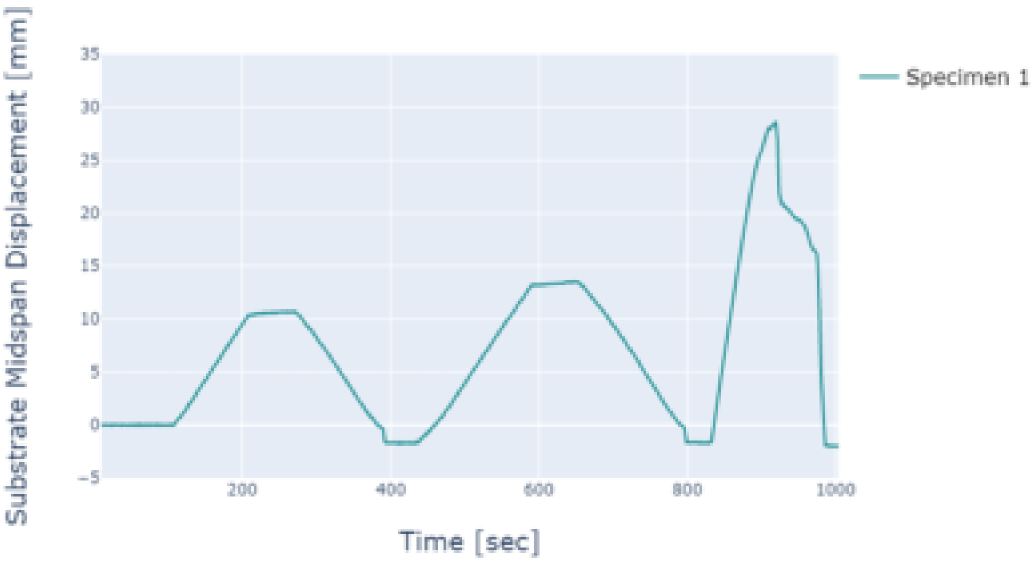


Appendix Figure C-2. ST900 specimen 2 force results

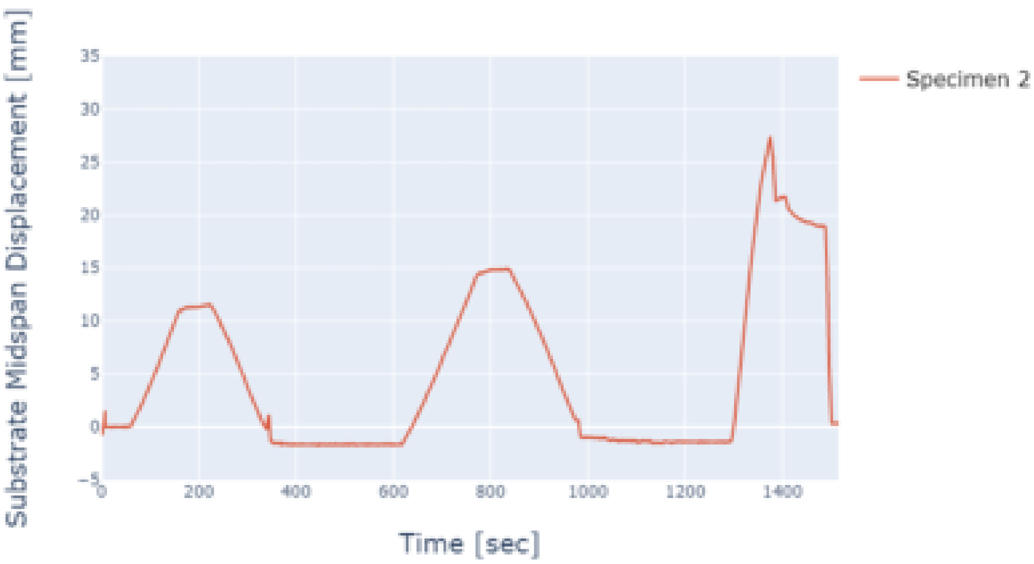


Appendix Figure C-3. ST900 specimen 3 force results

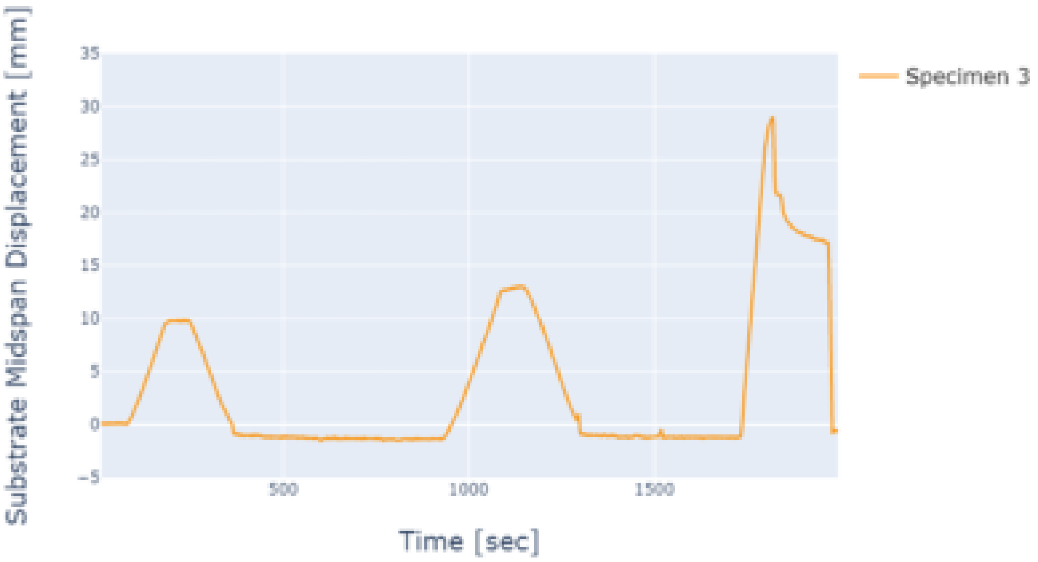
C.2 Substrate Midspan Displacement Results



Appendix Figure C-4. ST900 specimen 1 substrate midspan displacement results

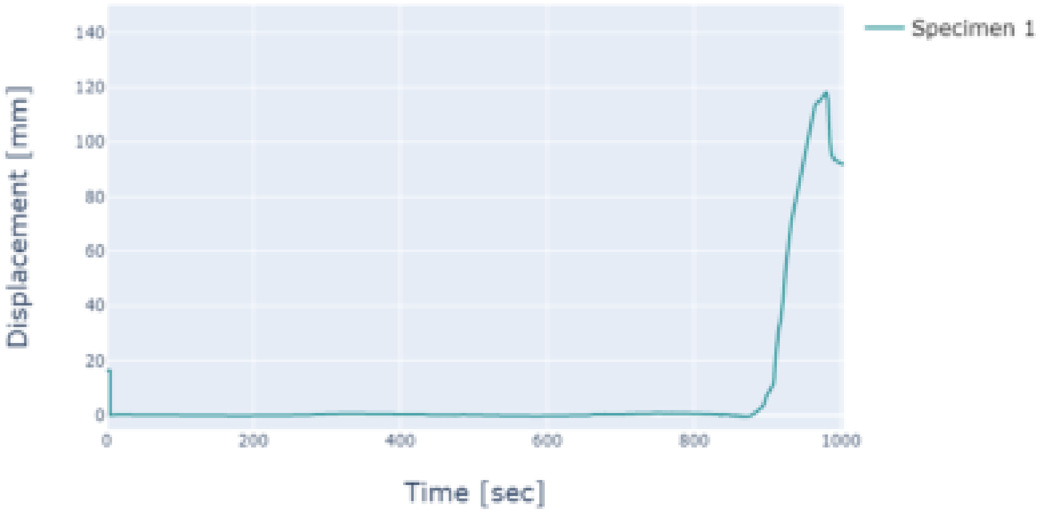


Appendix Figure C-5. ST900 specimen 2 substrate midspan displacement results

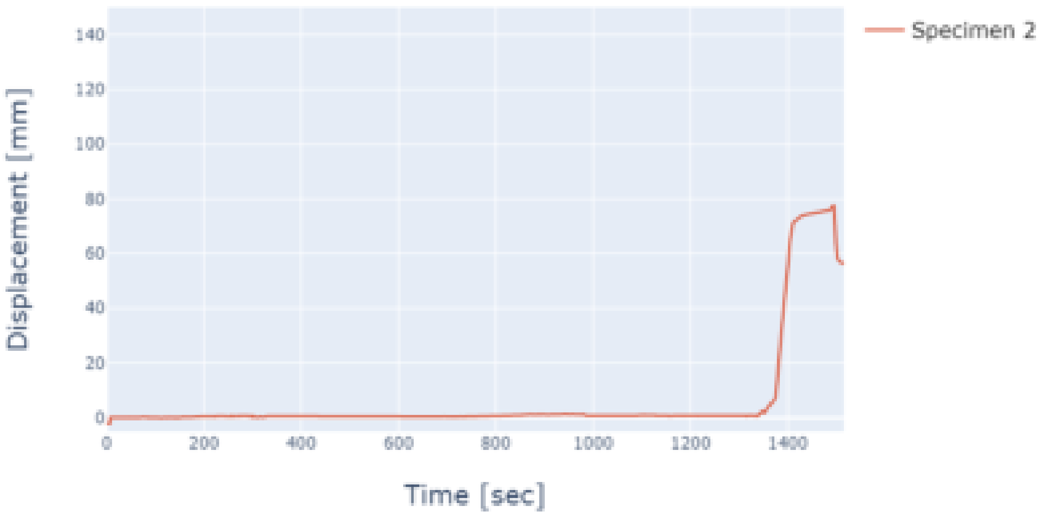


Appendix Figure C-6. ST900 specimen 3 substrate midspan displacement results

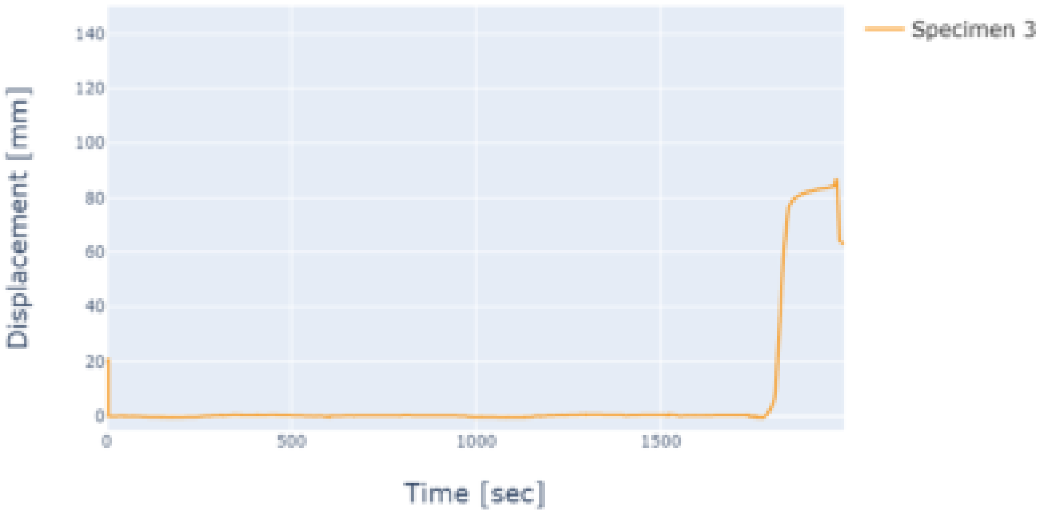
C.3 Relative Displacement Between PIR and Substrate at Midspan



Appendix Figure C-7. ST900 Specimen 1 midspan PIR-substrate relative displacement results

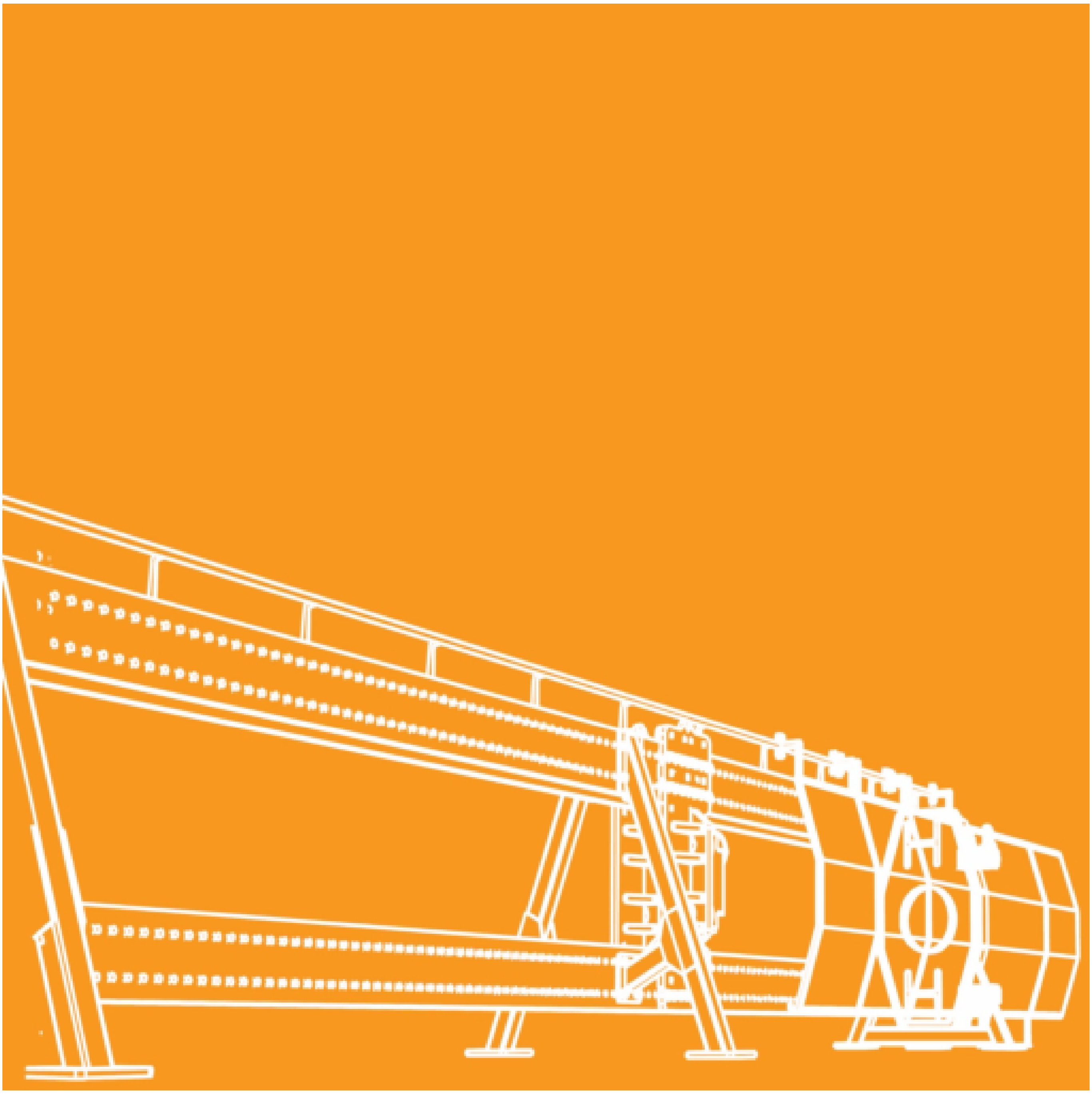


Appendix Figure C-8. ST900 Specimen 2 midspan PIR-substrate relative displacement results



Appendix Figure C-9. ST900 Specimen 3 midspan PIR-substrate relative displacement results

Appendix D – Metal roof substrate substitution report



Viking Roofspec WarmSpan²

Metal Roof Substrate Substitution

Holmes Solutions

Revision: 1.0
16/06/2023
Project: 144942.00

DISCLAIMER

Report Produced By:

Ben Scott
STRUCTURAL ENGINEER

Report Reviewed By:

Hayden Wright, P.Eng (Canada)
STRUCTURAL ENGINEER

Revision No:	Date	Revision
0.1	2 April 2023	For client review
1.0	16 June 2023	Final report

TABLE OF CONTENTS

FIGURES

TABLES

1 EXECUTIVE SUMMARY

Viking Roofspec have engaged Holmes Solutions LP to conduct a comparative analysis of their existing substrate used in their WarmSpan² roofing system (Steel and Tube's ST900 profile), with those of a similar profile, supplied by alternative suppliers; Dimond Roofing's "BrownBuilt 900" profile and Roofing Industries "MultiRib" profile.

After a product review, Roofing Industries MultiRib 0.55mm BMT and Dimond Roofing's BrownBuilt 900 0.55mm BMT profiles were determined to be suitable alternatives for the ST900, 0.55mm BMT, subject to wind loading and a maximum span of 1.8m. Although the relevant sectional properties are approximately 9% less than that of the ST900 profile, through calculations it was determined that the alternative profiles still have sufficient strength and stiffness to withstand wind loads.

Other alternative profiles – Steel and Tube's ST7 profile, 0.55mm BMT, and Metalcraft's Metcom7 profile, 0.55mm BMT, were also determined to be suitable alternatives to the ST900 profile. This is documented in Holmes Solutions report 113359 RP 1219 (1.0).

The technical literature for the BrownBuilt 900 profile states a maximum span of 1.6m when subject to point loading on an 'unrestricted' roof. It is therefore recommended that a maximum span of 1.6m is adopted for the BrownBuilt 900 profile, unless roof access is 'restricted' (type 2B), or the profile is subjected to further point load testing.

2 INTRODUCTION

Holmes Solutions have recently undertaken structural testing of the WarmSpan² warm roof product on behalf of Viking Roofspec. The results of this testing are summarised in the report "Viking Roofspec WarmSpan² Structural Testing" Revision 1.0, dated 27 February 2023.

Holmes Solutions have subsequently been engaged to offer engineering advice to Viking Roofspec regarding the substitution of materials used within the WarmSpan², in particular the ST900 0.55 Base Metal Thickness (BMT) profiled metal roofing substrate. Due to external factors, Viking Roofspec wish to offer alternatives to the ST900 product, which was included in the structural testing programme. The two suggestions by Viking Roofspec are Dimond Roofings BrownBuilt 900 (BB900) and Roofing Industries MultiRib. Both alternative profiles are also 0.55mm BMT.

3 TECHNICAL DISCUSSION

3.1 Application

The WarmSpan² product consists of a gypsum coverboard adhered to a polyisocyanurate (PIR) panel, which is affixed to a substrate using plastic plug washers and screws (Figure 3-1). One such tested substrate was Steel & Tube ST900 0.55 Base Metal Thickness (BMT) profiled metal roofing. The material was used to span a maximum of 1.8 m during testing.

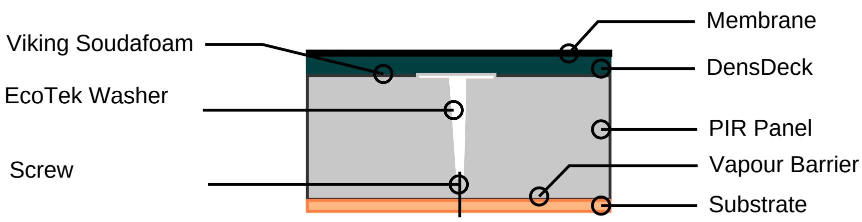


Figure 3-1. Example WarmRoof² construction.

The ST900 product is installed upside down relative to its typical orientation when used as a standalone roofing material (as shown Figure 3-2). This results in the wider section (75 mm) being in contact with the underside of the PIR panel, and the panel spanning 75 mm between support. The wider section has a subtle swage stiffener down the centre of the rib. The product has an overall depth of 38 mm.

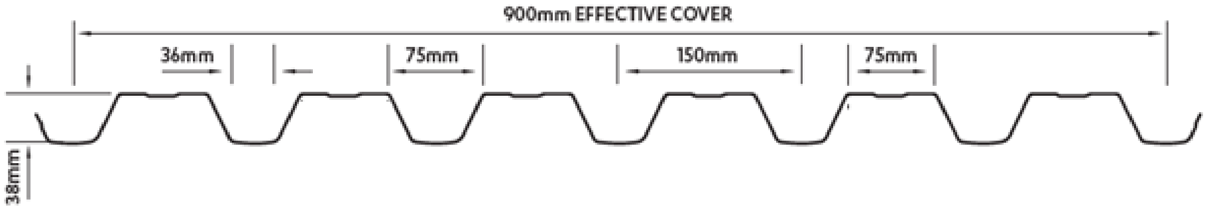


Figure 3-2. Existing ST900 profile (Note: Installed inverted as shown).

NOMINAL DIMENSIONS

Figure 3-3. Alternative acceptable profile - Steel and Tube ST7 profile (shown opposite to installed orientation)

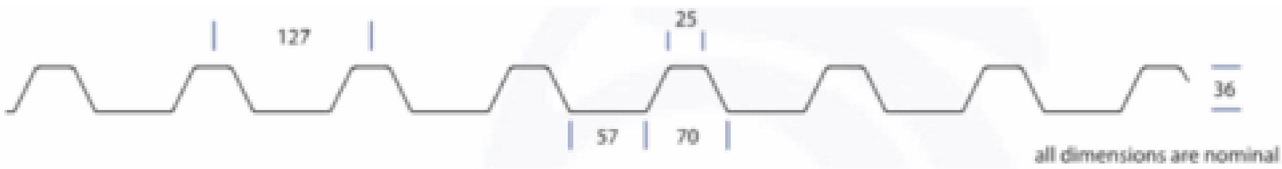


Figure 3-4. Alternative acceptable profile - Metalcraft Metcom 7 profile (shown opposite to installed orientation)

3.2 Analysis of Substrates

3.2.1 Engineering Background

An important aspect of cold-formed steel products when used in this application is their ability to withstanding buckling. As the substrate is installed upside down, the wider crests (as shown) are subject to compression stresses due to bending from wind uplift conditions; It is likely that localised buckling of the crest as a result of bending will initiate failure of the specimen, therefore the section modulus with regard to the distance from the centroid to the crest (Z_{TOP}) is the pertinent mechanical property to compare.

3.2.2 Materials

ST900 is formed from material with a yield strength of 550 MPa per the attached Product Technical Statement. Both BrownBuilt 900 and MultiRib are also formed from Grade 550 material, per respective attached product literature.

3.2.3 Geometry

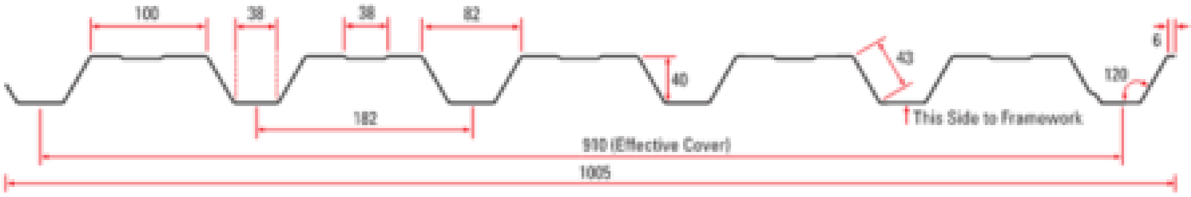


Figure 3-5. Proposed substitute: MultiRib section geometry (shown in intended orientation).

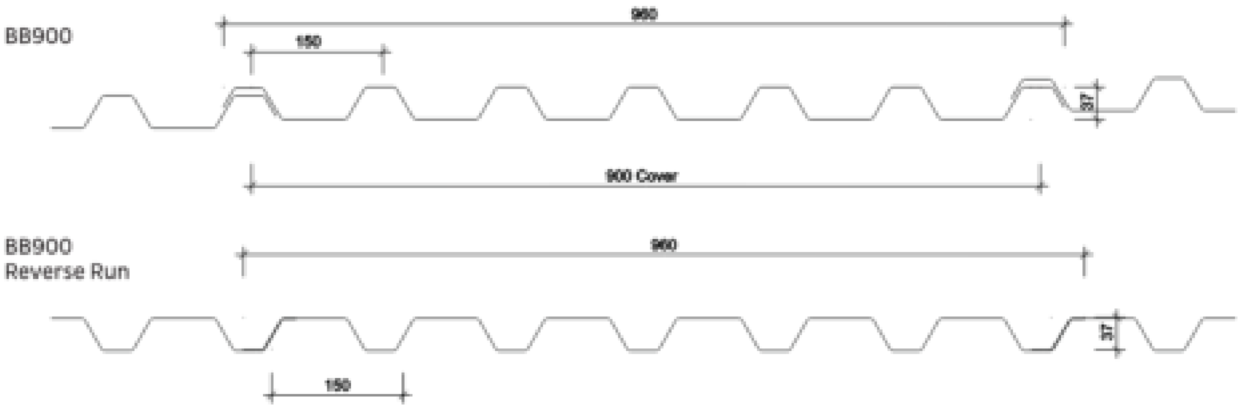


Figure 3-6. Proposed substitute: BrownBuilt 900 section geometry (lower profile shown in intended orientation.

3.2.4 Section Properties

ST900 provides section properties in its technical literature, and these are reproduced below in Table 3-1.

Table 3-1. ST900 provided section properties (reproduced from S&T ST900 PTS Feb 2015)

Measure Unit	Mass kg/m²	Area mm²	I mm⁴	Z Top mm³	Z Bottom mm³	Y (centroid) mm
.40mm B.M.T.	4.49	519	118851	5427	7382	16.1
.55mm B.M.T.	6.08	714	163480	7465	10154	16.1

Notes: *1. Properties are for 1 metre width of cladding 2. Values are nominal only 3. Yield strength is 550 MPa typical.*

Section properties are not provided for BrownBuild 900 or MultiRib in their corresponding product literature, therefore commercial Computer Aided Design (CAD) software was used to establish the relevant properties of all three profiles, based on the cross sections shown in Figure 3-2, Figure 3-5 and Figure 3-6. It is noted that the calculated Z_{TOP} value of the ST900 profile is higher than that stated in the ST900 product technical statement (7465mm^3), however all profiles were assessed using CAD software to be able to undertake a comparative analysis.

Table 3-2. Comparison of profiles

Profile	f_y (MPa)	Z_{TOP} (mm^3)	Notes
ST900 (0.55 mm BMT)	550	8018	
MultiRib	550	7270	91% of ST900 value
BrownBuilt 900	550	7296	91% of ST900 value

4 DISCUSSION

4.1 Point Loading

The following data is tabulated from the attached product guidance for the three products. It represents unrestricted access (Type 2A) loading when tested to the New Zealand Metal Roof Manufacturer's (NZMRM) Code of Practice (CoP). It was noted that BrownBuilt 900 has a shorter maximum end span when compared to ST900 and MultiRib, therefore in single span configuration, the BrownBuilt 900 profile should not span more than 1600mm, unless restricted access (Type 2B) is adopted for the roof, or further testing is undertaken.

Table 4-1. Maximum unrestricted access spans

Profile	Middle Span [mm]	End Span [mm]
ST900	2,300	1,700
MultiRib	3,000	2,000
BrownBuilt 900	2,400	1,600

4.2 Wind Loading

Calculated Z_{TOP} values of the two alternative substrates were inputted into Holmes Solutions' calculations, to assess their ability to resist wind uplift loads. A worst case ultimate limit state (ULS) wind load of 4.5kPa uplift (Extra high wind zone as per NZS 3604, and in a corner region of the roof as per NZS 1170.2) was assessed.

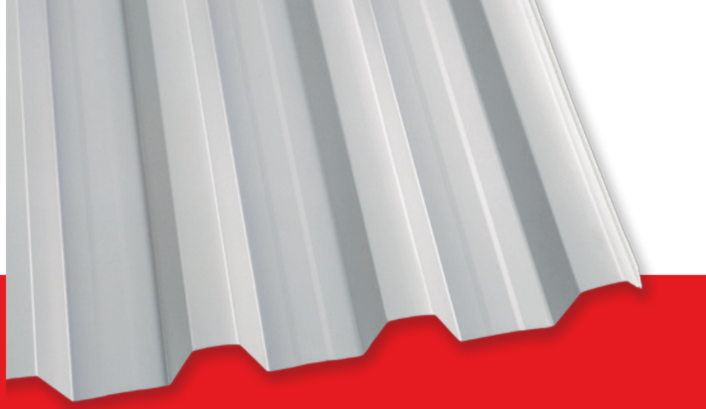
All three profiles are able to resist the imposed load when considering a 1800mm single span. It is also noted that in the physical testing of the WarmSpan^2 system, the governing failure mode was screws pulling out of the substrate, and not buckling of the steel substrate.

At serviceability limit state (SLS) loads, calculated deflections of the three profiles are similar (within 2mm). Physical testing of the ST900 profile in the WarmSpan^2 system also demonstrated that the other components of the roof system could accommodate the expected SLS deflections. It is therefore likely that SLS deflections using the alternative profiles is not of concern.

In summary, all three profiles have been shown through calculation to be able to span 1.8m under wind uplift loading. Fixing of the substrate to the underlying purlins should follow the manufacturers guidance.

Appendix A – ST900 product literature

steel&tube
STRONGER IN EVERYWAY

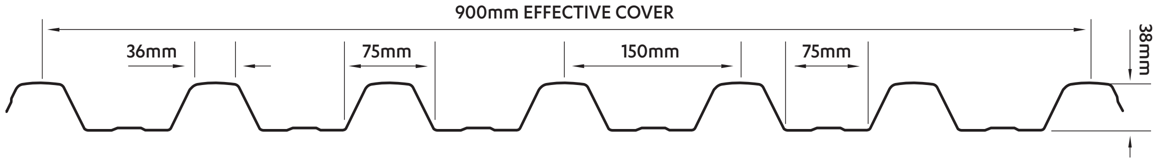


PRODUCT TECHNICAL STATEMENT

ST900

Profiled Metal Roofing and Cladding

NOMINAL DIMENSIONS



DESCRIPTION

ST900 is a medium rib profile. Developed for the commercial/industrial roofing and cladding markets, it is equally at home in residential settings where a bolder look is desired.

APPLICATIONS

- **Residential Roofing and Cladding**
- **Industrial/Commercial Roofing and Cladding**
- **Curving**

FEATURES

ST900 is distinguished by a subtle swage pan that adds stiffness to the pan, minimising canning and purlin line marking. Lapping ribs are interchangeable male/female, allowing flexibility to the installer, and feature a well-defined anti-capillary detail.

OPTIONS

ST900 in .55mm thickness can be crimp-curved to a minimum radius of 400mm. Matching translucent sheeting is available in GRP (fibreglass). The product can also be manufactured without the pan swage, in which case it should be specified and ordered as **STN900**.

MATERIALS

Available in metallic coated and pre-painted steel in .40mm and .55mm B.M.T. (base metal thickness) aluminium plain and prepainted in .70mm and .90mm, and other non-ferrous metals.

FASTENERS

Typically: Steelfix 12g x 65mm, Timberfix 12g x 75mm, Class 4 minimum, of material compatible with that being fastened and durability no less than the sheet material. Category 5 or non-ferrous fasteners are recommended for very severe marine environments.

DURABILITY

All material selections must be compatible with prevailing environmental conditions and adjacent materials, see *Roofing Solutions Product Guide* or *Specifiers Guide* for details. Areas not exposed to rain washing will require programmed maintenance.

WARRANTY PLUS

Steel & Tube **Warranty*Plus*** is the most comprehensive warranty available in the industry. **Warranty*Plus*** covers an extended range of performance criteria, is supported back-to-back by our suppliers, includes site-specific maintenance requirements and is transferable to subsequent owners.

SECTIONAL PROPERTIES

Measure Unit	Mass kg/m²	Area mm²	I mm⁴	Z Top mm³	Z Bottom mm³	Y (centroid) mm
.40mm B.M.T.	4.49	519	118851	5427	7382	16.1
.55mm B.M.T.	6.08	714	163480	7465	10154	16.1

Notes: *1. Properties are for 1 metre width of cladding 2. Values are nominal only 3. Yield strength is 550 MPa typical.*

PERFORMANCE DATA

Maximum spans for Normal and Heavy Traffic in millimetres. Distributed loads in kPa at maximum spans using 6 fasteners per sheet per support. Loads for alternative fastener frequencies available on request.

Gauge	Controlled Traffic*			
	Internal		End	
	Span	Load	Span	Load
.40mm	2400	2.95 st	1700	4.30 st
		2.19 sv		3.40 sv
.55mm	3500	3.15 st	2800	3.25 st
		1.90 sv		1.75 sv

Gauge	Heavy Traffic**			
	Internal		End	
	Span	Load	Span	Load
.40mm	1000	8.50 st	1000	7.10 st
		7.34 sv		6.40 sv
.55mm	2300	4.55 st	1700	6.10 st
		3.51 sv		3.00 sv

** Supports 1.1kN to PAN at midspan. ** Supports 1.1kN to RIB at midspan.*

st = Limit State Strength Load. sv = Limit State Serviceability Load.

Products tested in accordance with NZMCM recommendations.

MINIMUM PITCH

In accordance with Acceptable Solution E2, the minimum pitch for **ST900** is 3˚. Roof runs in excess of 65 metres should be checked for water runoff capacity.

FOOT TRAFFIC

Foot traffic up the roof must take place with load spread equally across two ribs, or in the pan and against an adjacent rib. Traffic across the roof must take place along the purlin lines.

SPECIFICATIONS

Recommended specifications are available in the branded sections of MasterSpec *BASIC* or MasterSpec *STANDARD*, or from your local Steel & Tube branch or visit our website.

DESIGN DETAILS

Design details covering many applications are available on our website in CAD and PDF under each product section. Visit www.steelandtube.co.nz.

IMPORTANT PUBLICATIONS

For your installation to perform to its potential, it is essential that it is designed, installed and maintained in accordance with good trade practice. Please refer to:

- Steel & Tube: Roofing Solutions Product Guide
- New Zealand Steel: Installation Guide
- New Zealand Steel: Builders and Specifiers Guide
- BRANZ: Good Profiled Metal Roofing Practice
- MRM: New Zealand Metal Roofing and Wall Cladding Code of Practice
- E2/AS1

INSTALLERS

A list of local installers for your area and contract type is available from your local Steel & Tube branch or visit www.steelandtube.co.nz.

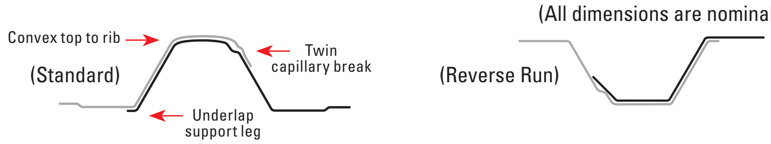
Note:
Trademarks apply to the following products presented in this publication: ST900, MasterSpec BASIC and MasterSpec STANDARD.

Appendix B – Roofing Industries "MultiRib" product literature

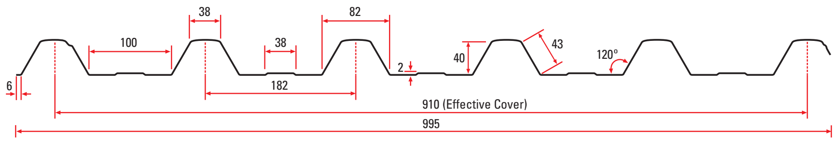
PROFILE TECHNICAL SUMMARY

(All dimensions are nominal and in mm.)

Multirib lap

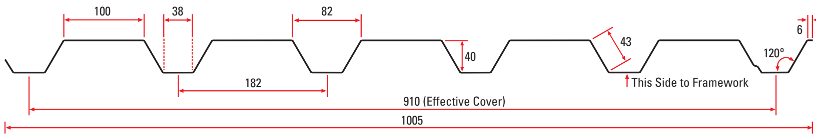


Multirib (Roofing and Wall Cladding)
Dimensioned Drawing of Multirib

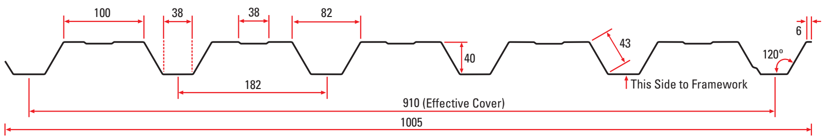


Multirib Reverse Run
Dimensioned Drawings of Multirib Reverse Run
(For wall cladding only)

Option A - Without swage



Option B - With swage



Minimum Pitch

The minimum roof pitch for Multirib is 3 degrees (approx 1:20).
Any variation from the above should be referred to Roofing Industries.

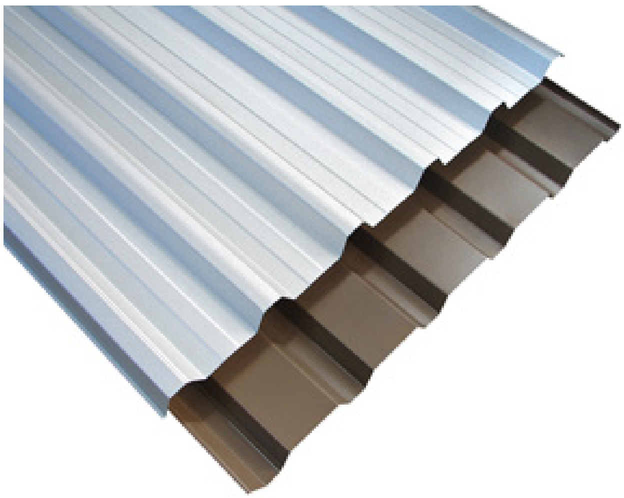
When a combination of sheets provide a run of in excess of 40 metres and up to 60 metres the roof pitch should be increased by 1 degree. Longer lengths require specific design.

When rainfall intensity exceeds 100mm/hour the minimum pitches need to be increased by a further 1 degree for every 10 metres of run over 40 metres.

The building design pitch may need to be higher to take into account any cumulative deflections of the frame, purlin and roof sheeting or penetrations.

With curved roofing the roof cladding must not terminate at a pitch lower than permitted above.

Side laps of curved sheets must be sealed to any areas below the minimum pitches permitted above.



Branches: • Whangarei • Auckland • Pukekohe (Franklin Metal Folding & Roofing Ltd) • Hamilton • Taupo • Palmerston North • Wellington • Christchurch

- Manufactured custom cut to length subject to transport and site limitations.
- As sheet lengths increase higher transportation costs may be applicable.
- Sheet lengths in excess of 28 metres require specialised transportation. Refer to Roofing Industries.
- Maximum recommended sheet lengths for **Aluminium** is 10-12 metres for dark coloured and 12-15 metres for plain and light coloured. Refer to Roof Expansions Provisions of this summary.

Information Table

Substrate Material	Steel		Aluminium	
Thickness	**.40mm BMT**	**.55mm BMT**	**.70mm BMT**	**.90mm BMT**
Aprox weight per lineal metre for Zincalume based material (kg/lm)	4.05	5.48	2.39	3.07
Purlin Spacings -General	Refer to separate section.		Refer to separate section.	
Unsupported Overhang (mm) [1]	250	350	200	300
Drape Curved Roof -min Radius (m)	N/R[2]	85	N/R[2]	85
Purlin Spacings for Curved Roofs -Intermediate (mm) -End (mm)	N/R[2] N/R[2]	2400 1600	N/R[2] N/R[2]	2400 1600
Precurved Roof -min Radius (mm) -Recommended Minimum Radius (mm)	N/A[3] N/A[3]	N/A[3] N/A[3]	N/A[3] N/A[3]	N/A[3] N/A[3]

[1] Not suitable for roof access without additional support) [2] N/R - Not recommended [3] N/A - Not Available

This technical data sheet is for steel and aluminium based substrates. Multirib can also be manufactured in other metals such as Copper or Titanium Zinc. Refer to Roofing Industries.

Specification

Refer to our Full Specification on Masterspec, our website, and our Selection Guide.

Building Design / Performance Criteria / Product Selection

During the design of buildings, it is necessary for the designer to take into account a number of issues to ensure that the most appropriate roofing and cladding product is chosen.

Whilst aesthetics and product availability do play a part, the chosen profile must meet certain performance criteria. These are centred around the profile's ability to shed water from the roof and the ability of the product to span purlin and girt spacings and meet design criteria. The minimum pitch for this profile is outlined elsewhere within this literature.

In terms of purlin spans and girt spacing it is necessary to follow due process.

If a building is being designed and constructed in full accordance with E2/AS1 and roofing and cladding products as covered by that document are chosen, then it is necessary for the design spans and fixing methodology to comply with those of E2/AS1. However E2/AS1 states that the use of the manufacturers information may provide a more optimum spacing of fixings, and this is recommended by Roofing Industries.

Further where a building is outside of the scope of E2/AS1 and the building or parts thereof are of specific design then it is necessary for the roofing and cladding to be suitable for the design and vice versa.

Loadings referred to in Roofing Industries graphs are the result of testing to a serviceability limit state which is more conservative than an ultimate limit state as quoted by some manufacturers.

Our Design Graphs are presented in a form to allow the designer to select suitable products and purlin spacings.

For most roof installations the purlin spacings will be limited by the trafficable limitations of the profile or the structural design. It is then necessary for the designer to calculate the design wind load for the roofing and cladding in accordance with generally acceptable practice, by reference to AS/NZS 1170.2: 2011, and/or NZS 3604: 2011 as appropriate. For a fuller explanation of this refer to the NZ Metal Roof and Wall Cladding Code of Practice. This result should be referenced to the Wind Load Span Design Graphs.

The purlin spacings should be limited to the lower of the trafficable limitations and design wind load with the capacity of the structure being greater than the design load for the application. However for roofs that are not able to be walked on and for wall cladding applications, the trafficable limitations may be exceeded providing the design wind loading criteria is met. However this should be done with caution as it may require considerable extra secondary fasteners within the laps.

The designer should always take into account in areas of heavy roof traffic, snow loadings, or where the roofing supports such items as air conditioning units, purlin spacing should be reduced accordingly. Consideration also needs to be given to limitations of purlin spacings for any translucent sheeting.

Reference should be made to the notes in the graphs.

It is our recommendation that for commercial and industrial roofing applications that .55mm BMT steel or .90mm BMT Aluminium is used as it has more resilience to damage particularly by other trades.

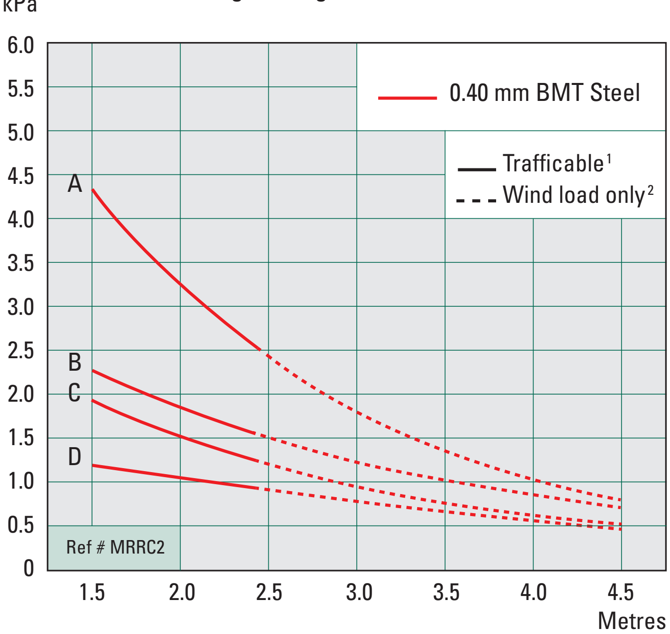
Underlay as per the project specifications should be used.

With an aluminium substrate steel netting should not be used where it may be in contact (either directly or through underlay degradation) with the aluminium roofing or cladding. Alternative material such as polypropylene strapping should be used where support is required, or the cladding separated from the underlay by a high density polystyrene batten or Thermakraft Drainage Matt or similar, and the use of an aluminium gutter flashing. This is also applicable to coated metal and zinc roofing in severe marine applications. In all the above cases self supporting paper should be used, including when support is required.

WIND & CONCENTRATED LOAD SPAN DESIGN GRAPH

Roofing - Steel Based Material

.40 Steel G550 High Strength



- Intermediate span in metres.
- End spans to be a maximum of 2/3 of this span.
- A, B, C and D represent alternative primary fixing methods

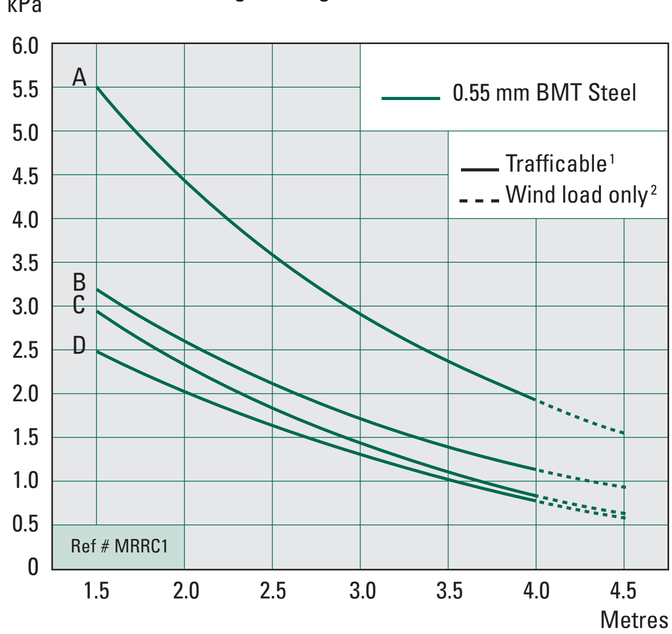
1) The solid line represents where walking is permitted within 300 mm of the purlin line or in the pan of the profile. Therefore for a normal roof, providing wind load requirements are met, purlin spans are limited to:

Maximum Spans	0.40 mm BMT
Intermediate	2.4 metres
End	1.6 metres
Type 2B *"Restricted Access"* Classification	

2) The broken line represents untrafficable roof areas and is wind loading only and has a Type 3 Classification.

In areas of heavy roof traffic, snow loadings or containing items such as air conditioning units purlin spacing should be reduced accordingly.

.55 Steel G550 High Strength.



- Intermediate span in metres.
- End spans to be a maximum of 2/3 of this span.
- A, B, C and D represent alternative primary fixing methods

1) The solid line represents where walking is permitted within 300 mm of the purlin line or in the pan of the profile. Therefore for a normal roof, providing wind load requirements are met, purlin spans are limited to:

Maximum Spans	0.55 mm BMT
Intermediate	4.0 metres
End	2.7 metres
Type 2B *"Restricted Access"* Classification	

2) The broken line represents untrafficable roof areas and is wind loading only and has a Type 3 Classification.

In areas of heavy roof traffic, snow loadings or containing items such as air conditioning units purlin spacing should be reduced accordingly.

For Type A "Unrestricted Access" Classification, refer to Purlin Spacing Limitations and Recommendations.
Classification types are from the NZ Metal Roof and Wall Cladding Code of Practice.
Testing confirms that .70mm Aluminium has similar results to .40mm Steel and that .90mm Aluminium has similar results to .55mm Steel and is adjusted for practical application. Aluminium requires load spreading profile washers and EPDM's at all time.

Primary Fixing Methods

Roofing Application

A - Fixed every purlin, every rib with approved screws & neos, load spreading profiled metal washers and EPDM washers.

B - Fixed every purlin with the same pattern, (hit-miss-hit-hit-miss-hit) with approved screws &and neos, load spreading profiled metal washers and EPDM washers. End purlins and periphery of roof to be fixed every rib.

C - Fixed every purlin with the same pattern, (hit-miss-hit-hit-miss-hit) with approved screws and neos and 25mm Aluminium embossed washers. End purlins and periphery of roof to be fixed every rib.

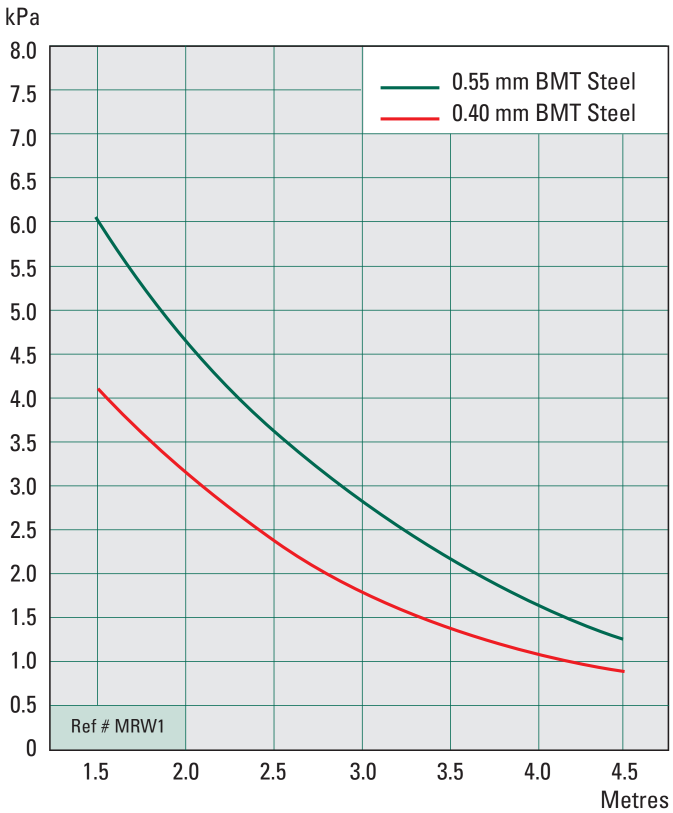
D - Fixed every purlin with the same pattern, (hit-miss-hit-hit-miss-hit) with approved screws and neos without washers. End purlins and periphery of roof to be fixed every rib.

Drape Curved Roofing

It is recommended that the first two purlins at each end of the sheet in drape curving situations, should be fixed using profile metal washers and EPDM washers to every crest, with the balance of the roof fixed as above.

Wall Cladding - Steel Based Material

Combined Graph, .40 and .55 Steel High Stength

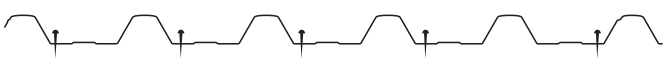


- Intermediate span in metres.
- End spans to be a maximum of 2/3 of this span.
- Type 3 Classification.

Testing confirms that .70mm Aluminium has similar results to .40mm Steel and that .90mm Aluminium has similar results to .55mm Steel and is adjusted for practical application.

Primary Fixing Methods

Fixed in the pan adjacent to every rib every girt, with approved screws & neos. At the laps the fixing is to be adjacent to the lap rib.



Classification type

All roofing and cladding has been tested in accordance with the NZMRM test procedure.
Classification Types are from the NZ Metal Roof and Wall Cladding Code of Practice and is adjusted for practical application.

PURLIN/GIRT SPACING LIMITATIONS AND RECOMMENDATIONS

(Dimensions in metres)

E2/AS1 states that a specific design may produce a more optimum spacing for fixing than as presented in this document. For profiles such as Multirib that is particularly applicable and as such the manufacturers information should be used.

Manufacturers recommendations for maximum spacings in accordance with NZ Metal Roof and Wall Cladding Code of Practice

		Steel Based Material			**Aluminium H36**	
		.40mm BMT		.55mm BMT	.70mm BMT	.90mm BMT
Restricted Access Roof (Type 2B) (Where walking is permitted within 300mm of the purlin line or in the pan of the profile)	Intermediate End	2.400 1.600	For wind design loads for steel based materials refer to graphs or Summary Chart.	4.000 2.700	1.800 (2.5kPa)* 1.200 (4.0kPa)*	3.000 (1.9kPa)* 2.000 (3.2kPa)*
Unrestricted Access Roof (Type 2A) (Where walking is permitted anywhere on the roof cladding)	Intermediate End	1.200 0.800		3.000 2.000	1.100 (4.5kPa)* 0.750 (4.7kPa)*	2.100 (3.6kPa)* 1.400 (5.2kPa)*
Non Accessible Roof and Wall Cladding (Type 3)	Intermediate End	2.900 1.900		4.100 2.700	1.800 (1.8kPa)* 1.200 (3.3kPa)*	3.000 (1.9kPa)* 2.000 (3.2kPa)*

*Wind design load for Aluminium using Primary Fixing Method A. See Summary Charts for steel

Classification Types are from the NZ Metal Roof and Wall Cladding Code of Practice and do not allow for any congregation of foot traffic.
Purlin spacing limitations to be read in conjunction with Wind Load Span Design Graphs and Charts.
In areas of heavy traffic purlin spacing should be reduced accordingly.
For curved roofing refer to Information Table.
When roof pitch is 8 Degrees or higher and self supporting paper is preferred to be used (without any support) purlin spacings must be limited to a maximum of 1.200 mtr centres for vertically run underlay and 1.150 mtr centres for horizontally run underlay. This is particularly relevant with aluminium and /or severe marine environments for the reasons designated under Building Design/Performance Criteria/Product Selection part of this document.

Snow Loads

When the possibility of snow exists it is necessary to allow for the extra imposed snow loads by increasing the strength of the structure, and/or minimising the build up of snow, and this is generally achieved by increasing the roof pitch by allowing easier shedding of the snow or otherwise as the designer determines.

The objective is to simplify rather complex loading patterns while remaining adequately cautious. The design loads should take account of drifting snow due to wind, but wind loads are not required to be combined with snow loads.

As snow loads are uniformly distributed loads they are similar to wind loads.

Snow loadings are not required to be taken into account for the North Island of New Zealand north of a line drawn from Opotiki to Turangi and New Plymouth.

However for other areas snow loadings may need to be taken into account dependent on the area and altitude of the proposed project. A fuller reference including a map and chart is available from the NZ Metal Roofing Roof and Wall Cladding Code of Practice Section 3.5.

SUMMARY CHART FOR ROOFING SPANS IN STEEL

Incorporating Wind and Concentrated Load Span Design Graphs, Primary Fixing Methods and Foot Traffic

.40mm BMT Steel

Purlin Spacing (mtrs)		WIND DESIGN LOADINGS - kPa's												
		Fixing Method A			**Fixing Method B**			**Fixing Method C**			**Fixing Method D**			**Foot Traffic**
Intermediate	End	Int.	End	Int (P)	Int.	End	Int (P)	Int.	End	Int (P)	Int.	End	Int (P)	
1.2	0.8	4.5	4.7	4.5	2.3	2.4	4.5	1.9	2.2	2.8	1.2	1.3	2.6	Unrestricted
1.5	1.0	4.3	4.5	4.3	2.2	2.3	4.3	1.8	2.1	2.7	1.2	1.2	2.5	
1.75	1.17	3.7	4.5	3.7	2.0	2.3	3.7	1.7	2.1	2.4	1.1	1.2	2.25	
2.00	1.33	3.2	4.4	3.2	1.8	2.2	3.2	1.5	2.1	2.2	1.0	1.2	2.0	Restricted Access Walk within 300mm of Purlins or in pan of roof
2.25	1.5	2.7	4.3	2.7	1.6	2.2	2.7	1.4	1.9	2.0	0.9	1.2	1.8	
2.4	1.6	2.5	4.0	2.5	1.55	2.1	2.5	1.3	1.8	1.8	0.9	1.2	1.7	
2.5	1.67	2.4	3.8	2.4	1.5	2.1	2.4	1.2	1.8	1.8	0.9	1.1	1.6	
2.75	1.83	2.0	3.4	2.0	1.3	1.95	2.0	1.1	1.7	1.5	0.8	1.1	1.4	Non Accessible
2.9	1.9	1.8	3.3	1.8	1.2	1.9	1.8	1.0	1.6	1.4	0.8	1.00	1.25	

.55mm BMT Steel

Purlin Spacing (mtrs)		WIND DESIGN LOADINGS - kPa's												
		Fixing Method A			**Fixing Method B**			**Fixing Method C**			**Fixing Method D**			**Foot Traffic**
Intermediate	End	Int.	End	Int (P)	Int.	End	Int (P)	Int.	End	Int (P)	Int.	End	Int (P)	
1.2	0.8	6.0	6.0	6.0	3.5	3.5	6.0	3.3	3.3	5.5	2.7	2.7	5.0	
1.5	1.0	5.5	6.0	5.5	3.2	3.5	5.5	2.9	3.3	5.0	2.5	2.7	4.6	
1.75	1.17	4.9	5.9	4.9	2.8	3.4	4.9	2.65	3.2	4.4	2.25	2.6	4.0	
2.0	1.33	4.4	5.7	4.4	2.6	3.3	4.4	2.3	3.1	3.7	2.0	2.5	3.4	Unrestricted
2.25	1.5	4.0	5.5	4.0	2.3	3.2	4.0	2.1	2.9	3.3	1.8	2.5	3.0	
2.4	1.6	3.6	5.3	3.6	2.15	3.1	3.6	1.9	2.8	2.9	1.65	2.4	2.7	
2.5	1.67	3.5	5.1	3.5	2.1	3.0	3.5	1.8	2.7	2.8	1.6	2.3	2.6	
2.75	1.83	3.3	4.7	3.3	1.8	2.75	3.3	1.6	2.5	2.4	1.45	2.2	2.2	
2.9	1.9	3.0	4.6	3.0	1.75	2.7	3.0	1.5	2.4	2.2	1.4	2.1	2.0	
3.0	2.0	2.9	4.4	2.9	1.70	2.6	2.9	1.4	2.3	2.1	1.3	2.0	1.9	Restricted Access Walk within 300mm of Purlins or in pan of roof
3.25	2.16	2.6	4.3	2.6	1.50	2.5	2.6	1.2	2.2	1.8	1.25	1.9	1.65	
3.5	2.33	2.3	3.8	2.3	1.35	2.2	2.3	1.1	2.0	1.5	1.0	1.75	1.4	
3.75	2.5	2.2	3.5	2.2	1.25	2.1	2.2	0.95	1.8	0.9	0.8	1.6	0.8	
4.0	2.70	1.90	3.2	1.9	1.1	1.8	1.9	0.8	1.7	0.8	0.75	1.4	0.75	
4.1	2.70	1.8	3.2	1.8	1.1	1.8	1.8	0.8	1.7	0.75	0.7	1.4	0.7	Non Accessible

Int (P) = Intermediate Periphery Loadings other than end spans (eg gable ends)

For wall cladding refer to Wall Cladding Graph. When fixed in accordance with the Primary Fixing Method loadings will always be higher than the above roofing charts.
Foot traffic classifications do not allow for any congregation of foot traffic.

PRIMARY FIXING CHART

Roofing - Crest fixed (To be read in conjunction with Roof Expansion Provisions and Load Span Design Graph)

	Wood Purlins	Steel Purlins or girts up to 1.5mm	Steel Purlins or girts 1.5-4.5mm	Steel Purlins or girts 4.5-12mm	Washers (When required)
Steel Based Material	14-10x75 Class 4 Type 17 Woodteks with neos or 14-10x100 Class 4 Type 17 Woodteks with neos	12-14x65 Class 4 Steelteks with neos	12-14x65 Class 4 Steelteks with neos	12-24x 65 Class 4 Series 500 Steelteks with neos	Multirib load spreading profile Steel and 36mm EPDM or 25mm Aluminium embossed washer
Aluminium Based Material	14-11x73 Alutite with bonded washer with Multirib load spreading profile 1.2mm Ali washers and 36mm EPDM, or Stainless steel grade 316, 14-10x100 Type 17 with neos through a 10mm dia. clearance hole with Multirib load spreading profile 1.2mm Ali washer & 36mm EPDM	Stainless steel grade 304, 14-14x70 Steelteks and bonded washer through a 10mm dia. clearance hole with Multirib load spreading profile 1.2mm Ali washer & 36mm EPDM	Stainless steel grade 304, 14-14x70 Steelteks and bonded washer through a 10mm dia. clearance hole with Multirib load spreading profile 1.2mm Ali washer & 36mm EPDM	Fabco stainless steel grade 304, 14-14x70 Type B screw and bonded washer through a 10mm dia. clearance hole with Multirib load spreading profile 1.2mm Ali washer & 36mm EPDM	Multirib load spreading profile 1.20mm Ali and 36mm EPDM

Wall Cladding - Pan fixed

	Wood Purlins	Steel Purlins or girts up to 1.5mm	Steel Purlins or girts 1.5-4.5mm	Steel Purlins or girts 4.5-12mm	Washers (When required)
Steel Based Material Direct fixed	12-11x40 Class 4 Type 17 Woodteks with neos	12-14x20 Class 4 Steelteks with neos	12-14x20 Class 4 Steelteks with neos	12-24x32 Class 4 Steelteks Series 500 with neos	
Steel Based Material 20mm Cavity	12-11x50 Class 4 Type 17 Woodteks or Roofzips with neos	12-14x45 Class 4 Steelteks with neos or 12x50 Roofzips with neos	12-14x45 Class 4 Steelteks with neos	12-24x50 Class 4 Steelteks Series 500 with neos	
Aluminium Based Material Direct Fixed	12-11x35 Alutite with bonded washer	Stainless steel grade 304, 14-14x25 Steelteks and bonded washer through a 10mm diameter clearance hole with 19mm bonded Ali washer	Stainless steel grade 304, 14-14x25 Steelteks and bonded washer through a 10mm diameter clearance hole with 19mm bonded Ali washer	Fabco stainless steel grade 304, 4-14x20 Type B screw and bonded washer through a 10mm diameter clearance hole with 19mm bonded Ali washer	19mm bonded Ali washer
Aluminium Based Material 20mm Cavity	12-14x55 Alutite with bonded washer	Stainless steel grade 304, 14-14x70 Steelteks and bonded washer through a 10mm diameter clearance hole with 19mm bonded Ali washer	Stainless steel grade 304, 14-14x70 Steelteks and bonded washer through a 10mm diameter clearance hole with 19mm bonded Ali washer	Fabco stainless steel grade 304, 14-14x70 Type B screw and bonded washer through a 10mm diameter clearance hole with 19mm bonded Ali washer	19mm bonded Ali washer

Note: All primary fasteners to have a minimum embedment into structural timber of 30mm. Adjust fastener length for both timber and steel fixings when necessary for battens etc. When using load spreading profile washers or 25mm Aluminium embossed washers for roofing fix ridging, roof flashings etc. using a 25mm Aluminium embossed washer and appropriate screw.

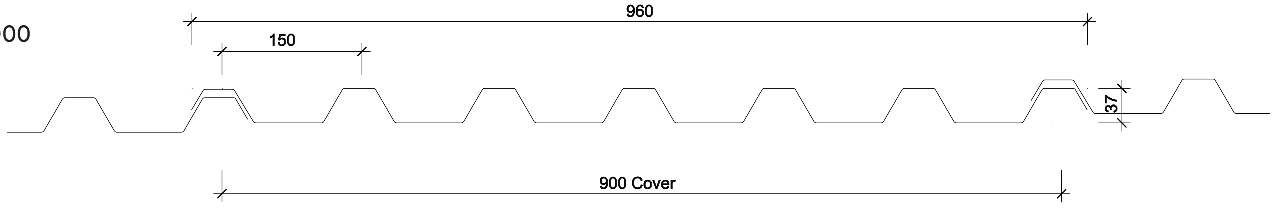
Secondary Fasteners (To be used in accordance with the NZ Metal Roof and Wall Cladding Code of Practice.)

These should be:
- Aluminium Blind Rivets AS5-3 x 4mm minimum (Residential)
- Aluminium Blind Rivets AS 6-3 x 4.8mm minimum (Commercial)
- Aluminium Bulb-tite Rivets
- 12-11x35 Alutites
- 12-11x25 Class 4 Type 17 Woodteks (Steel based material only)

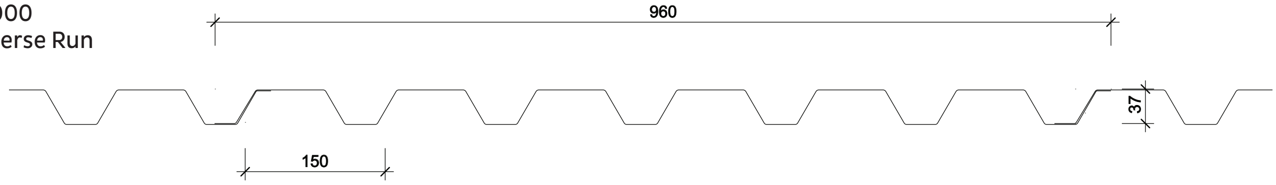
Appendix C – Dimond Roofings “BrownBuilt 900” product literature

DIMOND BROWNBUILT 900 (BB900) PROFILE PERFORMANCE

BB900



BB900
Reverse Run



BB900 Reverse Run Profile (for wall cladding only). Lapped sheet shown dotted.

Cover (mm)	900
Sheet width (mm)	960
Minimum Pitch	3° (approx. 1:20)

All dimensions given are nominal

Sheet Tolerances

Sheet width: ±5mm

Sheet width for aluminium +0, -15. If sheet cover widths are critical, advise Dimond at time of order.

Sheet length: +10mm, –0mm. For wall cladding where notified at time of order of intended use, tighter tolerances can be achieved +3mm, –0mm.

Material Options Profile	Steel			Aluminium		Stainless Steel	Duraclad®
Thickness (BMT) mm	0.4	0.55	0.75	0.7	0.9	0.55	1.7 (total thickness)
Nominal weight/lineal metre (kg/m)	4.12	5.55	7.47	2.31	2.96	5.36	2.90
Drape curved roof - min. radius (m)	n/r	90	90	n/r	90	n/r	24
Purlin spacings for drape curved roof (m)(1)	n/r	2.4	2.4	n/r	2.4	n/r	1.2
Machine crimp curved - roof min. radius (mm)	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Unsupported overhang (2)(mm)	250	350	450	200	300	350	200

(1) Recommended maximum purlin spacing at minimum radius
(2) Based on 1.1kN point load support, but not intended for roof access.
n/r – not recommended
n/a – not available

Roll-forming facility at:	Auckland
Manufacturing location for Duraclad®:	Auckland
Sheet lengths:	BB900 is custom run to order.

Where long sheets are used consideration must be given to:

- Special transportation licences for sheet lengths over 25m
- Site access for special lifting equipment
- Fixing techniques to accommodate thermal expansion.

Refer Section 2.1.3.4.

BROWNBUILT 900 LIMIT STATE LOAD / SPAN CAPACITY CHART

(span in mm, distributed serviceability loads in kPa)

Serviceability Category

		Unrestricted-Access Roof		Restricted-Access Roof			Non-Access Roof or Wall		
G550 Steel 0.40mm	End Span		800	1100	1300	1500	1500	1700	1900
	Internal Span		1200	1600	1900	2200	2300	2600	2900
	Serviceability		4.0	3.3	2.6	2.0	1.8	1.6	1.2
G550 Steel 0.55mm	End Span		1600	1700	2000	2300	2400	2500	2700
	Internal Span		2400	2500	3000	3400	3500	3800	4100
	Serviceability		3.7	3.5	2.7	2.0	1.9	1.7	1.5
G550 Steel 0.75mm	End Span		2000	2100	2400	2700	2800	3000	
	Internal Span		3000	3200	3600	4000	4200	4600	
	Serviceability		4.0	3.8	3.1	2.3	2.0	1.3	
5052 H36 Aluminium 0.70mm	End Span		900		900	1100	1200	1400	1600
	Internal Span		1300		1400	1700	1800	2100	2400
	Serviceability		3.1		2.8	2.2	2.0	1.5	1.2
5052 H36 Aluminium 0.90mm	End Span		1300	1400	1600	1900	1900	2200	2800
	Internal Span		2000	2100	2400	2800	2900	3300	3700
	Serviceability		3.8	3.6	2.8	2.1	2.0	1.5	1.2
Duraclad® 1.7mm (Note 4)	End Span				600	800	900	1100	1400
	Internal Span				900	1200	1300	1700	2100
	Serviceability Ultimate	 N/R	 N/R		– 4.5	– 4.5	– 4.5	– 3.2	– 2.0

Notes

1. In any category, spans above the maximum shown should not be used. Category 1 and 2 maximum spans are based on static point load testing as a guide, and further limited by practical experience of roof performance under dynamic foot traffic loads. Category 3 maximum spans are limited as a guide to achieving satisfactory appearance for wall cladding.
2. Loads given are based on 6 screw fasteners/sheet/purlin.
3. Loads given are limited to a maximum of 4.0 kPa. If design requirements exceed this limit, contact Dimond for specific advice.
4. Duraclad®
   – Serviceability Limit State loads are not applicable to the Duraclad® material, as it does not experience permanent deformation.
   – System must include Safety Mesh if intended for use as a Restricted-Access roof. Refer Section 2.2.1.8.
5. N/R = not recommended.
6. End span capacities given in this table are based on the end span being 2/3 of the internal span.
7. **Design Criteria for Limit State Capacities**

   a) Serviceability Limit State
   No deflection or permanent distortion that would cause unacceptable appearance, side lap leakage or water ponding, due to foot traffic point loads, inward or outward wind loads or snow loads.

   b) Ultimate Limit State
   No pull through of fixings or fastener withdrawal resulting in sheet detachment due to wind up-lift (outward) loads.
8. **System Design**
   The span capacity of Brownbuilt 900 is determined from the Brownbuilt 900 Limit State Load/Span Capacity Chart using the section of the chart appropriate to the grade and type of material, and to the category of serviceability selected from the three categories below. Serviceability loads have been derived by test to the NZMRM testing procedures. To obtain an ultimate limit state load we recommend factoring the serviceability load up by 1.4 in-line with NZMRM guidelines. The capacities given do not apply for cyclonic wind conditions.

   Serviceability Requirements
   While these categories are given for design guidance to meet the serviceability limit state criteria, foot traffic point load damage may still occur if there is careless placement of these point loads.

Service Category	Description
1. Unrestricted-access roof	Expect regular foot traffic to access the roof for maintenance work and able to walk anywhere on the roof. No congregation of foot traffic expected.
2. Restricted-access roof	Expect occasional foot traffic educated to walk only on the purlin lines, in the profile pans, or carefully across two profile ribs. Walkways installed where regular traffic is expected, and "Restricted Access" signs placed at access points.
3. Non-access roof or wall	Walls or roofs where no foot traffic access is possible or permitted. If necessary, "No Roof Access" signs used.
9. **Wind Pressure Guide**
   As a guide for non-specific design the following S.L.S. design loads in accordance with the MRM Roofing Code of Practice can be used for buildings less than 10m high, otherwise AS/NZS 1170.2 should be used

   Low wind zone = 0.68kPa, Medium wind zone = 0.93kPa, High wind zone = 1.32kPa, Very high wind zone = 1.72kPa and Extra high wind zone = 2.09kPa.

Fastener Design

Brownbuilt 900 should be screw fixed to either timber or steel purlins. The use of the appropriate length of 12g or 14g screw will ensure failure by screw pull out will not occur under loads within the scope of the Limit State Load / Span Capacity Chart.

Purlin Type	Screw Fastener			
	Roofing Rib		Wall Cladding Pan Fix	
	Screw Length* (mm)	Designation	Screw Length* (mm)	Designation
Timber	75	T17 - 14 - 10 x 75	50	Roofzip M6 x 50 HG-Z4
Steel	65	Tek - 14 - 10 x 65 Tek - 12 - 14 x 68	20	Tek - 12 - 14 x 20

*If sarking or insulation is used over the purlins or for wall cladding fixed onto a cavity batten, into the stud, the screw length will need to be increased.

For screw size range and fastener / washer assembly refer Section 2.2.3.1.

The Limit State Load / Span Capacity Chart is based on 6 screw fasteners/sheet/purlin without the use of load spreading washers (except for Duraclad® material, which must be fitted with profiled metal washers and 36mm EPDM seals.

Profiled metal washers are recommended for use:

1. On end spans, or large internal spans where the Ultimate Limit State distributed load is limiting. Contact Dimond for specific advice in these design cases.
2. When required to enable the fixing system to accommodate the thermal movement of long sheets – see Section 2.1.3.4 Thermal Movement.
3. Wherever the designer wishes to ensure the risk of fastener over-tightening will not cause dishing of the crest of the profile rib.

Use in serviceability categories (1) or (2) can allow the reduction of fasteners to 3 screw fasteners/sheet/purlin. If this is done, the distributed load capacities given in the chart should be reduced using a multiplying factor of 0.5.

Long spans may require the specification and use of side lap stitching screws – see Section 2.3.2C Installation Information: Layout and Fastening.

Design Example

Restricted access roof, 0.55mm G550 steel Brownbuilt 900 has a maximum end span of 2400mm and a maximum internal span of 3400mm. The following distributed load capacities apply.

	6 fasteners/sheet	3 fasteners/sheet
End Span	2300mm	2300mm
Internal Span	3400mm	3400mm
Serviceability	2.0 kPa	1.0 kPa

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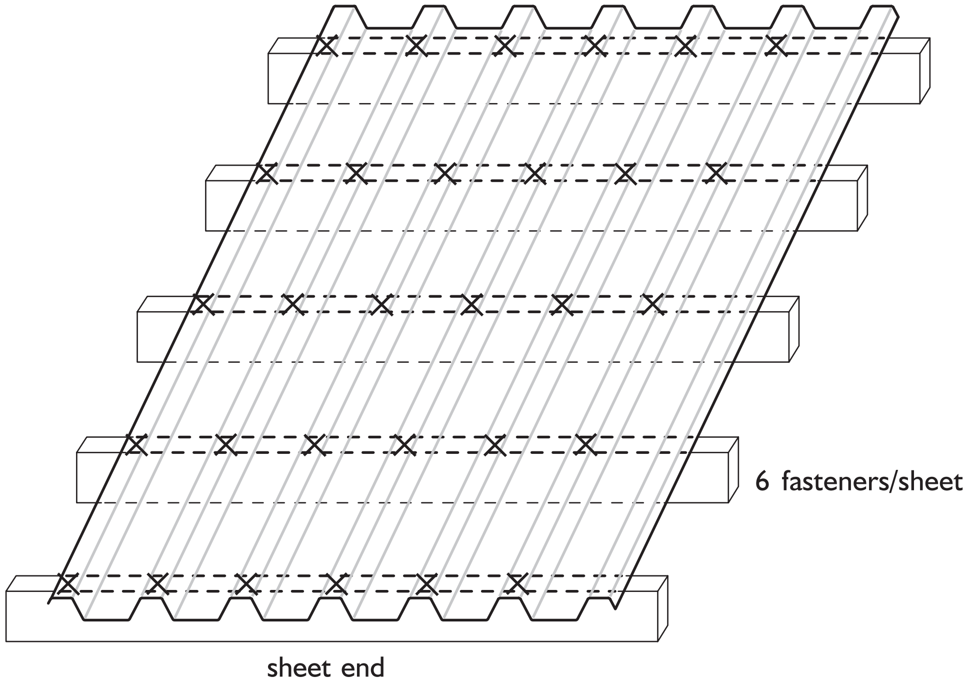
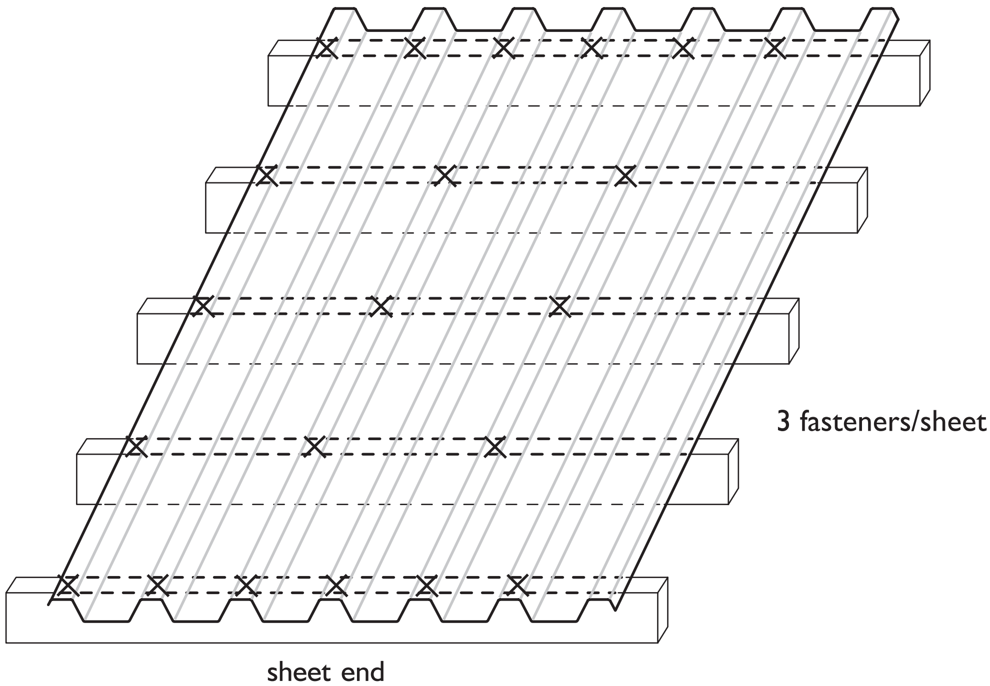
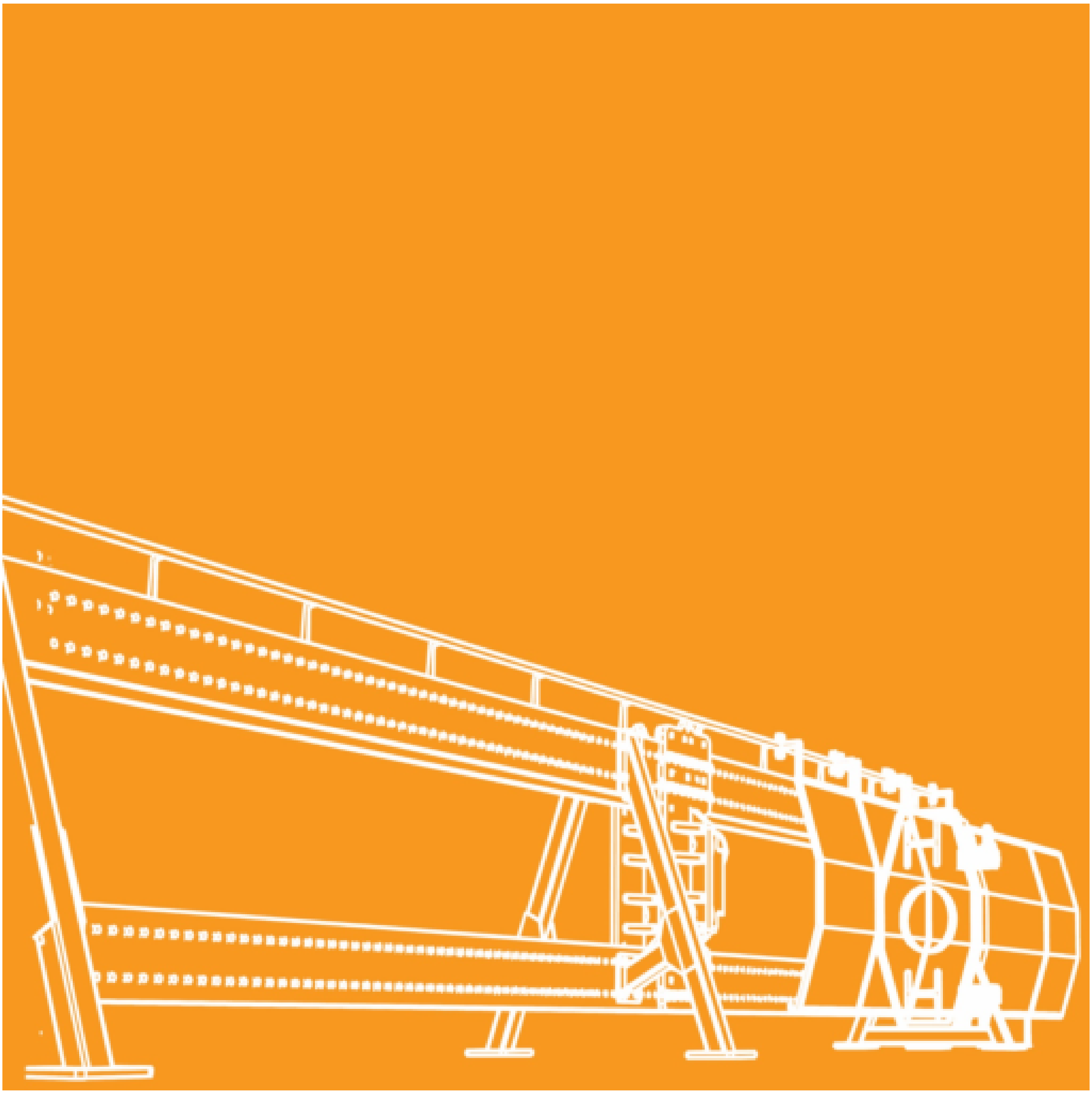
DIMOND BROWNBUILT 900 FASTENER LAYOUT OPTIONS







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