Building Science Summit New Zealand

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Test vs. Real-World

Envelope Testing Uncovered: Facts, Fallacies, and Findings

What AS/NZS 4284, NZS 4211, and Cyclonic Fatigue Testing Really Tell Us

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Laboratory and on-site NZBC compliance testing

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Why Envelope Testing Matters

The envelope is:
- A weather barrier
- A pressure moderator
- A durability ***system***

Failure modes:
- Water ingress
- Air leakage
- Progressive degradation
- Non-structural failure leading to structural risk

Wind Zone Ratings in New Zealand

Table 1 – Exposure rating

Approach to exposure determination	Exposure rating	p_{tp} (SLS) (Pa)[a]	p_{tp} (ULS) (Pa)[a]
NZS 3604 *NASH standard – Part 2: Light steel framed buildings*	L	± 510	± 720
	M	± 680	± 960
	H	± 970	± 1360
	VH	± 1250	± 1760
	EH	± 1515	± 2130
EM7	EM7	+ 2250/– 2750	+ 3200/– 3950
NZS 1170.2	SED (test report #)	Serviceability limit state net cladding pressures[b] p_n (SLS)	Ultimate limit state net cladding pressures[b] p_n (ULS)

[a] p_{tp} (ULS) = test pressures for ultimate limit states (strength testing).
p_{tp} (SLS) = test pressure for serviceability limit states (serviceability testing).

[b] SED parameters are net positive and negative limit state cladding pressures acting on the window, including local pressure coefficients.

NZS 4211:2008 Window Performance Specification

Scope

This Standard specifies requirements for the performance of windows to be installed in exterior walls within the wind pressure limitations of the wind zones defined in table 5 and table 6. The properties covered are strength, stiffness, operating facility, air infiltration, and water penetration.

Note: The test methods in NZS 4211 are derived from the Standard series AS 4420.0 – AS 4420.6 :1996

What NZS 4211 does NOT test

- The window installation
- Window/Cl
- Flashings p
- Rough Ope
- Performanc

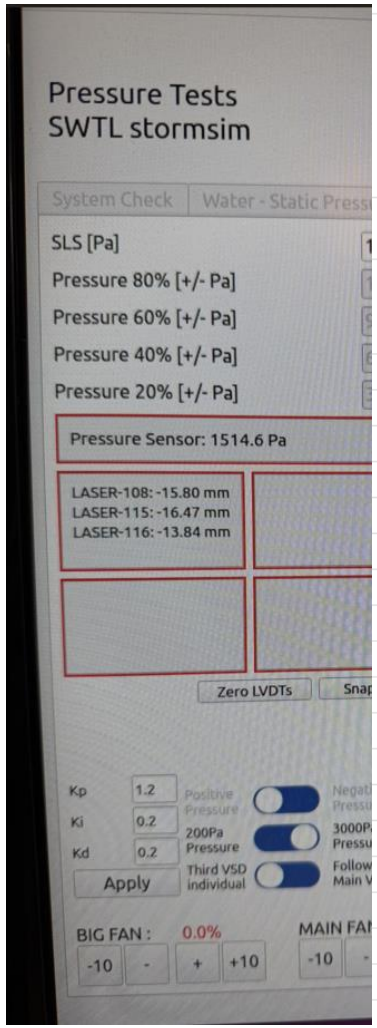
Sample #1

- Strength & Stiffness

Credit

ThermaDura

European Timber Windows & Doors
Energy Efficient - Durable - Sustainable



Gauge # and location	Gauge # (Bottom)	Gauge # (Top)	Gauge # (Middle)	† Calibration check of linear gauges with 10mm gauge block to be ±0.40mm on timber member or ±0.10 mm on a metal member		SNZ TS 4211 default = span/200	
	108	116	115				
Calibration check † (mm)				Net centre deflection mm	Adjusted net deflection mm	Default Ratio Check	Specified Ratio Check
POSITIVE PRESSURE							
SLS test pressure							
0	0	0	0	0			
`+50%	4.81	4.44	5.8	1.175		13%	13%
0 (Z1)	0.11	0.05	0.1	0.02		0%	0%
`+25%	2	1.75	2.73	0.835		10%	10%
`+50%	4.58	4.33	5.54	1.065		12%	12%
`+75%	7.37	7.04	8.71	1.485		17%	17%
`+100%	9.86	9.84	11.92	2.05		23%	23%
0 (Z2)	0.5	0.36	0.75	0.3		3%	3%
NEGATIVE PRESSURE							
`-50%	10.93	8.9	10.18	0.265		3%	3%
0 (Z1)	6.38	4.6	5.37	-0.385		-4%	-4%
`-25%	9.11	6.63	7.62	-0.13	0.255	3%	3%
`-50%	11.22	8.9	10.39	0.45	0.835	10%	10%
`-75%	13.87	11.87	13.36	0.61	0.995	11%	11%
`-100%	17.01	14.27	16.8	1.28	1.665	19%	19%
0 (Z2)	9.32	6.7	7.84	-0.05	0.335	4%	4%

Sample #1

- Operating Facility

OPENING FORCE

Function		Projecting sashes	Sliding sashes		Sliding doors
			Horizontal	Vertical	
Initiate	N	90	110	200	180
Recorded value	N				56
Pass/Fail					PASS
Sustain		90	90	160	110
Recorded value	N				34
Pass/Fail	N				PASS

CLOSING FORCE

Function		Projecting sashes	Sliding sashes		Sliding doors
			Horizontal	Vertical	
Initiate	N	90	110	200	180
Recorded value	N				54
Pass/Fail					PASS
Sustain		90	90	160	110
Recorded value	N				32
Pass/Fail	N				PASS

Sample #1

Credit

ThermaDura

European Timber Windows & Doors
Energy Efficient - Durable - Sustainable

- Air Infiltration

Sample Width	4.8	m	Sample Perimeter Length	15.596	m
Sample Height	2.498	m			
Sample Area	11.9904	m^2			

Atmospheric Conditions	Temperature	18.57	ºC
	Barometric Pressure	1018	hPa
	Relative Humidity	60	%

NEGATIVE PRESSURE

Pressure	Pa	Unsealed		Sealed
Negative	-75	75.25	-75	70.57
	-75	77.97	-75	70.52
	-75	78.75	-75	70.57
		77.32		70.55
Net m^3/hr			6.77	
Net l/s			1.88056	Class
Area	11.99	l/s/m2	0.16	Class 4
Perimeter	13.38	l/s/m	0.14	Class 4

Pressure	Pa	Unsealed		Sealed
Negative	-150	55.1	-150	51.2
	-150	53.54	-150	56.79
	-150	52.76	-150	54.19
		53.80		54.06
Net m^3/hr			-0.26	
Net l/s			-0.0722	Class
Area	11.99	l/s/m2	-0.01	Class 4
Perimeter	13.38	l/s/m	-0.01	Class 4

POSITIVE PRESSURE

Pressure	Pa	Unsealed		Sealed
Positive	75	36.65	75	35.87
	75	36.65	75	36.65
	75	36.65	75	35.87
		36.65		36.13
Net m^3/hr			0.52	
Net l/s			0.14444	Class
Area	11.99	l/s/m2	0.01	Class 4
Perimeter	13.38	l/s/m	0.01	Class 4

Pressure	Pa	Unsealed		Sealed
Positive	150	45.48	150	45.48
	150	43.93	150	47.43
	150	44.7	150	47.04
		44.70		46.65
Net m^3/hr			-1.9467	
Net l/s			-0.5407	Class
Area	11.99	l/s/m2	-0.05	Class 4
Perimeter	13.38	l/s/m	-0.04	Class 4

Sample #1

Credit

ThermaDura

European Timber Windows & Doors
Energy Efficient - Durable - Sustainable

- Water Penetration (Static Air Pressure)

Sample #2

- Strength & Stiffness

SERVICEABILITY LIMIT	+	970 Pa	Overall length	2082	mm
STATE TEST PRESSURE	-	970 Pa	Gauge length	2070	mm
*Specified maximum deflection ratio			Max defl. (1/	200	)
			Max defl. Specified	10.35	mm
NZS 4211 default = span/200			Max defl. Default	10.35	mm
Atmospheric Conditions			Temperature	26.91	ºC
			Barometric Pressure	1012	hPa
			Relative Humidity	73	%

	Bottom	Middle	Top
Gauge #	108	116	115

	SLS test pressure			Input Values (Direct Displacement			Net centre deflection mm	Default Ratio Check	Specified Ratio Check
POSITIVE PRESSURE									
Stage	Time	%	Pa						
	0 min	0%	0	0.0	0.0	0.0			
	2 min	50%	485	1.1	6.2	1.8	4.765		
Z1	2 min	0%	0	0.1	0.2	0.2	-4.68	<<= Zero Ref	
	1 min	25%	243	0.5	2.8	0.6	2.14	21%	21%
	1 min	50%	485	1.1	6.1	1.8	4.565	44%	44%
	1 min	75%	728	1.5	9.2	1.5	7.655	74%	74%
	1 min	100%	970	2.2	12.7	3.6	9.675	93%	93%
Z2	2 min	0%	0	0	0	0	-0.015	0%	0%
NEGATIVE PRESSURE									
	2 min	-50%	-485	1.7	8.4	4.2	5.35	52%	52%
Z3	2 min	0%	0	0.51	1.92	2.43	0.38	<<= Zero Ref	
	1 min	25%	243	0.88	4.88	3.26	2.36	23%	23%
	1 min	50%	485	1.65	8.37	4.61	4.79	46%	46%
	1 min	75%	728	2.55	12.28	5.78	7.665	74%	74%
	1 min	-100%	-970	3.17	16.22	7.51	10.43	101%	101%
Z4	2 min	0%	0	1.21	2.78	3.53	-0.04	0%	0%

FAIL

Sample #2

- Strength & Stiffness TAKE #2

Wind Zone: “Medium”

SERVICEABILITY LIMIT	680 Pa	Overall length	2082 mm
STATE TEST PRESSURE	- 680 Pa	Gauge length	2070 mm
*Specified maximum deflection ratio		Max defl. (1/	200)
		Max defl. Specified	10.35 mm
NZS 4211 default = span/200		Max defl. Default	10.35 mm
Atmospheric Conditions	##########	Temperature	26.24 ºC
		Barometric Pressure	1009 hPa
		Relative Humidity	80 %

	Bottom	Middle	Top
Gauge #	108	116	115

		SLS test pressure		Input Values (Direct Displacement			Net centre deflection mm	Default Ratio Check	Specified Ratio Check
Stage	Time	%	Pa						
	0 min	0%	0	0.0	0.0	0.0			
	2 min	50%	340	1.3	5.6	2.6	3.65		
Z1	2 min	0%	0	0.5	0.7	0.7	-3.545	<<= Zero Ref	
	1 min	25%	170	0.8	2.5	1.1	1.435	14%	14%
	1 min	50%	340	1.1	4.9	2.0	3.225	31%	31%
	1 min	75%	510	1.5	7.3	2.8	5.085	49%	49%
	1 min	100%	680	1.9	9.5	3.4	6.74	65%	65%
Z2	2 min	0%	0	1	1	1	0.04	0%	0%
				NEGATIVE PRESSURE					
	2 min	-50%	-340	0.4	5.3	2.5	3.675	36%	36%
Z3	2 min	0%	0	0.25	0.48	1.25	-0.415	<<= Zero Ref	
	1 min	25%	170	0.20	2.63	1.73	1.935	19%	19%
	1 min	50%	340	0.44	5.22	2.76	3.89	38%	38%
	1 min	75%	510	1.03	8.21	4.40	5.765	56%	56%
	1 min	-100%	-680	1.84	10.79	5.49	7.395	71%	71%
Z4	2 min	0%	0	0.02	1.10	2.11	0.305	3%	3%

Sample #2

- Air Infiltration

Atmospheric Conditions	#########	Temperature	25.01	ºC
		Barometric Pressure	1009	hPa
		Relative Humidity	91	%

			Litres per second (l/s)	
Sample Width	2	m		
Sample Height	2.2	m	Air conditioned	Non Air conditioned
Sample Area	4.4	m^2	1.6	8
Opening Joint Length	6.17	m	0.6	2

NZS 4211:2008 Maximum permitted air flow, l/s at 150 Pa booth pressure

		Air conditioned	Non Air conditioned
Overall Sample Area	=	7.04	35.2
Opening Joint Length	=	[illegible]	12.34
Geometric Mean	=	5.11	20.84

FAIL

POSITIVE PRESSURE

	Sample Unsealed			Sample Sealed		
	Δ P, Pa	Flow, m^3/hr	Flow l/s	Δ P, Pa	Flow, m^3/hr	Flow l/s
Reading 1	150	172.71	47.98	150	113.84	31.62
Reading 2	150	171.02	47.51	150	113.84	31.62
Reading 3	150	172.71	47.98	150	111.37	30.94
Average Air Flow			47.82			31.39
Net Air Leakage	16.43	l/s				

NEGATIVE PRESSURE

	Sample Unsealed			Sample Sealed		
	Δ P, Pa	Flow, m^3/hr	Flow l/s	Δ P, Pa	Flow, m^3/hr	Flow l/s
Reading 1	150	143.34	39.82	150	136.71	37.98
Reading 2	150	145.81	40.50	150	136.71	37.98
Reading 3	150	147.37	40.94	150	136.35	37.88
Average Air Flow			40.42			37.94
Net Air Leakage	2.48	l/s				

Sample #2

- Water Penetration (Static Air Pressure)

Sample #2

- Air Infiltration TAKE #2

Atmospheric Conditions	#########	Temperature	25.95	ºC
		Barometric Pressure	994	hPa
		Relative Humidity	77	%

			Litres per second (l/s)	
Sample Width	2	m	Air conditioned	Non Air conditioned
Sample Height	2.2	m		
Sample Area	4.4	m^2	1.6	8
Opening Joint Length	6.17	m	0.6	2

NZS 4211:2008 Maximum permitted air flow, l/s at		150 Pa booth pressure	
		Air conditioned	Non Air conditioned
Overall Sample Area	=	7.04	35.2
Opening Joint Length	=	[illegible]	12.34
Geometric Mean	=	5.11	20.84

FAIL

POSITIVE PRESSURE

	Sample Unsealed			Sample Sealed		
	Δ P, Pa	Flow, m^3/hr	Flow l/s	Δ P, Pa	Flow, m^3/hr	Flow l/s
Reading 1	150	70.57	19.60	150	39.64	11.01
ding 2	150	73.16	20.32	150	40.42	11.23
ding 3	150	70.7	19.64	150	43.66	12.13
rage Air Flow			19.85			11.46
Air Leakage	8.40 l/s					

NEGATIVE PRESSURE

	Sample Unsealed			Sample Sealed		
	Δ P, Pa	Flow, m^3/hr	Flow l/s	Δ P, Pa	Flow, m^3/hr	Flow l/s
ding 1	150	38.73	10.76	150	28.98	8.05
ding 2	150	38.86	10.79	150	31.45	8.74
ding 3	150	40.94	11.37	150	31.45	8.74
rage Air Flow			10.98			8.51
Air Leakage	2.47 l/s					

Sample #2

- Water Penetration (Static Air Pressure) TAKE #2

AS/NZS 4284:2008 Testing of building facades

SCOPE

> “ a method for determining the performance of a representative building façade under simulated conditions of loading”

The tests determine ***system*** performance under Wind, Rain, & Seismic* loads

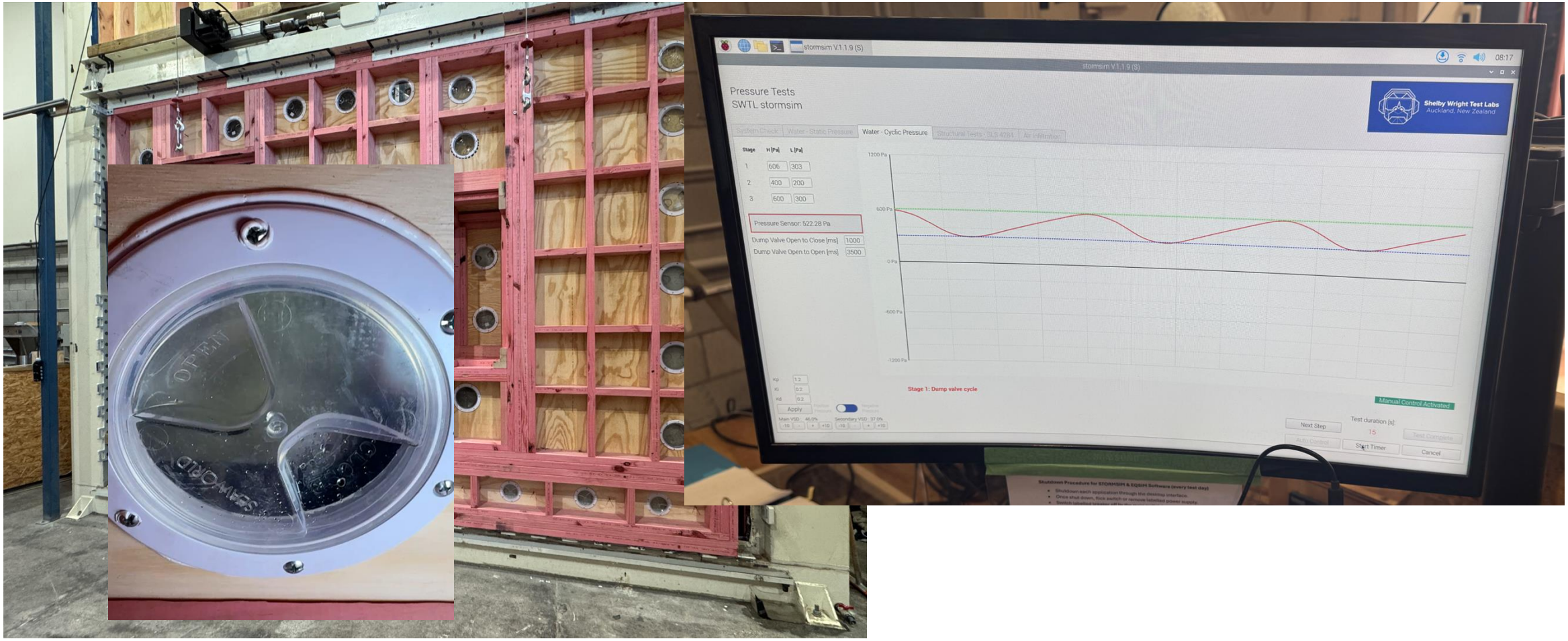
- 4284 water testing differs from 4211, with the addition of cyclic pressure testing
- Seismic testing is optional, and becomes mandatory for buildings over 10m

Images Credit:

Typical Sample Setup

Images Credit:

Cyclic pressure water testing



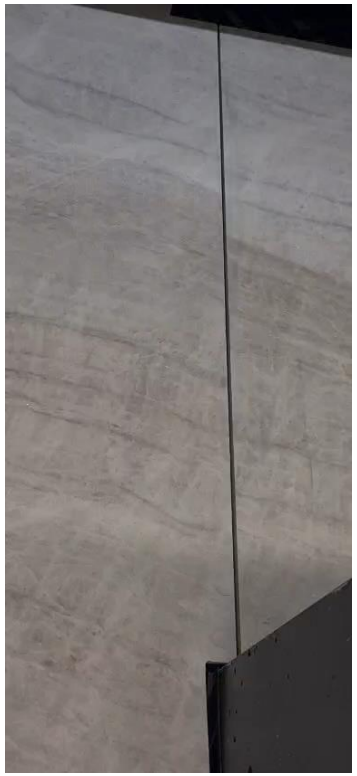
Images Credit:

Seismic testing

SLS - +/- 12mm racking

ULS - +/- 50mm racking
Mechanical Fixing System

ULS - +/- 50mm racking
Chem-Elastic Fixing System



AS/NZS 4284:2008 Testing of building facades

The test proves that the cladding and respective fixing systems can be rated to the same Climate Wind Zone as per the 4284 test result.

FALLACY

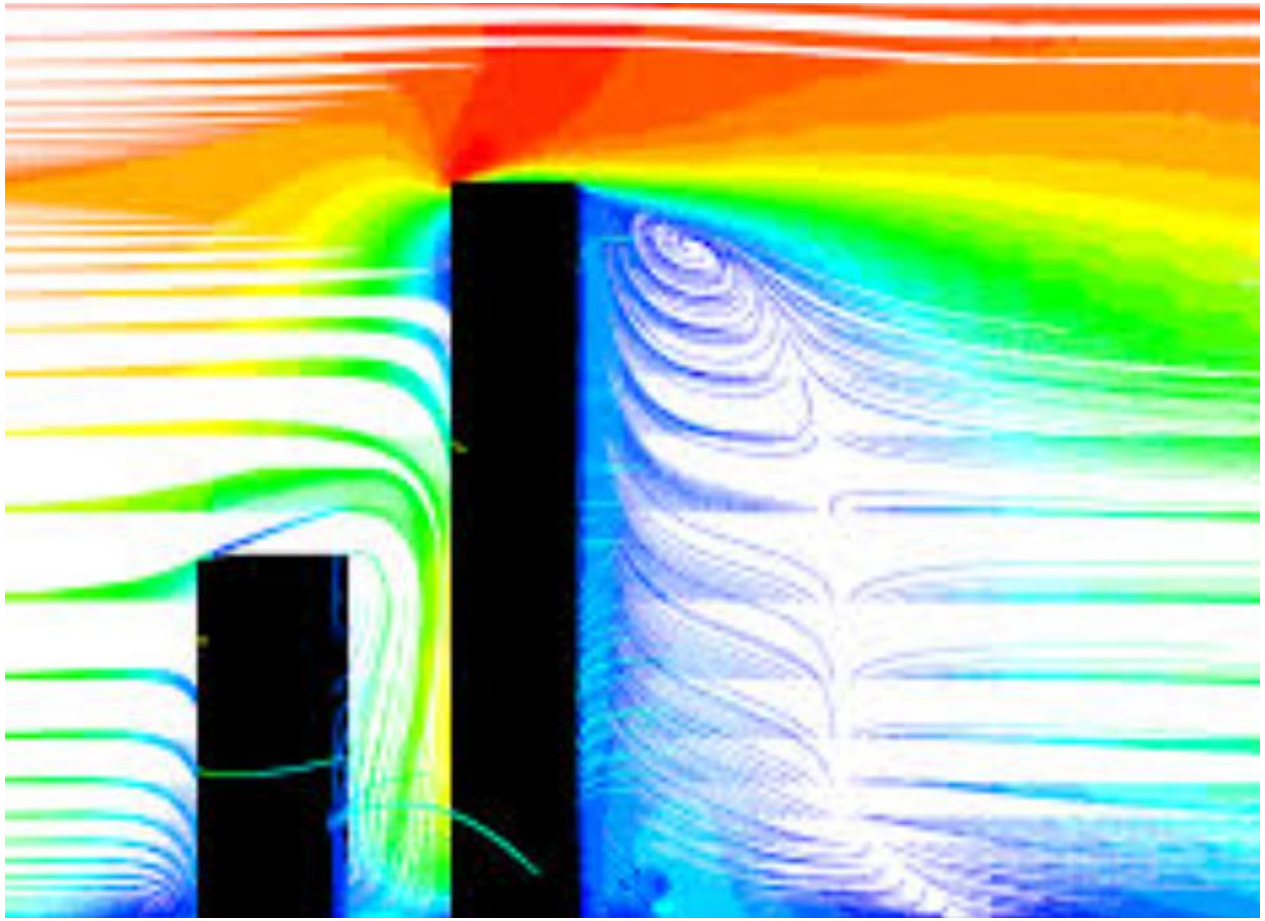
AS/NZS 4284 – Wind Zone Rating?

The air pressure applied in the structural SLS and ULS tests are introduced relatively slowly, and therefore is testing the “Air Barrier” only, and not the cladding’s structural wind zone performance.

During the cyclic pressure water testing, cycles are prescribed by the standard to be between 3-5 seconds, however, this is only up to 60% of SLS.

A real-world dynamic wind event applies pressure variations across the cladding in approximately 0.2 seconds.

Should we test to Positive, or Negative ULS wind pressures?

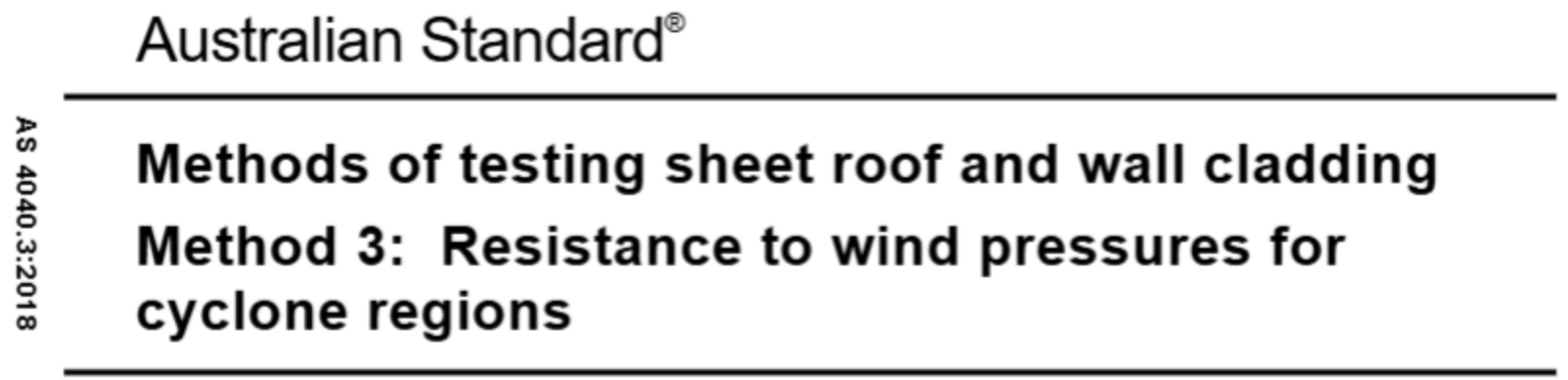


Negative pressure zones (lee side to wind typically at corners and roof edges) can generate pressures of ~50% and up to 150% above the positive wind pressures.

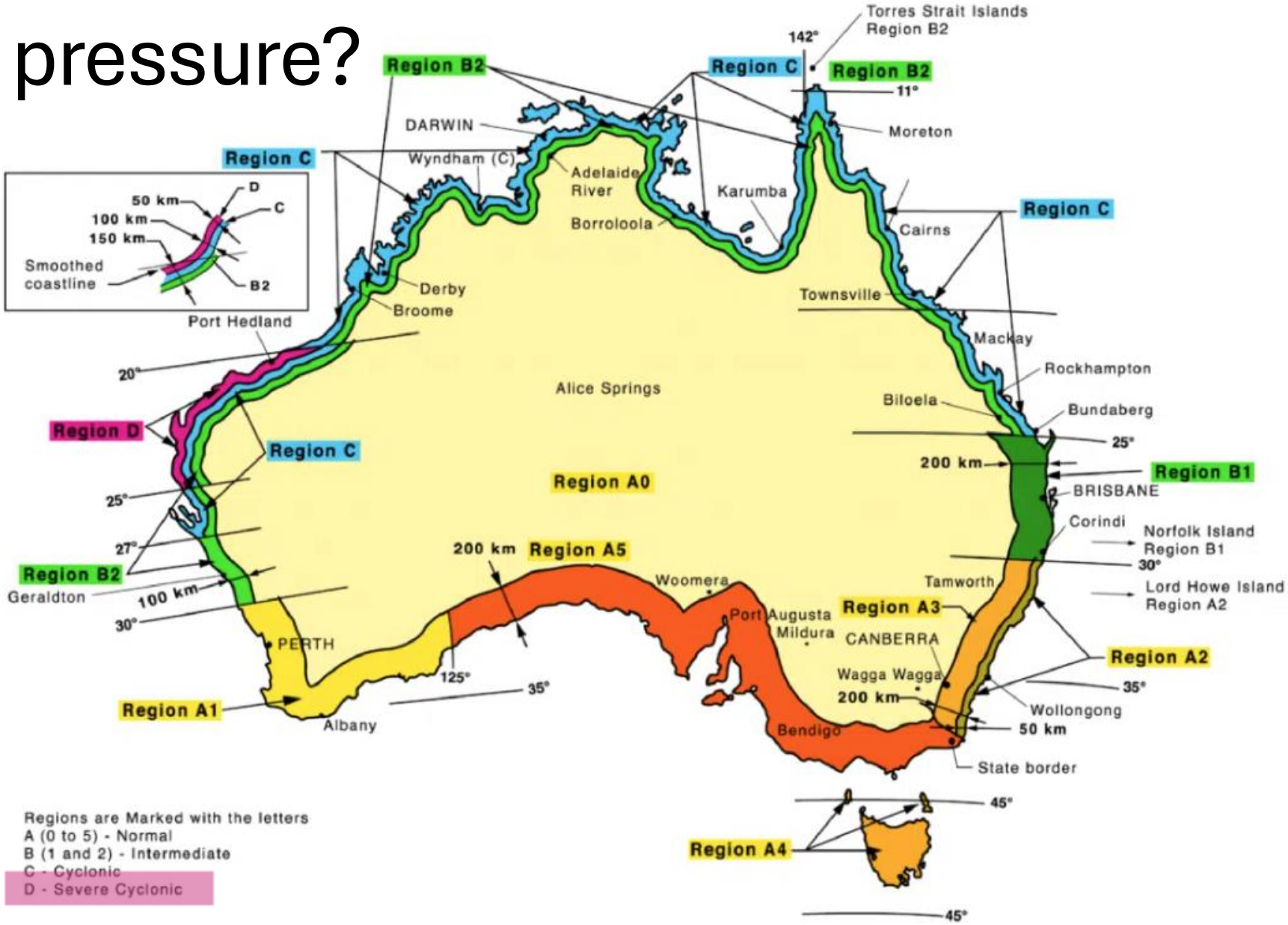
So that’s a positive on the NEGATIVE

So how do we test to see if a cladding system will work under high negative wind loads?

- AS 4040.3 : 2018



What ULS test pressure?



What ULS test pressure?

Table 3.1(A) — Regional wind speeds — Australia

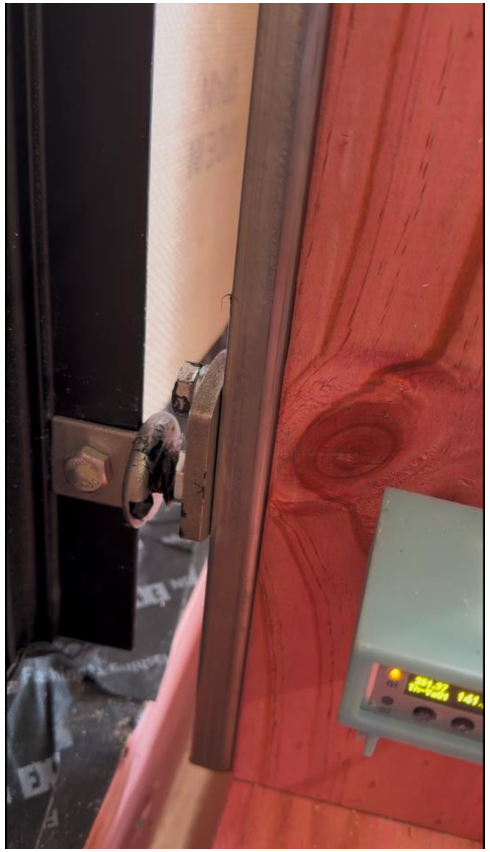
Regional wind speed (m/s)	Region			
	Non-cyclonic		Cyclonic	
	A (0 to 5)	B1, B2	C (maximum)	D (maximum)
V_1	30	26	23	23
V_5	32	28	33	35
V_{10}	34	33	39	43
V_{20}	37	38	45	51
V_{25}	37	39	47	53
V_{50}	39	44	52	60
V_{100}	41	48	56	66
V_{200}	43	52	61	72
V_{250}	43	53	62	74
V_{500}	45	57	66	80
V_{1000}	46	60	70	85
V_{2000}	48	63	73	90
V_{2500}	48	64	74	91
V_{5000}	50	67	78	95
V_{10000}	51	69	81	99
V_R ($R \geq 5$ years)	$67-41R^{-0.1}$	$106-92R^{-0.1}$	$122-104R^{-0.1}$	$158-142R^{-0.1}$

NOTE 1 The peak gust has an equivalent moving average time of approximately 0.2 s (Holmes and Ginger, 2012).

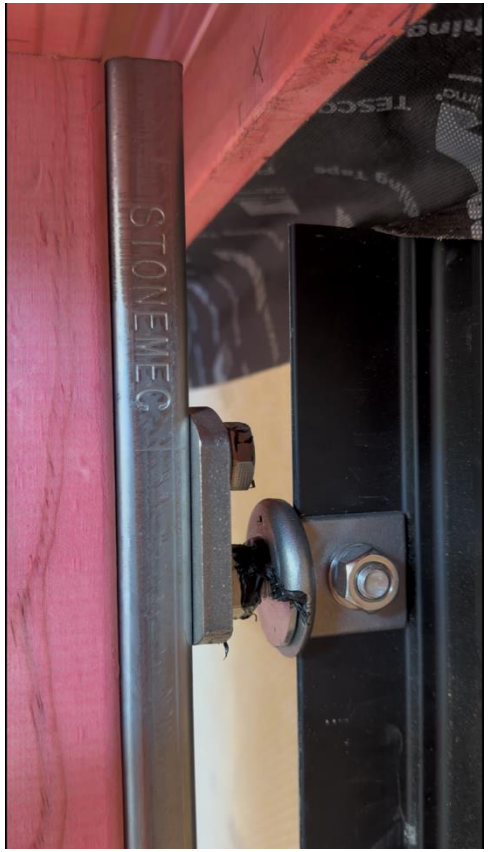
PARAMETER	VALUE
Design Wind Speed ($\mathbf{V_{wind}}$)	99 m/s (from AS/NZS 1170.2 – 2021)
Variability factor ($\mathbf{F_{Var}}$)	1.2 (from Table 5.1 of AS 1562.1)
Design Pressure ($\boldsymbol{P_{design}}$)	$P_{design} = 0.5\rho_{air} \cdot V_{wind}^2 = \left(99\frac{m}{s}\right)^2 \cdot 1.2\frac{kg}{m^3} \cdot 0.5 = 5.88\ kPa$
Test Pressure ($\boldsymbol{P_t}$)	$P_t = P_{design} \cdot F_{Var} = 5.88kPa \cdot 1.2 = 7.06\ kPa$

SEQUENCE	NUMBER OF CYCLES	LOAD	SEQUENCE PRESSURE (Pa)
A	4500	0 to 0.45 P_t	3176
B	600	0 to 0.6 P_t	4234
C	80	0 to 0.8 P_t	5645
D	1	0 to 1.0 P_t	7057
E	80	0 to 0.8 P_t	5645
F	600	0 to 0.6 P_t	4234
G	4500	0 to 0.45 P_t	3176

Load Path



Load Path #2



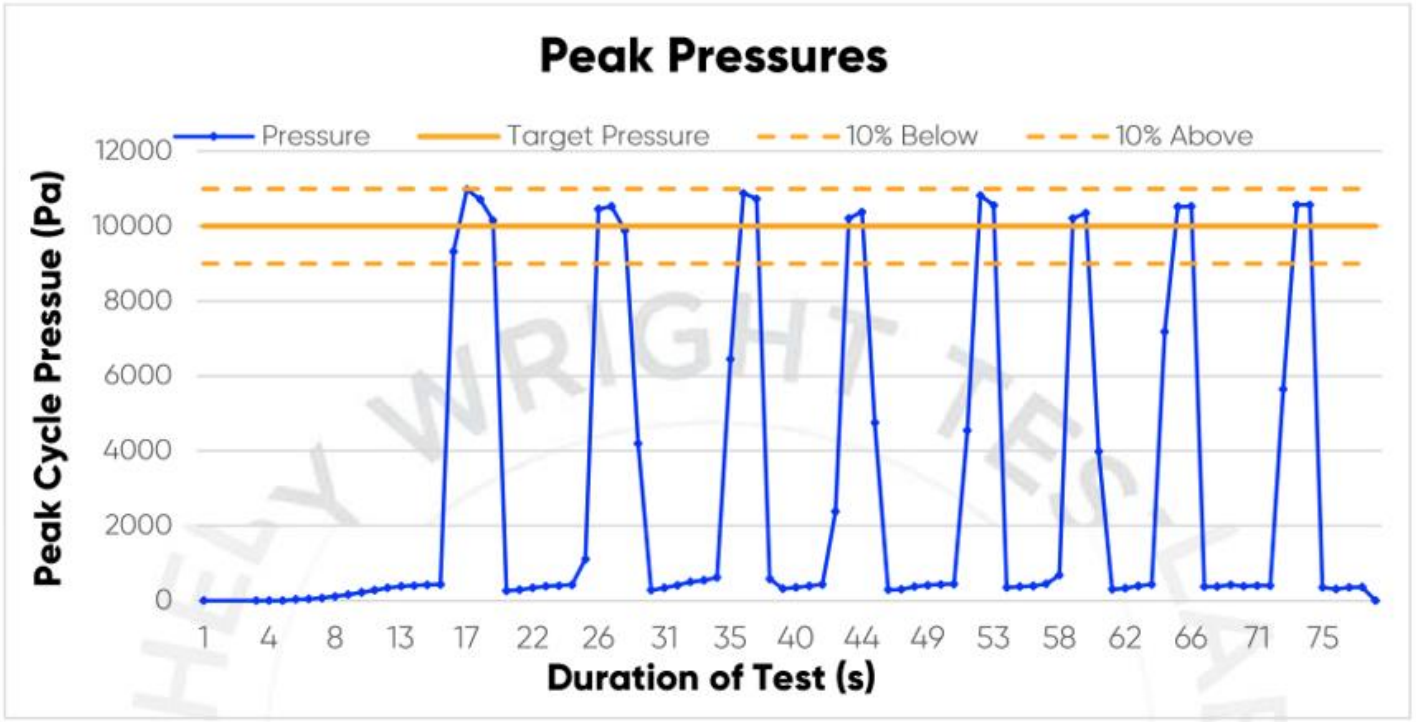
Just Cycling Away

Why we test

Images Credit:

STONE FACADE co
FIXING SYSTEMS FOR STONE

Let’s give it all we’ve got



Peak pressure: 10980 Pa

Images Credit:

STONE FACADE co
FIXING SYSTEMS FOR STONE

Building Science Summit New Zealand

Shaping the Future of Building Performance & Sustainability