Wind and Wind-Driven Rain Resistance of Residential Soffit Panel Systems

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FY 2011-12 Goals

1. Write and submit a paper to a peer-reviewed journal based on the outcomes of prior research directed at the performance of vinyl and aluminum soffit (accomplished in fall 2011; paper was also reviewed by industry)
2. Perform additional testing of fiber cement board, stucco and OSB soffits, which rounds out the major options for soffit systems in Florida (accomplished in spring/summer 2012)
3. Perform testing to characterize the air-permeability of conventional soffit systems in order to relate water ingress to the static pressure drop across the panel. Goals 1 and 2 address the major source of water ingress through panels, i.e. panel blowout. This component addresses water ingress through an intact panel (initiated in spring/summer 2012)
4. Investigate water ingress through roof vents (de-prioritized)

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Structural Wind Resistance

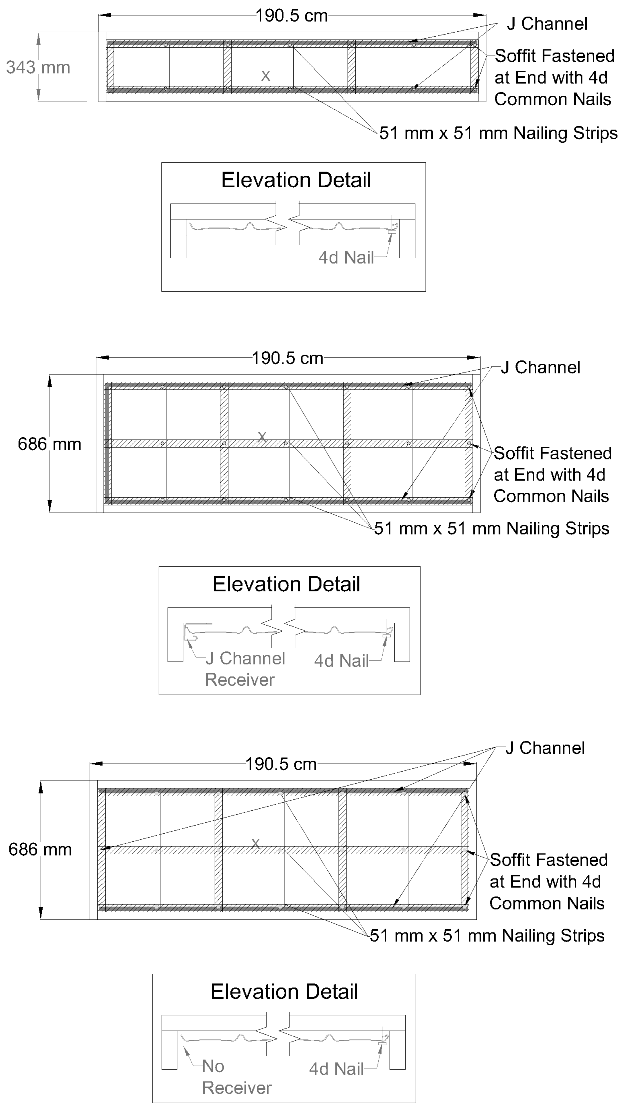
- Two datasets
  - Vinyl and aluminum soffit panels
  - Stucco, Fiber Cement Board and OSB soffits
- Configurations
  - 305 mm (1 ft) and 610 mm (2 ft)
  - Straight and corner sections
  - Some variations in fastener schedules / corner sections
- Loads
  - Quasi-static (ramp)
  - Dynamic (derived from wind tunnel)

Test Matrices

ID	Material	Profile	Design Pressure (kPa)	
			305 mm Width	610 mm Width
A1	Aluminum	Triple 4	2.4	2.4
A2		Quad 4	2.4	1.1
A3		Triple 4	2.4	2.4
V1	Vinyl	Triple 4	1.9	1.9
V2		Triple 4	2.3	1.1
V3		Double 5	1.9	1.9

ID	Material	Design Pressure (kPa)	
		305 mm width	610 mm width
FCB	Fiber Cement Board	2.6	2.6
OSB	Oriented Strand Board (OSB)	2.8	2.8
Stucco	Stucco Plaster	N/A	N/A

Aluminum and Vinyl Soffit Panels



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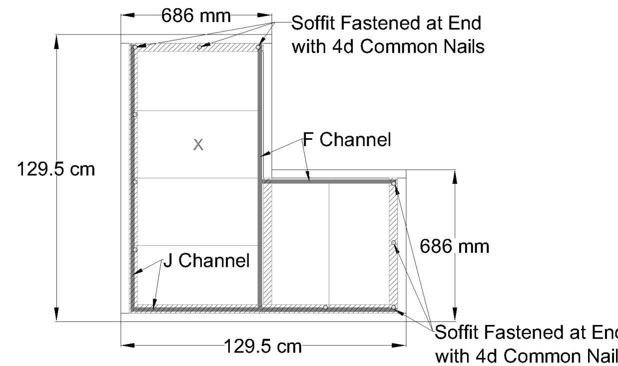
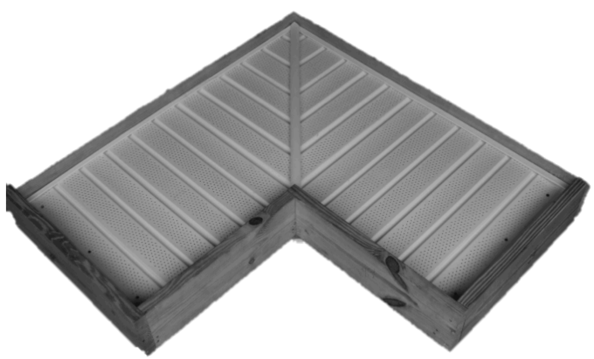
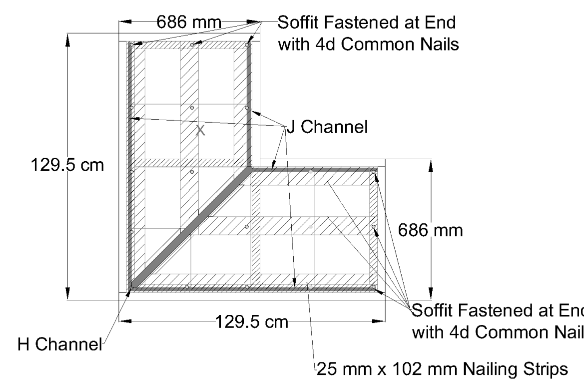
Aluminum and Vinyl Soffit Panels







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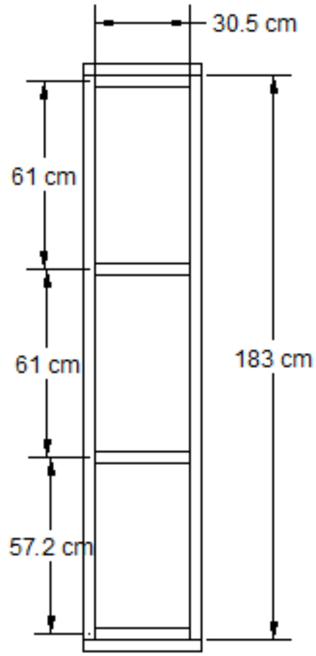
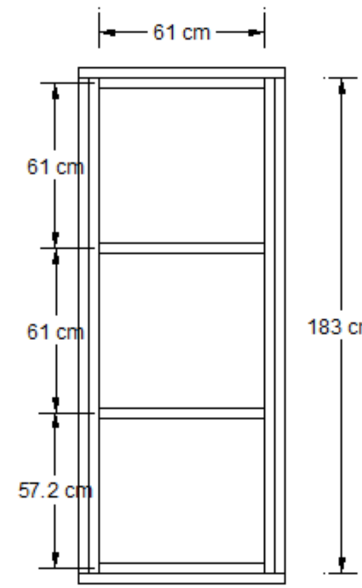
Stucco, FCB and OSB Panels





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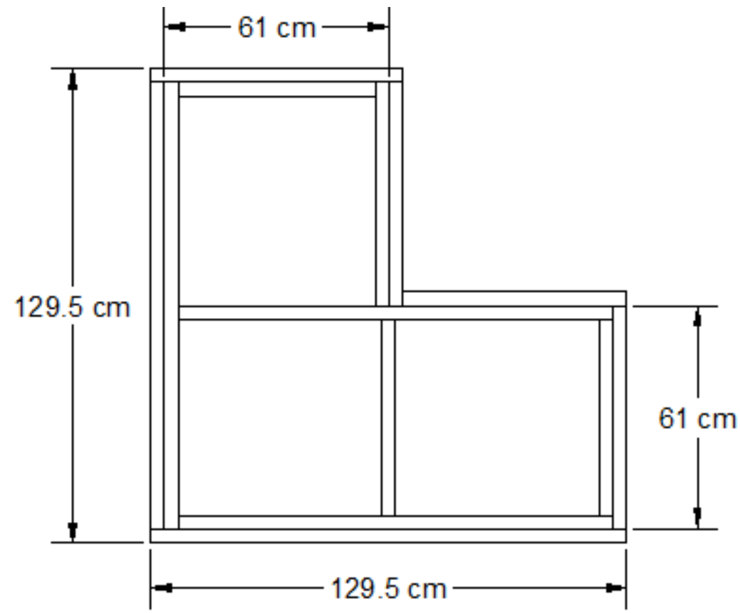
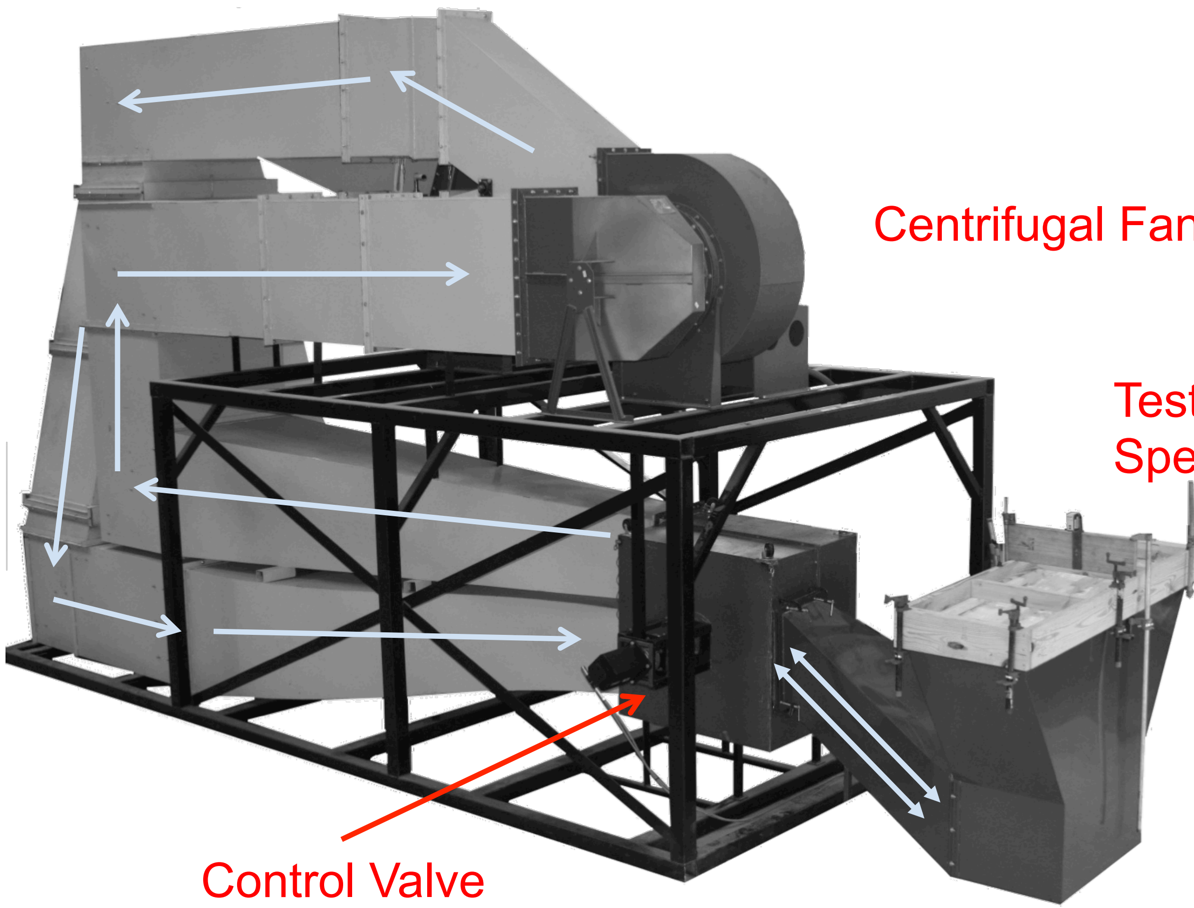
Stucco, FCB and OSB Panels



High Airflow Pressure Loading Actuator



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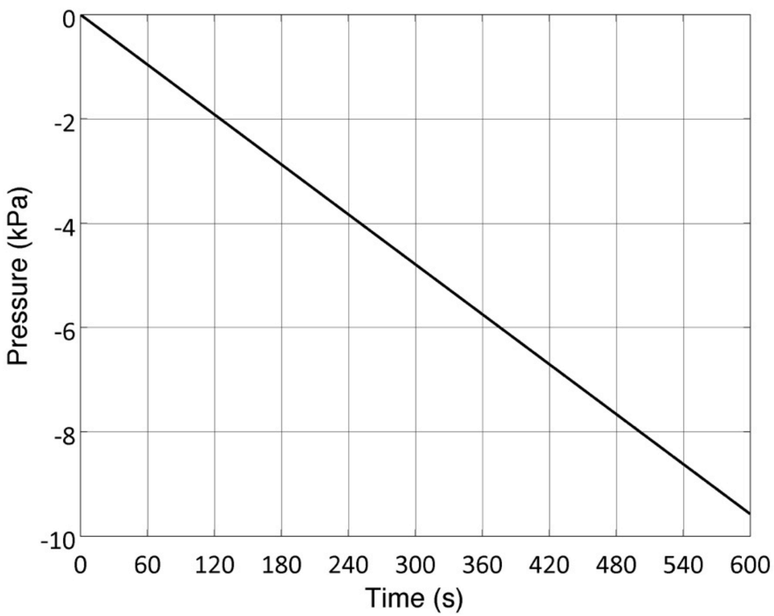
High Airflow Pressure Loading Actuator

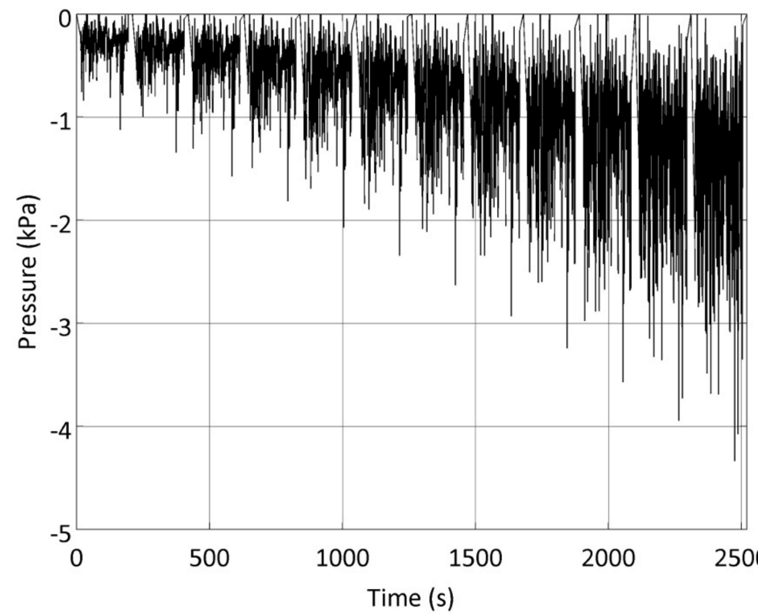
Straight Section

Corner Section

High Airflow Pressure Loading Actuator



Quasi-Static Load



Dynamic Load

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Results: Vinyl and Aluminum Soffit

305 mm Quasi-Static Straight

ID	End Receiver?	$p_{Failure}$ (kPa)			
		Trial 1	Trial 2	Trial 3	Ave.
A1	No	-4.33	DNF	DNF	N/A
A2	No	-3.59	-4.26	-3.91	-3.92
A3	No	DNF	-5.77	-3.56	-4.67
V1	No	DNF	DNF	DNF	DNF
V2	No	-4.01	DNF	DNF	-4.01
V3	No	-4.46	-4.11	-3.99	-4.19

610 mm Quasi-Static Straight

ID	End Receiver?	$p_{Failure}$ (kPa)			
		Trial 1	Trial 2	Trial 3	Ave.
A1	No	-2.04	-2.25	-2.05	-2.11
A2	No	-1.01	-0.93	-0.93	-0.96
A3	No	-1.56	-1.98	-1.77	-1.77
V1	No	-2.04	-2.35	-2.20	-2.20
V2	No	-2.20	-1.60	-2.50	-2.10
V3	No	-2.22	-2.26	-2.18	-2.22
V1	Yes	-1.81	-1.61	-1.50	-1.64
V2	Yes	-1.28	-1.37	-1.29	-1.31
V3	Yes	-1.81	-1.63	-1.69	-1.71

305 mm Dynamic Straight

ID	End Receiver?	$p_{Failure}$ (kPa)			
		Trial 1	Trial 2	Trial 3	Ave.
A1	No	DNF	DNF	DNF	DNF
A2	No	DNF	DNF	DNF	DNF
A3	No	DNF	DNF	-3.01	N/A
V1	No	DNF	DNF	DNF	DNF
V2	No	DNF	DNF	DNF	DNF
V3	No	DNF	DNF	DNF	DNF

610 mm Quasi-Static Dynamic

ID	End Receiver?	$p_{Failure}$ (kPa)			
		Trial 1	Trial 2	Trial 3	Ave.
A1	No	-2.43	-3.15	-3.00	-2.86
A2	No	-1.47	-1.74	-1.38	-1.53
A3	No	-1.80	-2.77	-2.15	-2.24
V1	No	-2.26	-2.74	-2.66	-2.55
V2	No	-1.72	-2.08	-1.18	-1.66
V3	No	-2.91	-1.79	-2.15	-2.28
V1	Yes	-1.59	-1.50	-1.33	-1.47
V2	Yes	-1.10	-1.15	-0.98	-1.08
V3	Yes	-1.80	-1.26	-1.56	-1.54

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Results: Vinyl and Aluminum Soffit

ID	End Receiver?	$p_{Failure}$ (kPa)			
		Trial 1	Trial 2	Trial 3	Ave.
A1	No	-2.43	-3.15	-3.00	-2.86
A2	No	-1.47	-1.74	-1.38	-1.53
A3	No	-1.80	-2.77	-2.15	-2.24
V1	No	-2.26	-2.74	-2.66	-2.55
V2	No	-1.72	-2.08	-1.18	-1.66
V3	No	-2.91	-1.79	-2.15	-2.28
V1	Yes	-1.59	-1.50	-1.33	-1.47
V2	Yes	-1.10	-1.15	-0.98	-1.08
V3	Yes	-1.80	-1.26	-1.56	-1.54

610 mm
Dynamic
Straight

ID	Config.	$p_{Failure}$ (kPa)			
		Trial 1	Trial 2	Trial 3	Ave.
A1	F-Chan	-1.36	-1.67	-1.57	-1.53
A2	F-Chan	-1.24	-1.34	-1.19	-1.26
A3	F-Chan	-1.78	-1.99	-2.24	-2.00
V1	F-Chan	-1.06	-0.95	-1.22	-1.08
V2	F-Chan	-0.53	-0.66	-0.59	-0.59
V3	F-Chan	-0.57	-0.96	-0.86	-0.80
A1	H-Chan	-1.72	-1.47	-1.53	-1.57
A2	H-Chan	-1.18	-1.28	-1.19	-1.22
A3	H-Chan	-1.87	-2.16	-2.21	-2.08
V1	H-Chan	-1.26	-1.43	-2.11	-1.60
V2	H-Chan	-1.54	-2.13	-1.33	-1.67
V3	H-Chan	-2.51	-3.49	-3.16	-3.05

Worst Case?

Best Case?

610 mm
Dynamic
Corner

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Results: Vinyl and Aluminum Soffit

- Straight 305 mm (1 ft) overhang soffit (both aluminum and vinyl) installed with J-channels to nailing strips is expected to fail at pressures well above design requirements in hurricane-prone areas
- Straight 610 mm overhang (2 ft) soffit sections consistently failed at lower pressures than their 305 mm equivalents, yet many of the product approval documents reviewed for this study list the same value for different overhang lengths
- The observed failure pressures of the straight 610 mm soffit were generally within 20% of the published design pressures, which implies that the true load factor is at or below unity

Results: Vinyl and Aluminum Soffit

- The range of observed failure pressures caused by dynamic loading were consistent with field observations of soffit damage to single-story homes in Hurricane Charley made by Gurley and Masters (2011). The subject homes experienced failures in 50 m/s (110 mph) winds, which corresponds to ~1.5 kPa threshold in suburban conditions at the height of a one-story building.
- Corner sections were shown to be potentially more susceptible to wind loading than straight sections. We note that very little guidance for installing corner sections is available in the public domain.

Results: OSB, Stucco and FCB

- In contrast to the aluminum and vinyl soffit sections, the OSB, stucco and fiber cement board systems generally performed adequately under steady and time-varying wind load conditions with the exception of the fiber cement board, which did not fail at 150% of the unfactored design pressure.

305 mm Overhang

ID	$p_{FAILURE}$(kPa)				δ (cm)			
	Trial 1	**Trial 2**	**Trial 3**	**Avg.**	**Trial 1**	**Trial 2**	**Trial 3**	**Avg.**
FCB	-5.60	-5.10	-5.82	-5.51	119.76	112.40	112.31	114.82
OSB	DNF	DNF	DNF	DNF	0.83	1.49	0.94	1.08
Stucco	DNF	DNF	DNF	DNF	1.75	2.58	1.37	1.90

Quasi-Static Straight

ID	$p_{FAILURE}$(kPa)				δ (cm)			
	Trial 1	**Trial 2**	**Trial 3**	**Avg.**	**Trial 1**	**Trial 2**	**Trial 3**	**Avg.**
FCB	-4.45	-	-4.51	-4.48	2.14	-	2.73	2.43
OSB	DNF	DNF	DNF	DNF	1.15	1.02	1.03	1.07
Stucco	DNF	DNF	DNF	DNF	0.84	0.94	-	0.89

Dynamic Straight

610 mm Overhang

Quasi-Static Straight

ID	$p_{FAILURE}$(kPa)				δ (cm)			
	Trial 1	Trial 2	Trial 3	Avg.	Trial 1	Trial 2	Trial 3	Avg.
FCB	-5.60	-5.10	-5.82	-5.51	119.76	112.40	112.31	114.82
OSB	DNF	DNF	DNF	DNF	0.83	1.49	0.94	1.08
Stucco	DNF	DNF	DNF	DNF	1.75	2.58	1.37	1.90

Dynamic Straight

ID	$p_{FAILURE}$(kPa)				δ (cm)			
	Trial 1	Trial 2	Trial 3	Avg.	Trial 1	Trial 2	Trial 3	Avg.
FCB	-4.45	-	-4.51	-4.48	2.14	-	2.73	2.43
OSB	DNF	DNF	DNF	DNF	1.15	1.02	1.03	1.07
Stucco	DNF	DNF	DNF	DNF	0.84	0.94	-	0.89

Quasi-Static Corner

ID	$p_{FAILURE}$(kPa)				$\delta_{FAILURE}$(cm)			
	Trial 1	Trial 2	Trial 3	Avg.	Trial 1	Trial 2	Trial 3	Avg.
FCB	-4.91	-4.23	-	-4.57	1.06	1.08	*	1.07
OSB	-7.05	-7.22	-7.21	-7.16	1.34	4.17	0.99	2.17

Dynamic Corner

ID	$p_{FAILURE}$(kPa)				$d_{FAILURE}$(cm)			
	Trial 1	Trial 2	Trial 3	Avg.	Trial 1	Trial 2	Trial 3	Avg.
FCB	-4.32	-3.12	-3.16	-3.53	0.85	2.09	1.82	1.59
OSB	DNF	DNF	DNF	DNF	0.69	0.95	0.85	0.83

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Recommendations

- Establish a separate testing application standard or a section in an existing testing application standard that specifically addresses soffit panel systems. The rationale is twofold:
  - We acknowledge that the motivation for using a universal approach (i.e. TAS 202, 203) was to achieve a ‘level playing field’ for evaluating all building envelope products, however the lack of specific guidance for families of products is problematic—particularly for soffit panels, which differ from wall systems in that they are vented and oriented parallel to the ground.
  - Moreover, a review of the product approvals found that soffit materials are qualified under multiple tests, including ASTM D5206, ASTM E330, TAS 202-95 and/or TAS 203-95. TAS 100-95(a) is also used to evaluate soffit performance, however its applicability appears to extend only to establish water ingress requirements. Although the ASTMs and TASs establish similar requirements, allowing products to be qualified under different test procedures introduces experimental uncertainties associated variations between the test methods. This issue further reinforces the need to develop specific guidelines for testing soffit panel systems.

Recommendations cont.

- Include steady and time-varying load sequences
  - Quasi-static (ramp) or staircase (step-and-hold) pressure sequences are both acceptable to recreate the steady load conditions.
  - The fatigue sequences may be taken from Tables 1625.4 and 1626 to achieve consistency between wall and soffit dynamic loads, which are highly correlated. We note that the fatigue sequence in Table 1626 was determined from a peer-reviewed study performed by Texas Tech University.

Recommendations cont.

- Allow for the option of using high-fidelity, full-scale replication of pressure sequences obtained from wind tunnel modeling in addition to the rainflow analysis-derived fatigue sequences set forth in Tables 1625.4 and 1626.
- Require testing of both straight <u>and corner sections</u>
  - Corner sections are not currently being evaluated
  - The results strongly indicate that the corner sections are the weak link, therefore we conclude that this issue represents a critical deficiency in the testing application standards
  - Manufacturer instructions for corner installations were difficult to locate
  - Mandating testing of corner sections will also ensure that installation guidelines for corner details are publicly available for installers

Recommendations cont.

- Require separate tests for common overhang lengths (1 ft and 2 ft)
  - The support conditions change when intermediate nailing members are added. In most cases, the tributary area for a single center fastener will be twice that of the edge fastener.
  - It is not clear if this issue is recognized. At least one manufacturer specifies the same design pressure for multiple overhang lengths, which is at odds with the mechanics.
- Stipulate failure criteria, which should include fastener pull-out, material pull-over and tearing, panel unlocking, plastic deformation and possibly, excessive deformation.

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Recommendations cont.

- Test specimens should be constructed using mockups of the roof overhang and a wall surface. Fasteners should be installed using pneumatic guns, which is standard field practice. The wall ensures realistic gun alignment, which is an important consideration for panels susceptible to pull-over and tearing.
- All components in the assembly should be specified. While this is generally the case, we note that the make and model of the channels used in vinyl and aluminum soffit were not found in the product approval documentation
- Next step / Question for HRAC: Update TAS?

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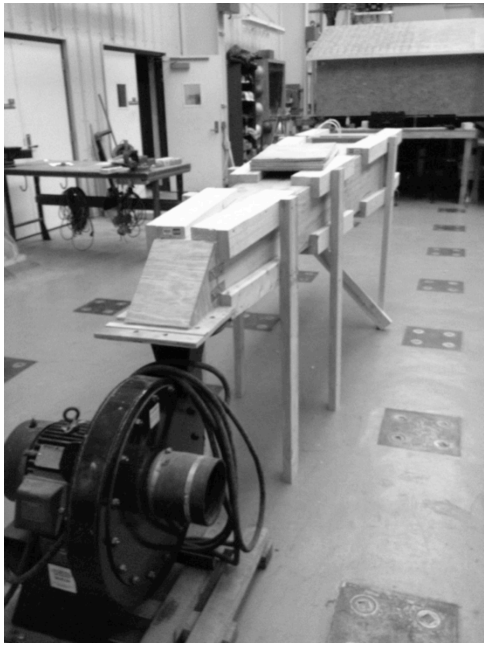
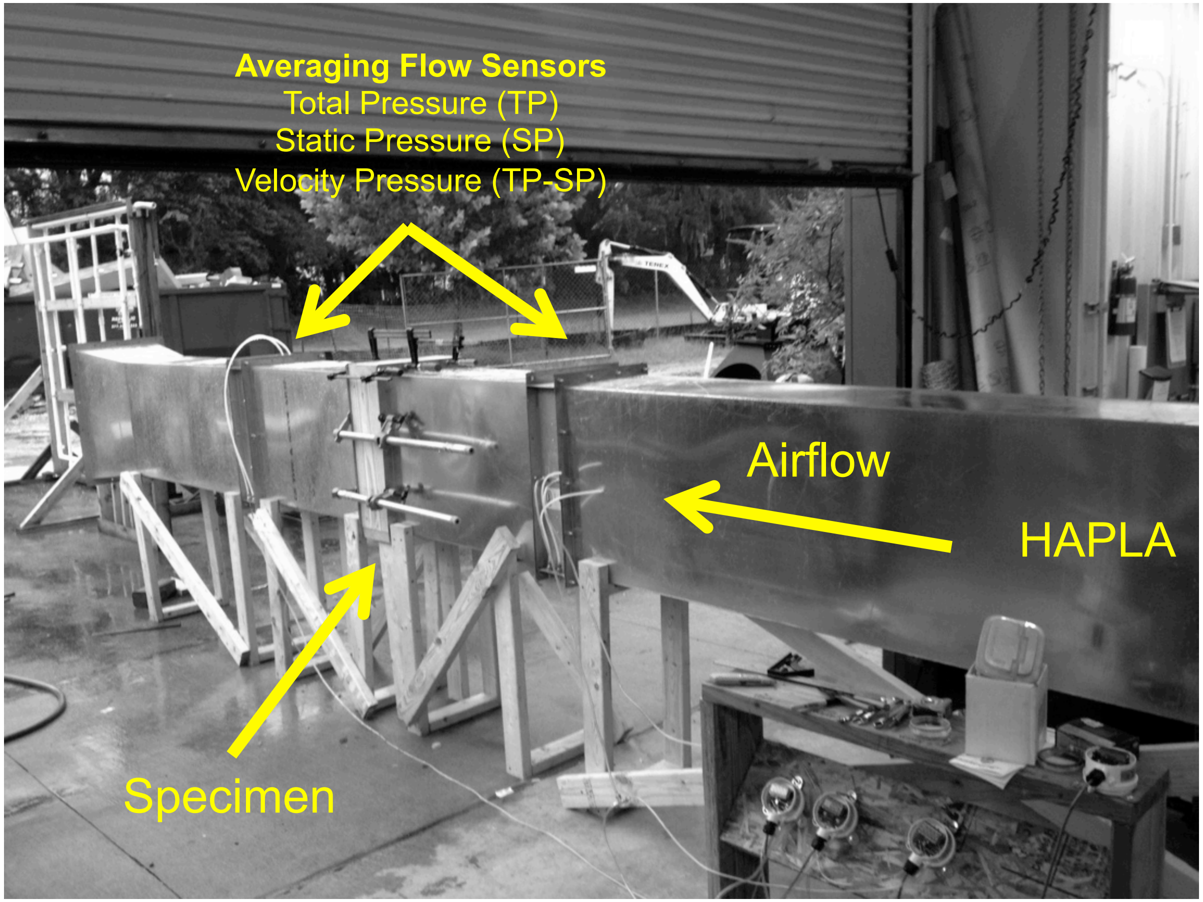
Air Permeability



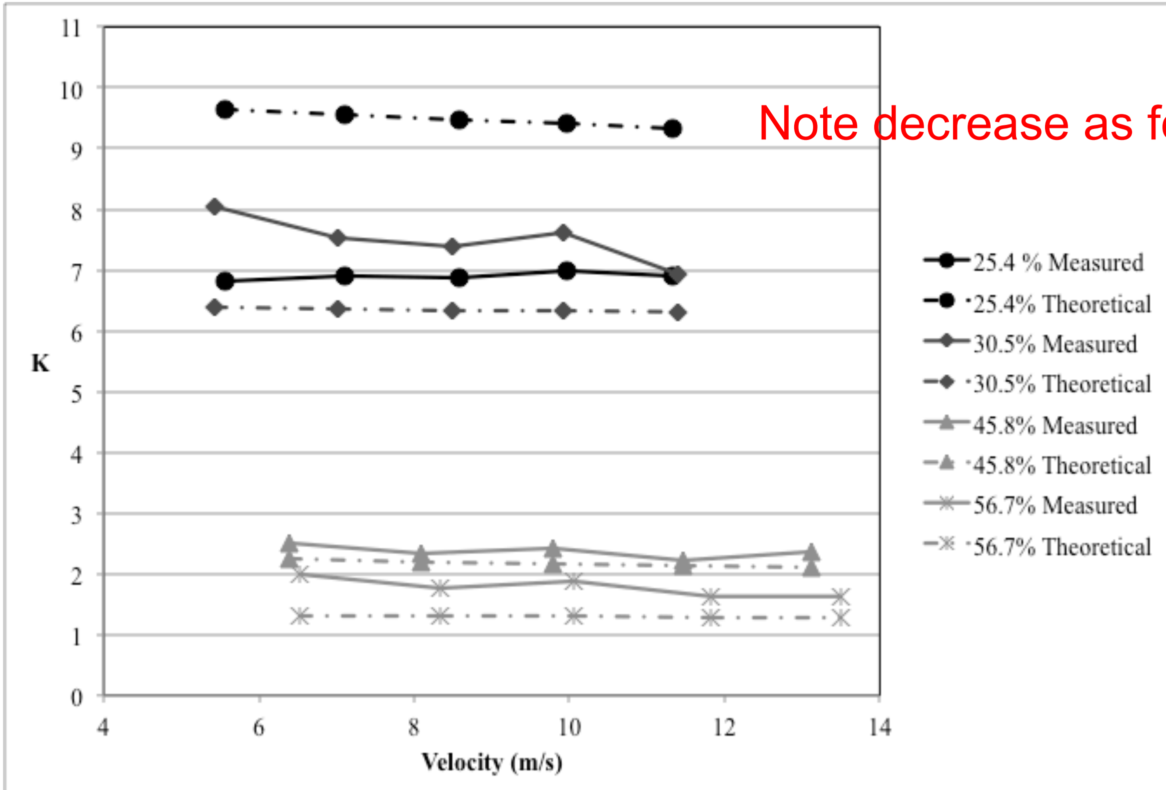
First Effort



Final Configuration

Air Permeability of Screens (Validation)

$\frac{\text{Static Pressure Drop}}{\text{Velocity Pressure}}$



Note decrease as fcn of velocity

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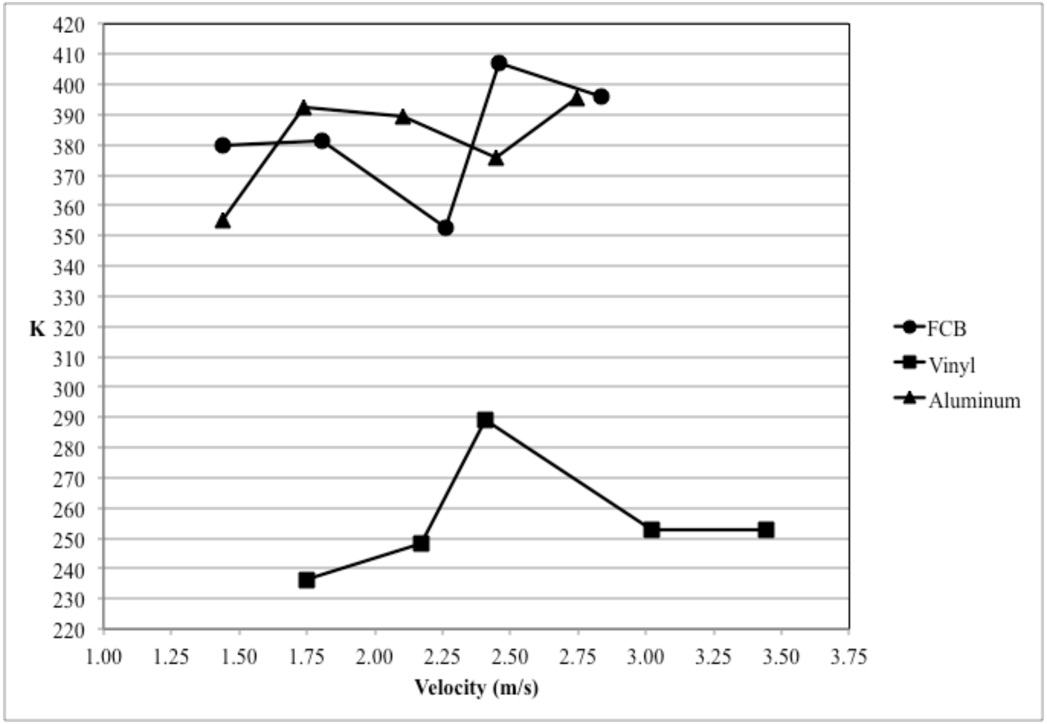
Air Permeability of Soffits



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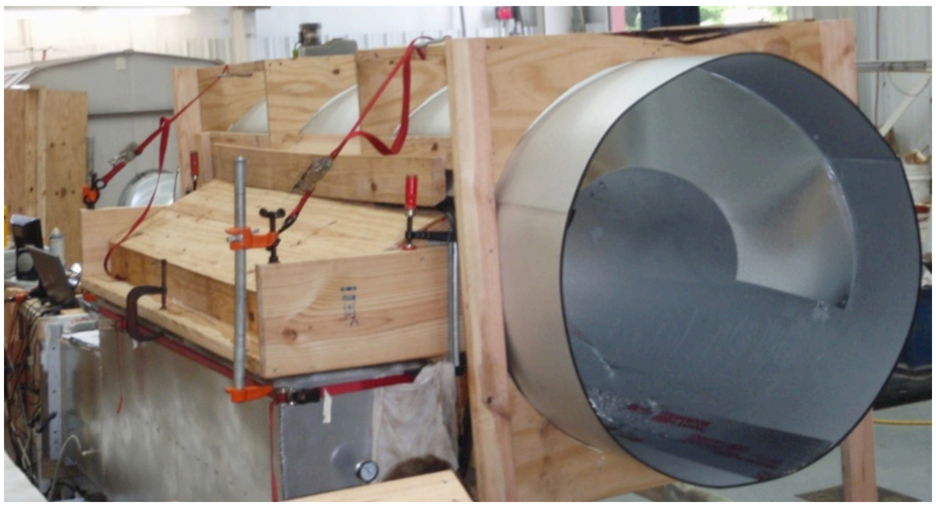
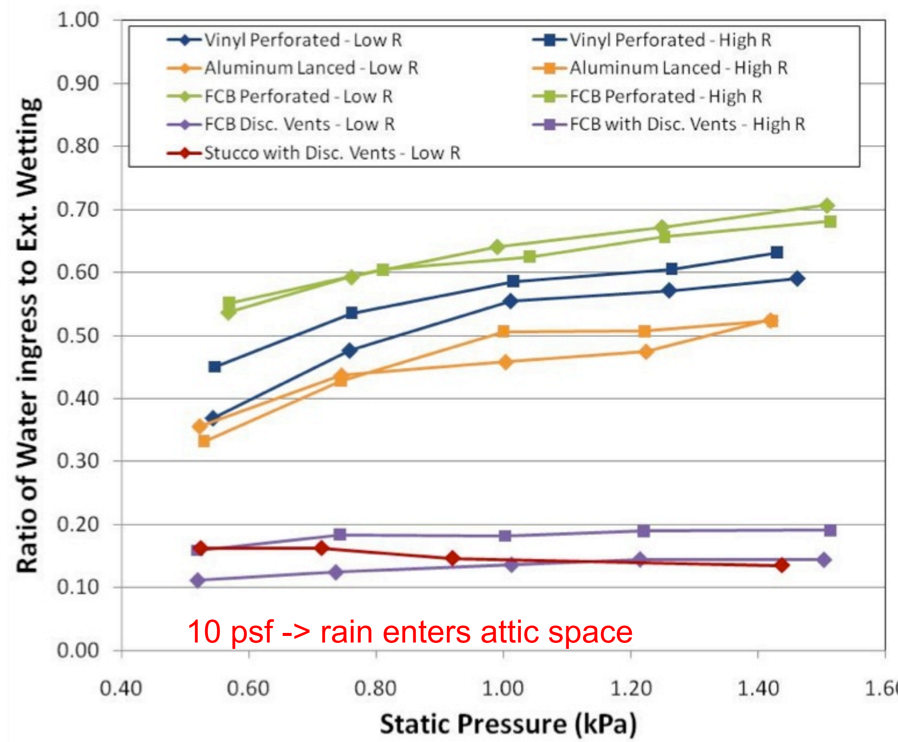
Water Ingress





Concern: how well does this configuration replicate natural conditions?

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Recommendations: Water Ingress

What we know:

- ✓ Pressure thresholds associated with blowout
- ✓ Air permeability (SP / VP): orifice and friction losses
- ✓ Ratio of water ingress to external wetting is nearly constant
- ✓ The ingress/wetting ratio is linearly dependent on static pressure
- ✓ How to collect water ingress

What we need to know:

- ❑ What are the design requirements? Not stipulated in Code and not easy question to answer
- ❑ The missing pieces:
  - ❑ Rain intensity and velocity at soffit
  - ❑ Method to realistically simulate wetting for product approval. Spray nozzles produce highly non-uniform distributions (both raindrop size diameter and intensity)
- ❑ This information can be obtained from computer modeling and validated with full-scale tests in a facility such as the IBHS Research Center

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Questions?