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Weatherproofing ICF Walls

Lessons from BC Research

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Research precipitated by wood building failures in BC

- "Leaky Condo" crisis 1980 - 2010
- $4 B damages
- 900 Buildings
- 31,000 Residential Units

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Coastal British Columbia is renowned for it's scenic mountains and forests. What some forget is that these incredible forests rely on a great deal of moisture to grow, meaning that the prevailing conditions there are extremely wet.

At its core, this research was precipitated by a massive series of failures in wood-framed structures in Vancouver and the surrounding region, mostly due to failures of EIFS stucco application over wood walls.

Building codes have evolved to solve many of the issues, but building officials and warranty insurance providers have been left with a keen suspicion of anything that hints of water risk.

BC Housing Water/Air Intrusion Testing

- Joint project by BC Housing and ICF industry partners
- Evaluate ICF methods & materials for control of water and air penetration
- Support “best practice” recommendations for residential buildings
- Clarify code treatment of ICFs in BC

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Today’s presentation is a summary of a joint research project undertaken by the Province of BC and a consortium of ICF manufacturers, beginning in 2014 and concluding in 2016.

The objective was to evaluate methods and materials used to construct ICF walls and their ability to control both air and water infiltration.

The intent was to use findings to support a revision of BC Housing Corporation’s “Building Envelope Guide for Houses”, scheduled in 2016/2017, and to help building officials to clarify how the code treats ICFs.

BC Housing Water/Air Intrusion Testing

Industry Objectives:

- Independent testing under national standards
- Repeatable details
- Use “off-the-shelf” materials, tools & techniques
- Meet or exceed building code expectations

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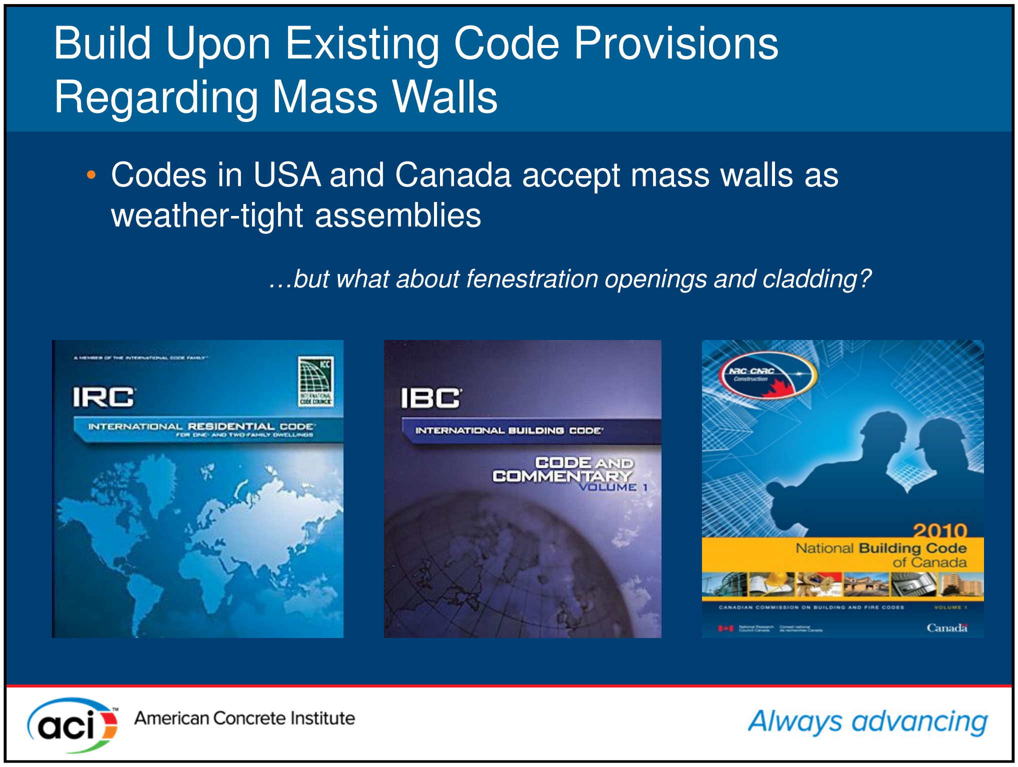
From the industry’s perspective, ICF producers wanted independent research under national and international standards that could support claims to code compliance in both Canada and USA.

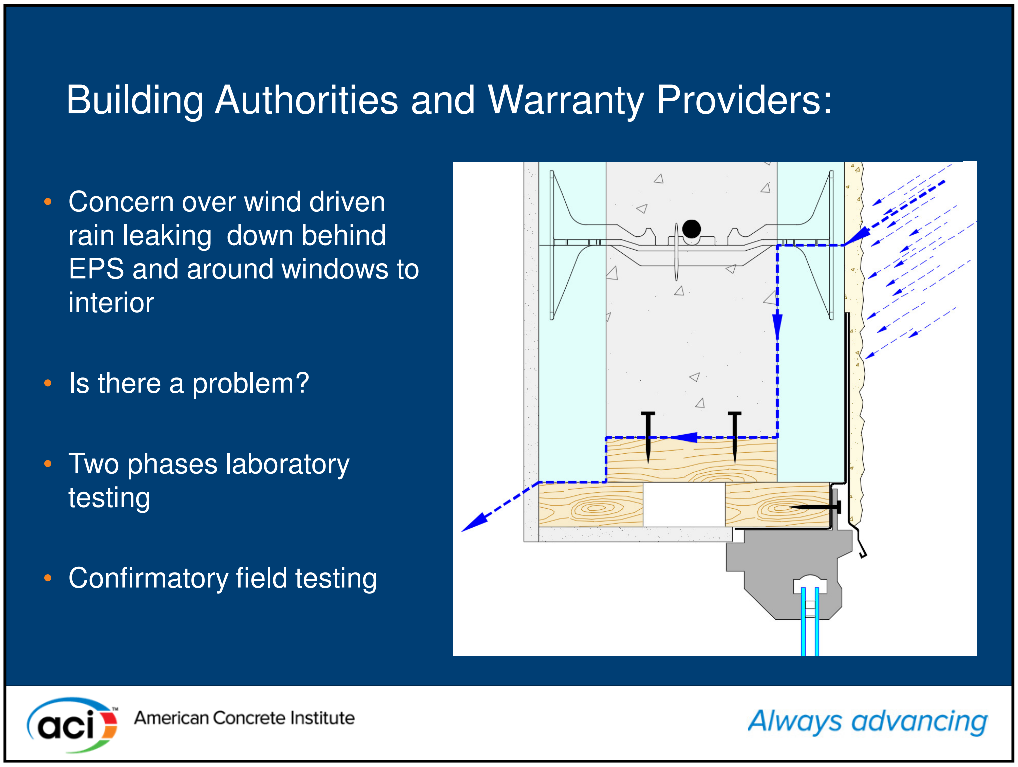
They sought testing of simple and repeatable details, using “off-the-shelf” materials, tools, and techniques that could meet or exceed national and local building codes.



Even though building codes in both USA and Canada accept mass walls as a weather-tight plane, without the benefit of either cladding or building paper, building officials in both countries have often been confounded by the EPS layer on the exterior.

Consequently, they would often resort back to requirements for wood-framed structures that they were more comfortable with.

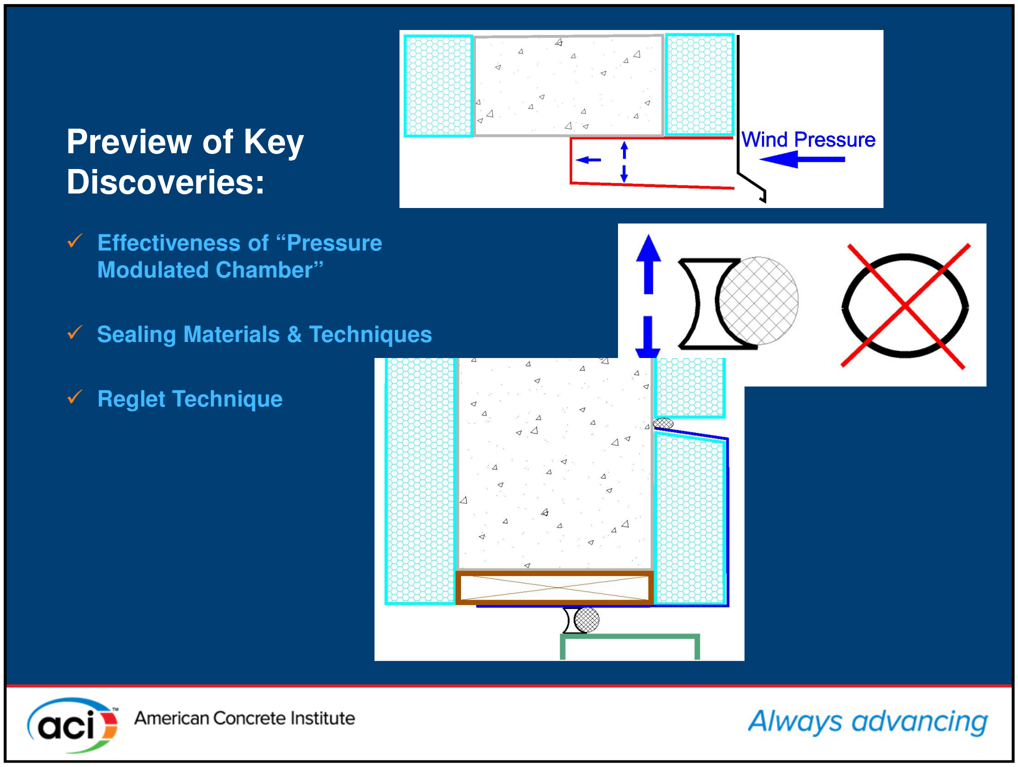
This research seeks to settle the question and propose the “best practice” methods for ICFs in order to achieve the objectives of the building code.



In absence of proof to the contrary, regional building officials and warranty insurance providers questioned the ability of ICF walls and associated detailing to keep water out of the building.

The suspicion was that, if the exterior cladding somehow failed, there could be migration of moisture through the ICF layer and eventually into the building.

To answer the question, the research and education division of BC Housing Corporation teamed up with the ICF industry to provide answers. Two round of laboratory testing and one round of comfirmatory field testing were undertaken.



Before we take a look at how the testing was conducted, let me share a preview of some key findings, which I would ask you to keep in the back of your mind as we view this project.

First is the high degree of effectiveness of what building science experts call a "pressure modulated chamber", which is formed at the connection between the window and the supporting structure.

Second is the importance of both the shape and positioning of sealing materials, or caulking.

Third is the effective use of a through-wall flashing technique (which we call a "reglet") to connect the water-tight concrete core to the window.

Phases I & II: Laboratory Testing

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Testing for Phases I and II were performed on 6 ft. x 6t ft. ICF wall sections like the ones in this photo.

Each module had a 2x2 window installed into a buckout that varied according to the test plan.

Note the cable loops to facilitate lifting of these modules, each of which weighed about 1,400 lbs.

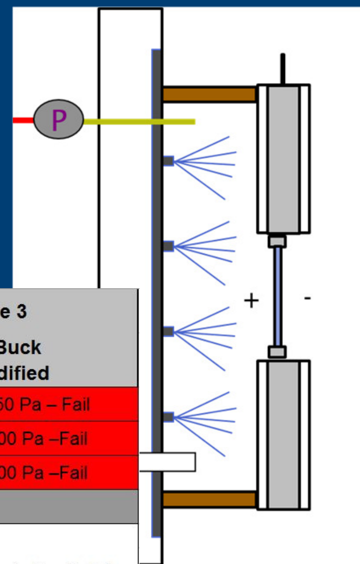
The 3 key techniques found in the industry included full-width lumber buckouts (called "exterior" bucks) that spanned from one side of the ICF assembly to the other.

Next was the "internal" buckout, which fits inside the ICF assembly and is fastened into place through the EPS layers.

Third was a popular proprietary buckout system, which you likely know as V-Buck.

Phase I Testing

Use benchmark performance levels associated with fenestration components (windows/doors) vs ASTM E1105



	Module 1 Internal Buck Unmodified	Module 2 External Buck Unmodified	Module 3 Vinyl Buck Unmodified
Water Test Results	150 Pa – Pass	150 Pa – Fail	150 Pa – Fail
	300 Pa –Fail	300 Pa –Fail	300 Pa –Fail
	700 Pa –Fail		700 Pa –Fail
	1400 Pa –Fail		
	3 Penetration Points	2 Penetration Points-Excessive amounts of water	5 Penetration Points
Rank	?	?	?

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The consulting engineers for the project, RDH Building Science, suggested that the test criteria be borrowed from the fenestration industry, which is required to test their products to varying performance levels, according to climate conditions and building use, or ASTM E1105.

The image at right shows the position of the ICF test wall in a very sophisticated (and expensive) test apparatus operated by Cascadia Windows in Langley, BC. This device simulates a wide range of wind-driven rain conditions.

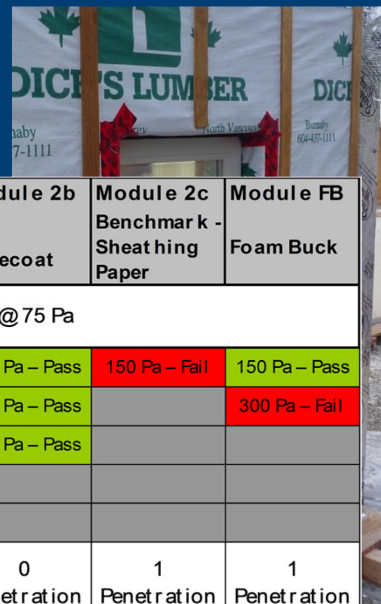
According to industry standards, the bottom level of resistance is 150 Pascals of pressure, suitable for temperate climates and small, low-rise buildings.

The next level is 300 Pascals, which is deemed to be more extreme conditions, suitable for mid-rise construction.

The highest level is 700 Pascals, which exceeds climate criteria and is suitable for high-rise buildings, even to 40+ stories.

The amount of red ink on this table doesn't indicate much success with any of the three main buckouts tested. In fact, it raises cause for concern when one looks at how common these techniques are.

Phase II Testing



	Module 1a Internal w/ Buck Flash	Module 1b External w/ Buck Flash	Module 2a Direct to Concrete	Module 2b Eifs Basecoat	Module 2c Benchmark - Sheathing Paper	Module FB Foam Buck
Air Test Results	≤0.0039 L/s.m2 @ 75 Pa					
Water Test Results	150 Pa – Pass	150 Pa – Pass	150 Pa – Pass	150 Pa – Pass	150 Pa – Fail	150 Pa – Pass
	300 Pa – Pass	300 Pa – Pass	300 Pa – Pass	300 Pa – Pass		300 Pa – Fail
	700 Pa – Pass	700 Pa – Fail	700 Pa – Pass	700 Pa – Pass		
			1400 Pa – Pass			
			5000 Pa - Pass			
	0 Penetration Points	1 Penetration Point	0 Penetration Points	0 Penetration Points	1 Penetration Point	1 Penetration Point

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The second round of testing included a number of modifications and some yet-untried techniques.

It is interesting to note that one of the new techniques was to emulate the water resistant barrier methods used for wood-framed walls. Even more interesting is the fact that it failed even the lowest pressure levels.

Another new player was the direct-to-concrete connection, commonly found in mid to high rise construction, and one example of face-sealed EIFS basecoat wrapped back into the window opening.

This chart shows a much higher level of success, with the exception of the wood-frame method.

In fact, the direct to concrete method performed to pressures that simulate 575 mph wind speeds, without failure. That was over 7 times the highest pressure (700 Pa) given in the test standard for high-rise buildings.

Phase III

- Field tests to confirm lab results
  - Four examples over broad range of applications

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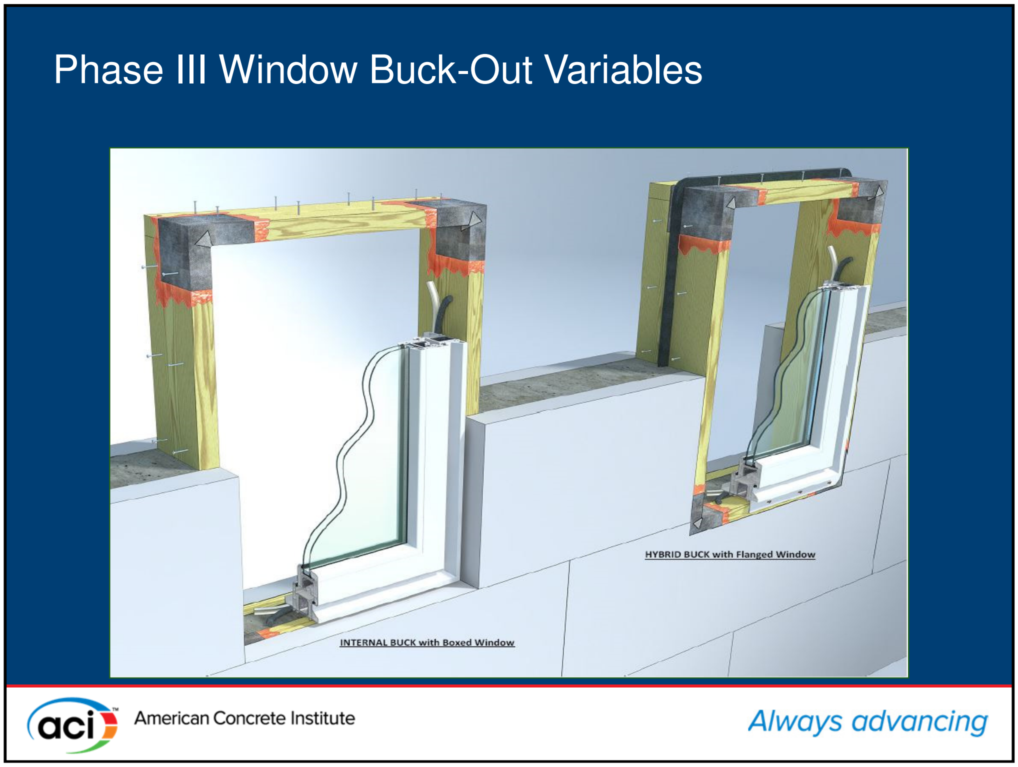
After two rounds of laboratory testing, followed by field test confirmation, a broad range of applications was narrowed down to 4 examples.

Two of these examples proved to be 100% successful at preventing the ingress of air and water, even to the most stressful of conditions.

These were the examples where windows were sealed either directly to concrete or to an EIFS basecoat that is wrapped back into the window opening.

Modules where wood buck-outs were left in place were somewhat less resistant, but did perform to levels required in mid-rise construction.

A pressure chamber was set up on the interior, which was intended to pull water through the assembly at carefully monitored levels of negative pressure.



These photos give a sense of how the openings were prepared for the examples where the forming materials were left behind.

The idea behind this was to offer at least one option where a common flanged window could be fastened to the forms left permanently in the concrete.

Phase III EIFS Face-Seal and Recessed Options

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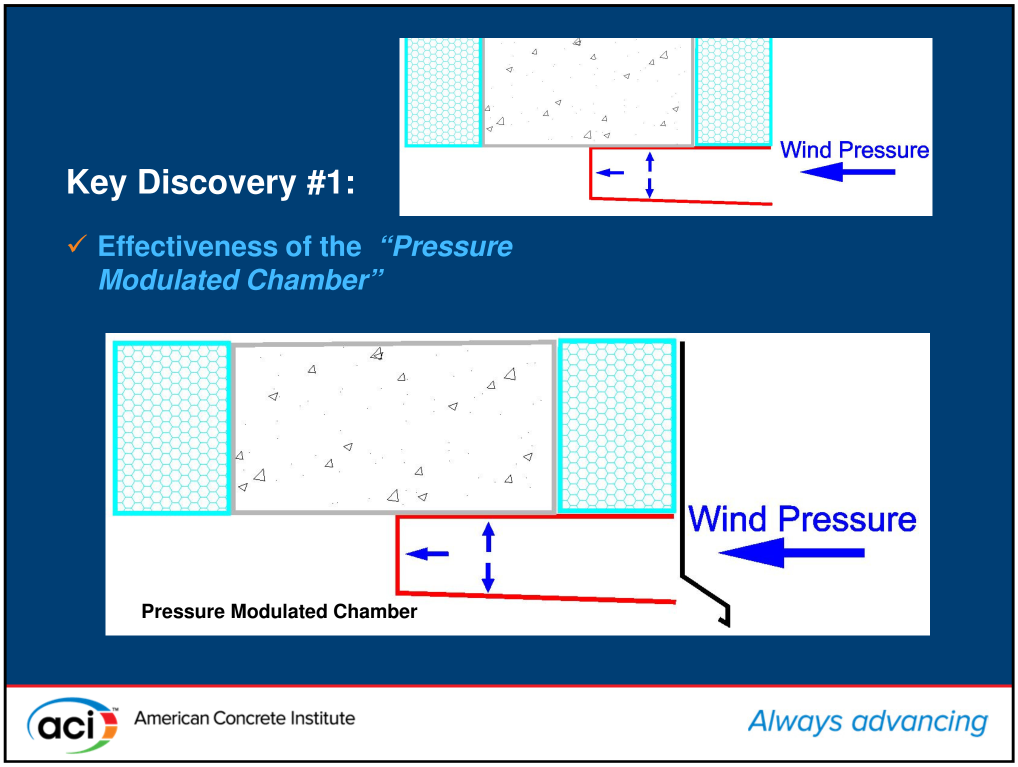
These photos show the EIFS example (left) and a treated-wood buckout (right) flashed with self-adhered membrane.

For the flanged-window module, the head-flashing was sealed directly to the concrete, which was exposed in the reglet cut above the opening.

These are “post-mortem” photos of the most successful example, where the window was sealed directly to the concrete.

This example is not only the most successful, but quite likely the least expensive to construct.

Results of this program are posted on the BC Housing website, as well as construction details in their upcoming Building Envelope Guide.



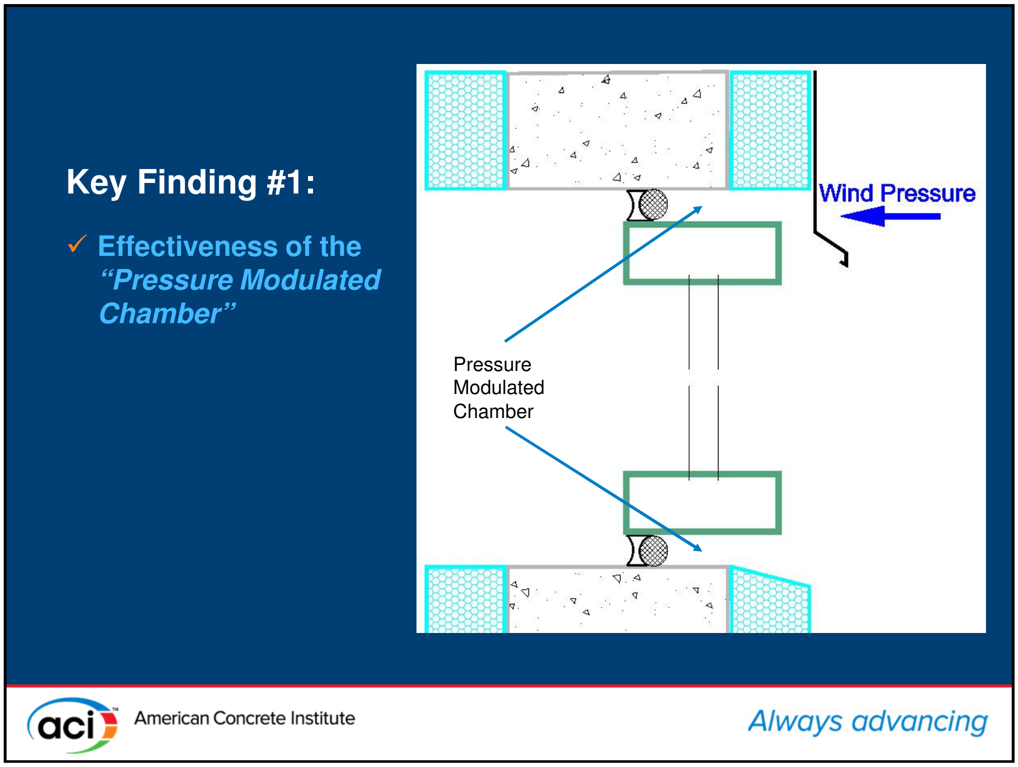
Turning now to the key findings in the research, we witnessed the high degree of effectiveness of what building science experts now recommend in terms of connection details, creating what is termed a "pressure modulated chamber.

In this simple diagram, the assembly elements form the "C" shaped cup shown in red here.

As wind pressure acts on this element, there is a finite amount of pressure that can build up within, which is resisted by the seal at the back of the structure.

To understand this principle, it is helpful to imagine a car door. There is no exterior seal on a car door, only an interior seal. The exterior is left open to drain any moisture that enters the cavity, yet the interior of the car stays dry.

Pressure is further mitigated when a drip-flashing is places to obstruct the wind pressure, as shown here.

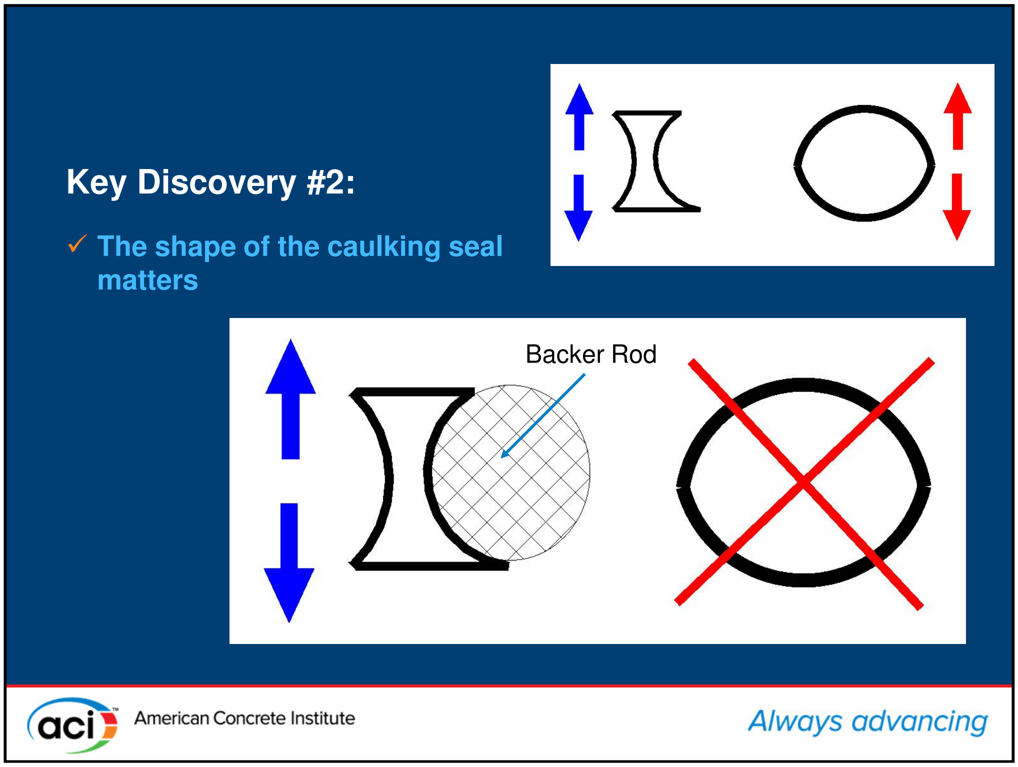


Now, as we view the installed window assembly, the space between the window and the structure becomes the pressure modulated chamber, with the rod and caulk at the back creating the seal.

The front of the structure can actually be left open to provide drainage, but if caulked, must have weep holes left open at the bottom to allow escape of any moisture that does intrude.

A seal on the exterior of the window is, therefore, optional.

If only one caulking seal is to be made, it should be the interior one, not the exterior.



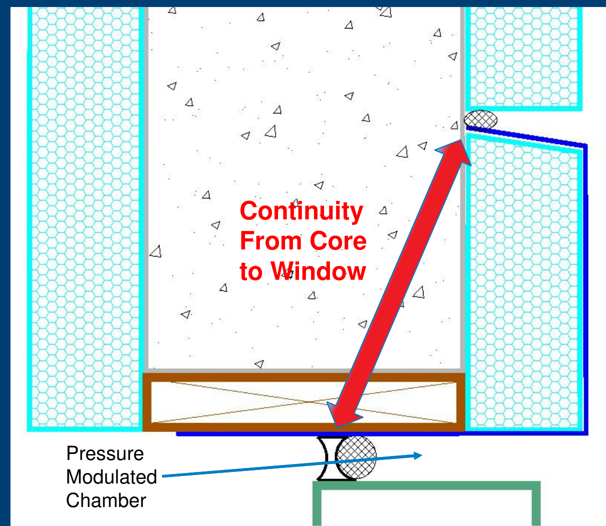
The next finding concerned the application of sealant to the window.

Building science experts are recommending the use of foam backer-rod whenever window caulking is applied. This results in a more resilient, hour-glass shaped bead, which is able to stretch when small movement occurrs between building elements. The round bead is less able to stretch, since its strength is in the middle.

The hour-glass shaped caulk is better able to absorb motion over a long period of time and is therefore more resilient over time.

Key Discovery #3:

✓ Effectiveness of a “reglet” above openings where forms are left in place



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The third key finding was the effectiveness of an ICF-specific adaptation of through-wall flashing, which we are calling the “reglet” technique.

A narrow cut is made above each opening, with the bottom of the cut sloped at about 15 degrees, and exposing a narrow band of concrete at the back of the reglet.

This allows for either self-adhering or liquid-applied membrane to be sealed to the concrete core and extended around the face of the ICF and into the window opening. There, the window can be sealed to the membrane.

This method now provides continuity of the water-tight plane from the concrete core to the window. The pressure modulated chamber below now does the rest of the heavy lifting in terms of resisting wind and water pressure.

Key Discovery #3:

✓ Effectiveness of a “reglet” above openings where forms are left in place

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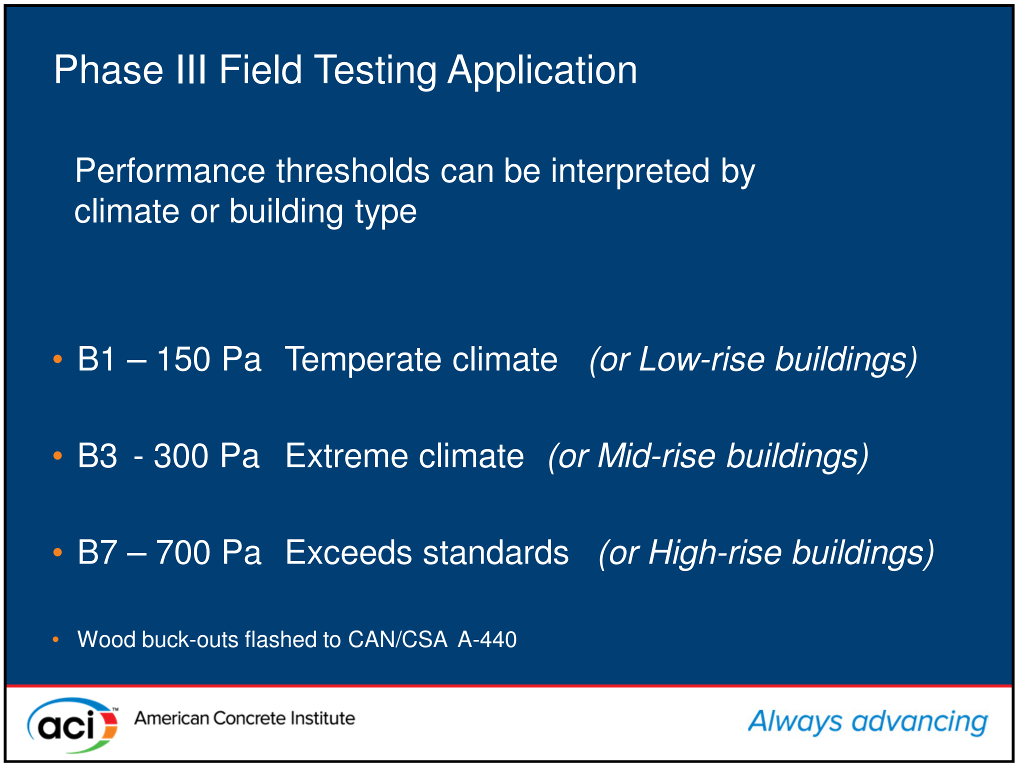
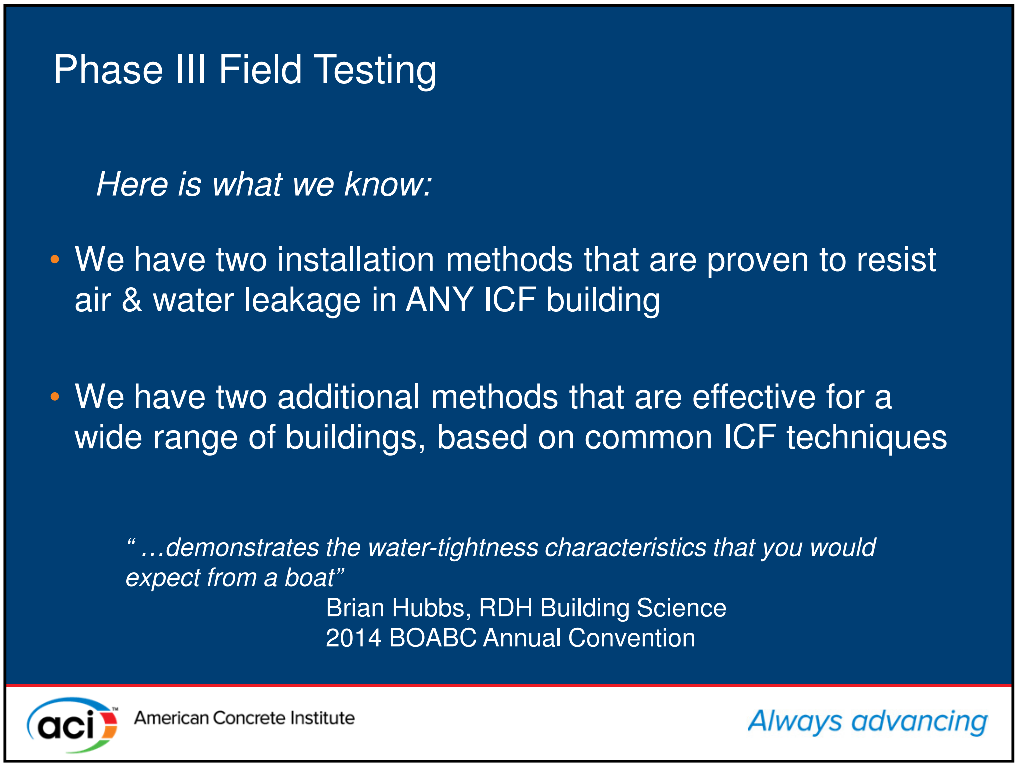
Since the industry was quite insistent on a “flanged window” option, we did successfully test that with an added head flashing that extended over the window flange.

The green layer on the exterior is a second head-flashing that shingles down over the head flange.



Part of the ICF industry’s “ask” on this research project was that the results were applicable to as wide a range of buildings as possible, as well as a wide variation of climate conditions.

The performance (pressure) benchmarks can be said to represent conditions acting in or upon the following climates or building types, which includes a very wide range.



In the end, here is what we discovered:

We have two methods that are expected to resist water and air intrusion in ANY building, regardless of height or exposure.

We have two additional methods, based on more conventional ICF practices, that are expected to perform satisfactorily in all but the most extreme conditions and high-rise construction.

Phase III Field Testing

Regional standards for water/air leakage of windows:

ASTM E1105

	Internal Buck-out	Direct to EIFS	Hybrid Buck-out	Direct to Concrete
Temperate or Low-rise	150 Pa	150 Pa	150 Pa	150 Pa
Extreme or Mid-rise	300 Pa	300 Pa	300 Pa	300 Pa
High-rise	700 Pa	700 Pa	700 Pa	700 Pa *(5000 Pa)**

* Based on Phase II laboratory testing

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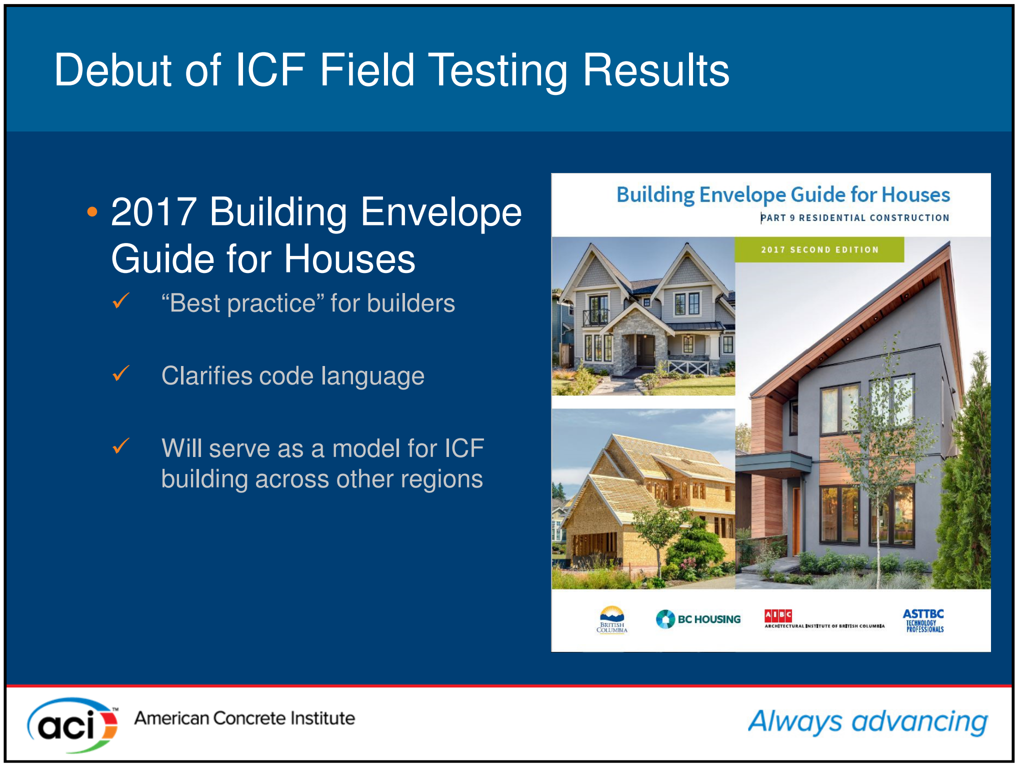
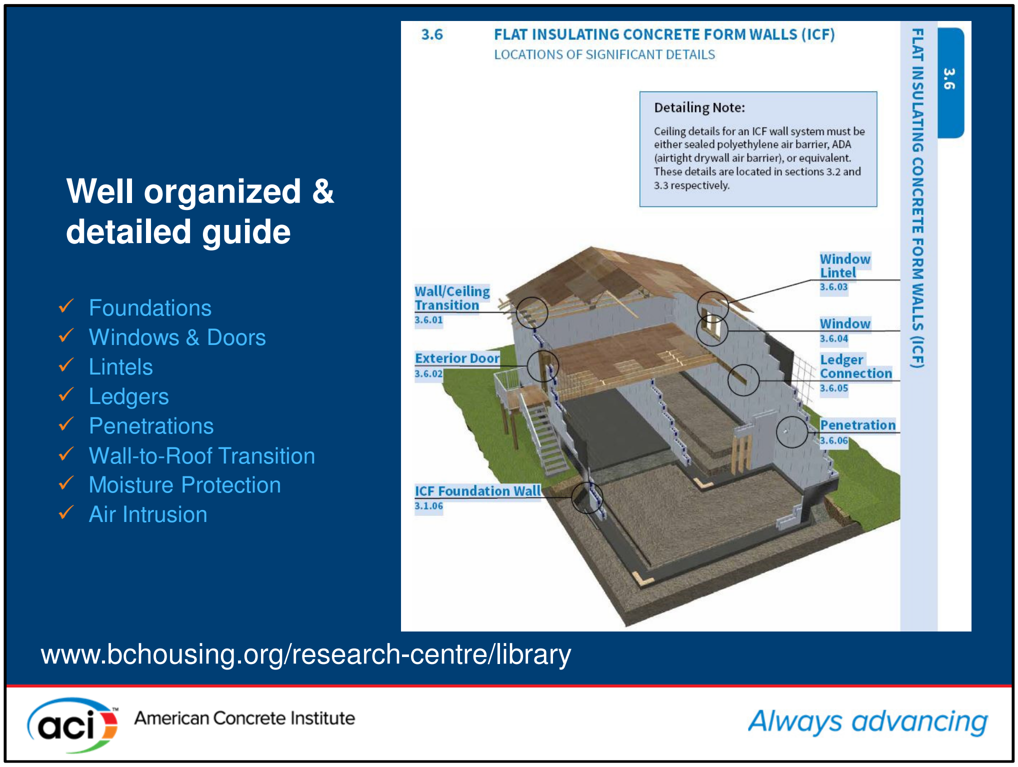
This table outlines the pressure levels attained by each of the final configurations.

It is interesting to note that the Direct to Concrete example was actually successful in laboratory tests to pressures more than double the ones shown on this field-test report.



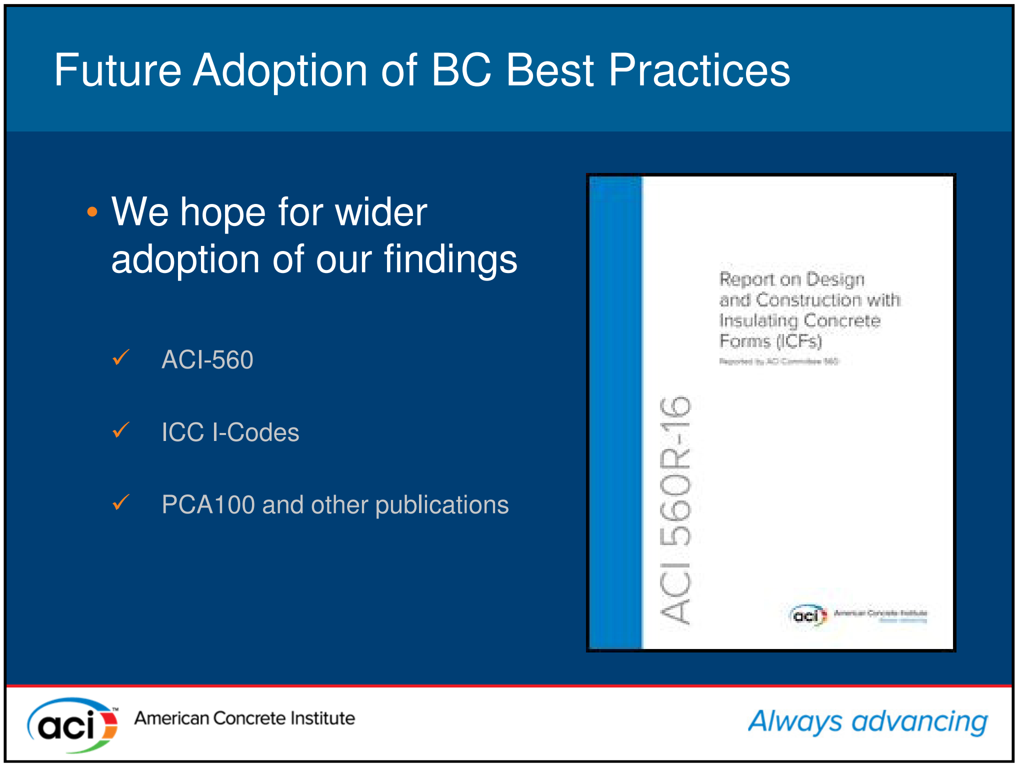
Currently there is a revision underway of the residential building guide from BC Housing Corporation. It features a greatly expanded section on ICF wall construction, supported in part by the project we just discussed. It details code-compliant methods and best-practices for ICF installation.

We are looking forward to this guide serving to clarify existing code requirements in BC as well as guiding emerging standards across Canada.



The Building Envelope Guide for Houses is a very well organize and easy-to-use document that is a practical guide to the “best practices” for construction of single family homes in BC.

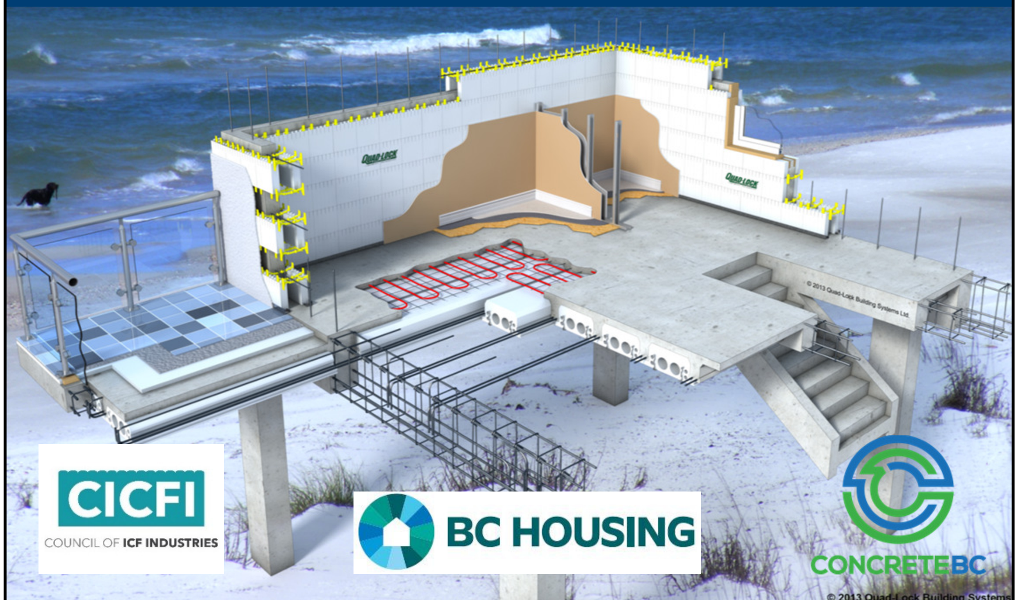
The ICF section has been compiled with the input of the ICF industry to ensure that constructability and efficiencies are maintained.



In addition to Canada, we hope that US-based organizations, like ACI are able to benefit from this work, including ACI 560, the ICC, and PCA. ACI 560 is the first to get a close look at this research.

On behalf of myself, my company and the Insulating Concrete Form Manufacturer's Association, we thank you and welcome your interest in this work.

Thank You!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