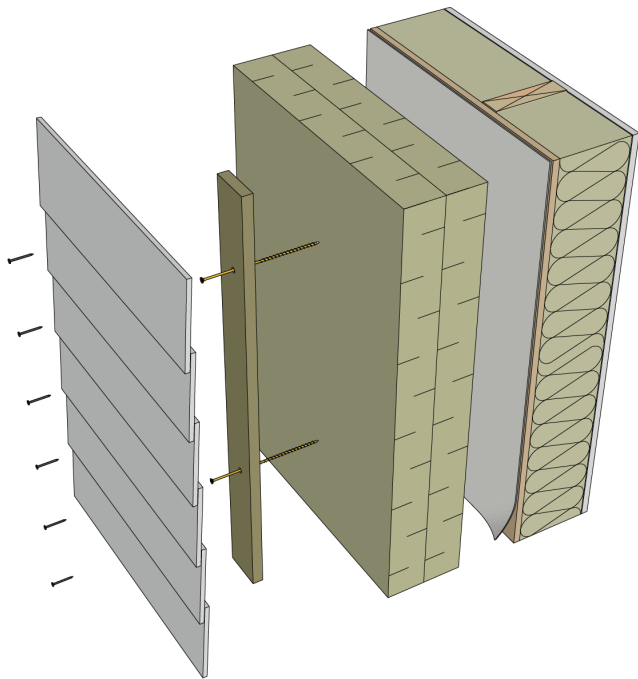


Performance of Strapping Attachment on Walls with Long Screws Through ROCKWOOL Rigid Insulation

Introduction & Background

As the construction industry moves toward more energy-efficient buildings, installing continuous exterior insulation is an effective way to achieve higher thermal performance in wall assemblies. Research and in-situ performance has shown that attaching exterior strapping with just screws directly through layers of ROCKWOOL rigid stone wool insulation is an efficient solution both thermally and structurally as a cladding support solution and can also be beneficial with respect to air and water control.

Despite having been used in many applications, there is in some cases skepticism in the industry regarding supporting thicker layers of insulation and claddings using this long screw approach. However, both industry experience and related research support the use of this cladding attachment approach.



Schematic illustration of vertical strapping attachment with screws through rigid insulation into the backup wall assembly.

In addition to questions regarding the structural performance, there are also questions related to air and water control when utilizing this assembly approach. The potential for air and water leakage at fastener penetrations through the sheathing membrane has been identified as a potential risk for exterior insulated assemblies. Compared with the structural integrity of the system, less work has been completed to characterize these risks.

Several factors potentially affect the risk associated with exterior insulated systems, including the following:

- ▶ Exposure to driving rain
- ▶ Water penetration resistance of the cladding
- ▶ Provisions for drainage and drying within the wall assembly
- ▶ Type of exterior insulation used
- ▶ Type of cladding attachment system
- ▶ Self sealing capabilities of the sheathing membrane and sheathing

To support the industry in understanding the performance of this long screw exterior insulation and cladding attachment approach, two laboratory studies were completed by RDH Building Science Inc.

This bulletin outlines the recently completed testing by RDH which evaluated the following performance considerations:

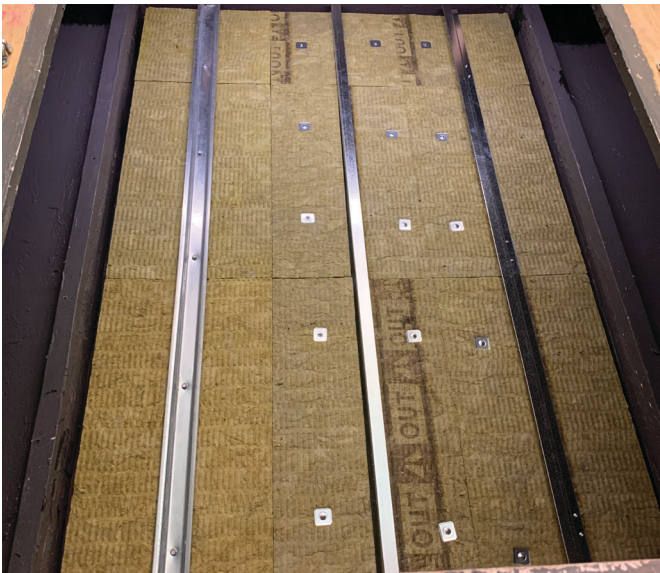
- ▶ Assess the air and water penetration performance of a long screw cladding attachment approach, and compare with frequently used systems such as vertically positioned Z-girts and Z-clips with vertical furring channels. Testing included a general comparison of ROCKWOOL rigid stone wool insulation and extruded polystyrene (XPS) insulation.
- ▶ Structural screw testing focusing on the deflection of the strapping supporting the cladding system and the impact of insulation compression on the structural performance of the system.

Air and Water Testing

Overview

RDH completed a laboratory research study to assess the air and water performance of exterior insulation with long screws. This research focuses on evaluating the impact of the following key areas relating to air and water penetration resistance of exterior insulated assemblies:

- ▶ Comparison between wall frame types (wood-frame versus steel-stud)
- ▶ Performance of rainscreen walls with no exterior insulation and exterior insulated assemblies using 3" exterior rigid insulation (ROCKWOOL Comfortboard® 80, ROCKWOOL Cavityrock®, and XPS) with different cladding attachment approaches
- ▶ Water penetration risk assessment with intentionally created commonly observed deficiencies in the water resistive barrier/sheathing (i.e., fasteners that miss the stud as well as fasteners that miss the stud and are removed).

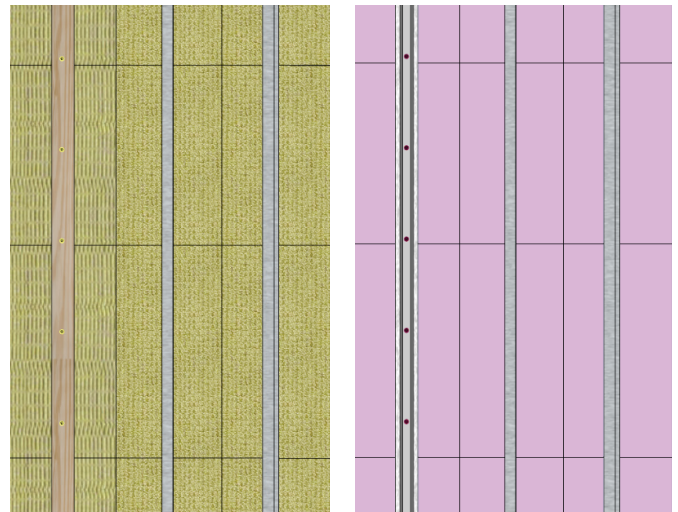


Exterior insulated test wall installed in RDH Air and Water Chamber with ROCKWOOL Comfortboard® 80 and ROCKWOOL Cavityrock®.

Methodology

The area of the test wall was divided into three sections to accommodate three different cladding attachment strategies which were: long screws through strapping or hat-track (depending on wall frame type), continuous Z-girts, and Z-clips with a continuous furring channel. Each of these strategies was installed with exterior insulation side-by-side on a single test wall.

The intent was to install all three exterior insulated cladding support approaches such that they reflect typical construction practices. To facilitate an evaluation of a new installation of each approach, sheathing with self-adhered vapour permeable membrane, studs (except for the end studs and top/bottom plates/tracks), cladding attachments, fasteners, and insulation material were replaced for each test.



Test wall divided into three sections to accommodate three different cladding attachment strategies using both ROCKWOOL Comfortboard® 80, ROCKWOOL Cavityrock®, and XPS (seen on right schematic of test wall).

Three wall assemblies were tested on both wood and steel back-up wall types: drained and ventilated ("rainscreen") with no exterior insulation, drained and ventilated with 3" of ROCKWOOL exterior insulation, and drained and ventilated with 3" of XPS. Walls were tested with and without cladding to simulate unlikely but extreme exposure to water for evaluation purposes.

The following tests were completed on each wall assembly:

1. Quantitative air leakage testing at a pressure difference of ± 300 , ± 600 , ± 900 Pa
2. Smoke tracer testing through cladding attachment fasteners.
3. Water penetration testing of long screws for cladding attachments and screw misfires. Evaluated while pressurizing the test chamber at 0 Pa up to 900 Pa.

Wood Frame Test Wall

- ▶ 2" x 4" studs with 1/2" (13mm) plywood sheathing and self-adhesive sheathing membrane.
- ▶ 3" x 3/4" wood strapping fastened with 5 5/8" #12 GRK R4 counter sunk wood screws, or 1" and 4" deep Z-girt fastened with 2" #8 wood screws, or 1" and 3" deep Z-clips with 1" continuous furring channel fastened with 2" #8 wood screws. All fasteners were installed 12" (305mm) on center, embedded at least 1" in to the stud, excluding the tapered tip of the fastener.

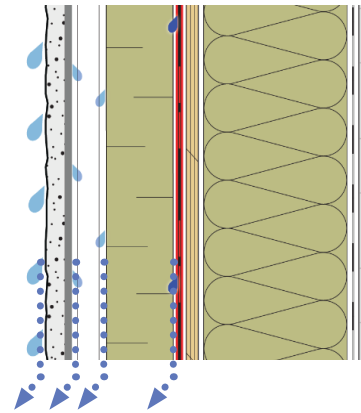
Steel Stud Test Wall

- ▶ 3-5/8"x1-1/4" 18-gauge steel studs with 1/2" (13mm) glass mat gypsum sheathing and self-adhesive sheathing membrane.
- ▶ 3" x 7/8" Hat-Track fastened with 6" #12 self-tapping metal screws, or 1" and 4" deep Z-girt fastened with 2" #8 metal screws, or 1" and 3" deep Z-clips with 1" continuous furring channel fastened with 2" #8 metal screws. All fasteners were installed 12" (305mm) on center, embedded at least 1" in to the stud, excluding the tapered tip of the fastener.

Findings

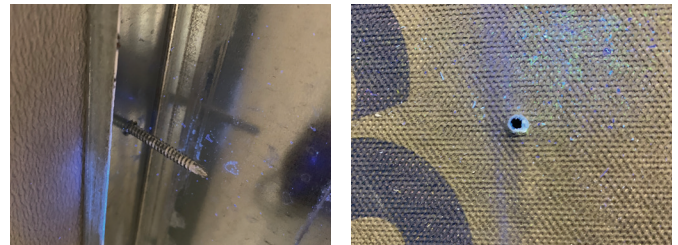
The airtightness measurements demonstrated that all cladding attachment arrangements performed similarly. Typical performance required for airtightness of whole buildings are in the order of 1-2 L/s·m². Airtightness testing of the cladding attachment approaches resulted in air leakage rates less than or equal to 0.02 L/s·m², indicating that the fastening of the strapping or hat-track approach is not likely to significantly impact overall airtightness of a building. This result was visualized using smoke tracer testing, where no smoke was visually observed through potential air leakage paths created by the fasteners.

The findings of the water penetration testing demonstrated the benefits of utilizing exterior insulation from the perspective of water control in a drained wall approach. A drained (and vented or ventilated) wall assembly provides three key drainage planes: the front of the cladding, the back of cladding, and the exterior face of the water resistive barrier membrane. When exterior insulation is added to this assembly, the insulation creates an additional drainage plane, further reducing risk of water penetration to the interior, as illustrated in the following graphic.



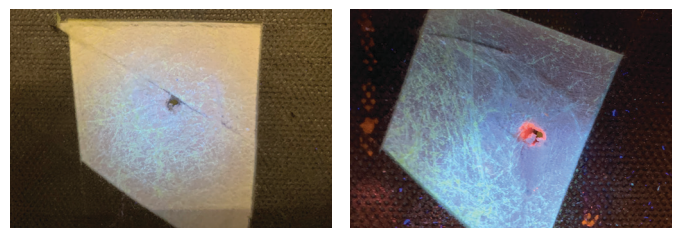
Schematic drawing of an exterior insulated drained (and ventilated) wall assembly. Blue arrows indicate drainage planes in this assembly. Note that the face of the exterior insulation provides an additional drainage plane, reducing the amount of water which reaches the WRB.

The performance of the test walls was frequently evaluated during water penetration testing to observe any signs of water ingress. During water spray application, no water was observed to be leaking through the penetrations made to secure the cladding attachment supports, as seen in the following figures.



For all test walls where fasteners were installed to secure cladding supports, no water leakage was observed on the interior side during testing (left). Once testing was completed on exterior insulated walls, the fastener penetrations were reviewed on the exterior side after the insulation had been removed. Typically, no moisture was observed at fastener locations for cladding supports (right).

Generally, testing of the steel stud test walls showed a greater potential for water ingress than did the wood-framed walls. Deconstruction of the steel stud test wall utilizing exterior insulation showed that the additional drainage plane provided by the insulation resulted in significantly less moisture present at the fastener penetration locations used to secure the cladding supports. Conversely, the steel stud assembly utilizing a drained and vented water management strategy, but no exterior insulation, showed moisture present at almost all of the fastener penetration locations, as seen in the following figures.



Steel stud test walls which incorporated exterior insulation typically showed no signs of moisture present at fastener penetrations (left). By comparison, steel stud test walls which did not include exterior insulation showed moisture present at almost all of the fastener penetrations.

Performance of Strapping Attachment on Walls with Long Screws Through ROCKWOOL Insulation

The following tables summarize observed leaks and severity of the leaks observed from the interior side during long exposure testing (1 hour of continuous water and pressure) at 300 Pa, with no cladding attached (greatest exposure to water).

■ = Moisture Present ■ = Slow Drip ■ = Steady Drip

Back-Up Wall	Insulation	Location of Penetrations	No Cladding		
			Long Screw	Z-Girt	Z-Clips
Wood	No Exterior Insulation	Stud	No Leaks	No Leaks	No Leaks
		Miss	No Leaks	No Leaks	No Leaks
		Hole	■	■	■
	3" Stone Wool	Stud	No Leaks	No Leaks	No Leaks
		Miss	No Leaks	No Leaks	No Leaks
		Hole	■	■	■
	3" XPS	Stud	No Leaks	No Leaks	No Leaks
		Miss	No Leaks	No Leaks	No Leaks
		Hole	■	■	■
Steel	No Exterior Insulation	Stud	No Leaks	No Leaks	No Leaks
		Miss	■	■	■
		Hole	■	■	■
	3" Stone Wool	Stud	No Leaks	No Leaks	No Leaks
		Miss	No Leaks	No Leaks	No Leaks
		Hole	■	■	■
	3" XPS	Stud	No Leaks	No Leaks	No Leaks
		Miss	No Leaks	No Leaks	No Leaks
		Hole	■	■	■

The following tables indicate the presence of moisture at screw penetrations from the exterior side during the deconstruction of the test walls. Moisture observed at penetrations does not indicate a leak to the interior side of the walls. Note that the Z-clips required two screws each (6 screws total), where the long screws and Z-girts required 5 screws.

■ = ≤50% penetrations with moisture present ■ = >50% penetrations with moisture present

Back-Up Wall	Insulation	Location of Penetrations (Number of Penetrations)	No Cladding		
			Long Screw	Z-Girt	Z-Clips
Wood	No Exterior Insulation	Stud (5-6)	Dry	Dry	Dry
		Miss (6)	Dry	■	■
		Hole (6)	■	■	■
	3" Stone Wool	Stud (5-6)	Dry	Dry	Dry
		Miss (6)	Dry	Dry	Dry
		Hole (6)	■	■	■
	3" XPS	Stud (5-6)	Dry	Dry	Dry
		Miss (6)	Dry	Dry	Dry
		Hole (6)	■	■	■

Back-Up Wall	Insulation	Location of Penetrations (Number of Penetrations)	No Cladding		
			Long Screw	Z-Girt	Z-Clips
Steel	No Exterior Insulation	Stud (5-6)	■	■	■
		Miss (6)	■	■	■
		Hole (6)	■	■	■
	3" Stone Wool	Stud (5-6)	Dry	Dry	Dry
		Miss (6)	Dry	Dry	Dry
		Hole (6)	■	■	■
3" XPS*	Stud (5-6)	Dry	■	Dry	
	Miss (6)	Dry	■	Dry	
	Hole (6)	■	■	■	

*slight gap between the insulation boards and continuous z-girt from installation resulted in relatively direct water ingress path

Note that "Stud" refers to locations where a fastener is installed into the stud, "Miss" refers to where the fastener missed the stud, and "Hole" refers to where the fastener missed the stud and was removed, leaving a hole.

Additional observations made during deconstruction of the test wall assemblies showed that while a minimal amount of water was observed on the sheathing membrane with all 3 cladding support approaches, the long screws securing the strapping and a vertically positioned hat-track resulted in the least water present on the sheathing membrane behind the insulation. This is likely due to the tighter installation of the insulation achieved by the increased pressure by the strapping and hat track.

In summary, key findings of the air and water testing are as follows:

- ▶ Fastener penetrations through the sheathing membrane did not significantly affect the airtightness of the wall assembly.
- ▶ Qualitative airtightness testing using theatrical smoke indicated that no visually noticeable air leakage path was created by fasteners that penetrated the sheathing to secure the cladding attachment systems to the stud framing.
- ▶ Water penetration testing demonstrated benefits of continuous exterior insulation with respect to water control. The additional drainage plane provided by the exterior insulation reduced frequency and severity of water ingress at intentional defects as compared to similar assemblies with no exterior insulation.
- ▶ Less water was observed on the sheathing membrane in the test area where insulation was installed using long screws with strapping or hat-tracks. This observation is likely due to the additional pressure on the insulation board for a tighter install against the sheathing membrane.

Structural Performance Testing

Overview

RDH completed a comprehensive laboratory-based research study, presented in full in the [Structural Testing of Screws through Thick Exterior Insulation](#) report and the [Structural Testing of Screws through Exterior Stone Wool Insulation for Steel-Frame Walls](#) report (see References on page 8).

This research builds on existing work, with specific additional focus on evaluating the impact of the following key items relating to deflection of the strapping when vertical cladding loads are applied:

- ▶ Backup wall type (wood-frame versus steel stud)
- ▶ Exterior rigid insulation density and type (ROCKWOOL Comfortboard® 80, ROCKWOOL Comfortboard® 110, and XPS)
- ▶ Insulation thickness including 6" and beyond
- ▶ Screw arrangement
- ▶ Screw head type
- ▶ Screw substrate (stud versus sheathing alone)
- ▶ Preloading of strapping
- ▶ Pre-compression of exterior insulation

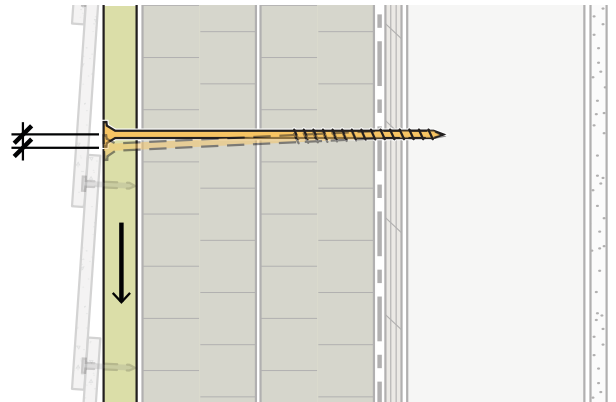


Overview of the strapping load/deflection test apparatus

Methodology

A mechanical loading apparatus was used to apply a simulated cladding dead load to a single strap between two adjacent straps at 16" on center on either side.

The test walls were situated horizontally to isolate the cladding load applied (i.e. ignore the self-weight of the insulation) and measure its affect alone on potential deflection. Load and displacement were measured as the load was increased to determine their relationship (i.e. vertical deflection). Loading was increased beyond standard cladding weights to assess the failure mechanism for this strapping attachment technique.



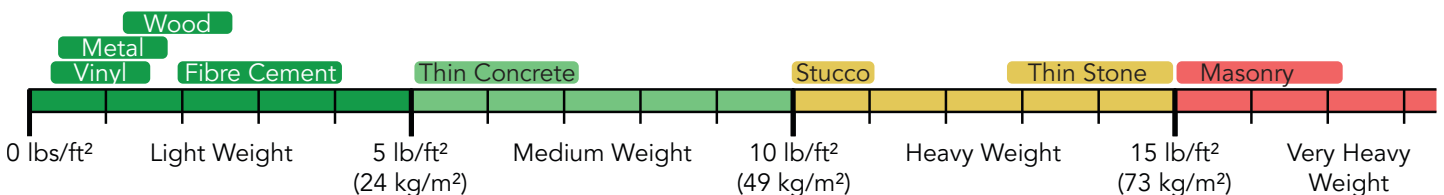
Wall cross section with schematic view of the strapping loading and deflection measurement

The wood-frame test wall assembly was tested with 6 to 12 inches of exterior insulation, and the steel stud wall was tested with 3 to 9 inches of exterior insulation. Both rounds of testing were completed using ROCKWOOL rigid stone wool insulation (Comfortboard® 80 and Comfortboard® 110) and XPS rigid foam for comparison purposes.

In each test arrangement the center strap was loaded as follows:

1. Loaded up to approximately 100 lb (45 kg), which equates to approximately 33 lbs (15kg) per screw fastener. This initial load was held for 2 hours.
2. Loaded up to approximately 900 lb (409 kg) or 300 lb (136 kg) per screw, held for 120 seconds.

The first loading was representative of a very heavy weight cladding weighing up to 25 lb/ft² (122 kg/m²). For reference, typical cladding weights and corresponding cladding examples are shown below.



Wood Frame Test Wall

- ▶ 2x6 studs spaced at 16" (406 mm) complete with top and bottom plates.
- ▶ Typically sheathed with 7/16" (11 mm) oriented strand board or 1/2" (13mm) plywood.
- ▶ Spun bonded polyolefin sheathing membrane mechanically fastened with staples.
- ▶ Insulation secured with screws through 3/4" thick x 3" wide (19 mm x 76 mm) pressure treated SPF plywood strapping, aligned with studs.
- ▶ HECO-TOPIX screws by HECO-Schrauben GmbH & Co. KG, 0.20~0.21" (5.05~5.45 mm) diameter, both counter sunk and pan head screws, spaced at 12" (305 mm) along each strap and fastened at least 1" excluding the tapered tip into the stud (where applicable).

Steel Stud Test Wall

- ▶ 3-5/8"x1-1/4" 18-gauge steel studs
- ▶ 1/2" (13 mm) glass mat gypsum sheathing
- ▶ Polyethylene-faced self-adhered sheathing membrane
- ▶ 20-gauge 7/8"x1-1/4" steel hat track strapping
- ▶ The centre strapping, centre screws and insulation layers were replaced after each test (after both loadings).
- ▶ TRUFAST #14 HD Roofing Fasteners by Altenloh, Brinck & Co. U.S., Inc., 0.180" (~4.6 mm) diameter, self tapping pan head screws.

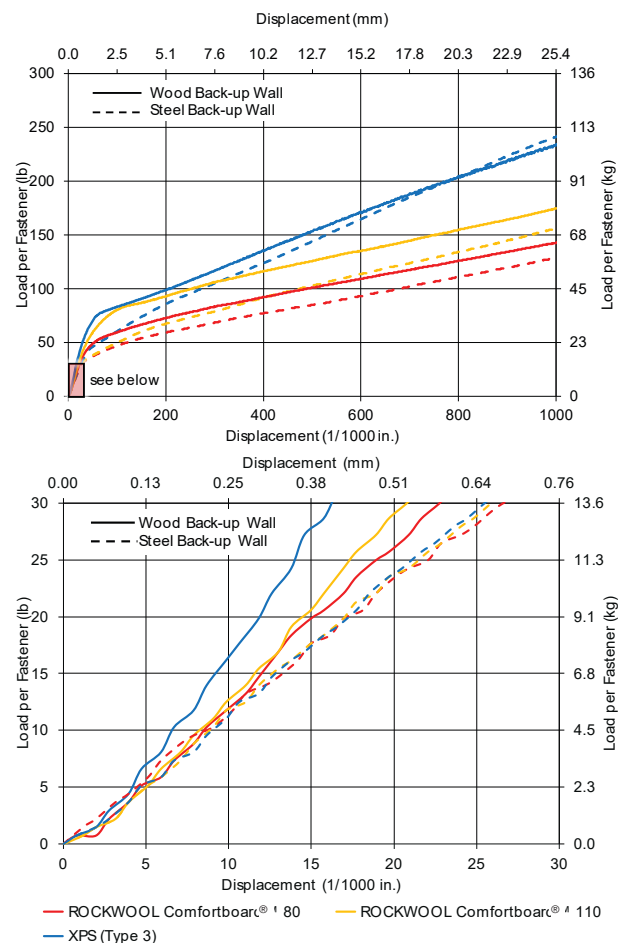


Pan head and counter sunk screws used to attach strapping on the wood-frame backup walls

Findings

Testing of the various insulation thicknesses, arrangements, and compressive strengths found very little difference in stiffness for lower loads. As shown in the graphs below for 6" of exterior insulation, the displacement (i.e. strapping "vertical" deflection) due to the load is less than 30 mils (0.75 mm) for typical cladding load ranges, even beyond very heavy weight cladding (>15 lb/ft² or 73 kg/m²). At significantly higher loads, the difference in insulation compressive strength is more apparent. The "yielding point" for the strapping and screws on the steel stud test wall is lower and less pronounced than that of the wood-frame wall. This is likely due to the difference in load resistance mechanisms for the fasteners installed in to wood-framing versus steel-framing. For wood-framing the screw-to-wood connection provides some moment resistance, whereas the screw-to-steel connections acts more similarly to a pin connection.

The results shown in the graphs below are also representative of the typical trends found from the testing with thicker insulation.



Load-displacement plots comparing ROCKWOOL Comfortboard® 80, ROCKWOOL Comfortboard® 110, and XPS at 6" thickness with higher load range (top) and typical cladding weight load range (bottom)

Furthermore, structural screw testing shows that supporting cladding dead loads on strapping fastened through ROCKWOOL exterior stone wool insulation with long screws is an appropriate structural solution to support the dead loads of many common claddings. Key supplementary findings of this testing work include:

- ▶ Insulation compressive strength has negligible effect on the overall stiffness of the test wall assembly at typical cladding weights.
- ▶ Of the variables assessed, insulation thickness was the most impactful on the load-deflection response of the system.
- ▶ Wood-frame walls generally result in a stiffer strapping/fastener system than steel stud walls for the same insulation type and thickness.
- ▶ For wood strapping, screw head type (countersunk and pan-head) has negligible effect on the overall stiffness when each screw was loaded up to 25lb (9.1kg).

In addition to the testing summarized in this technical bulletin, results from the full test program show the following additional results:

- ▶ Pre-compressing the insulation had no significant impact on the load-deflection response.
- ▶ Angles at which screws are installed and the screw arrangement (truss systems) in wood-frame walls increases the overall stiffness of the assembly when each screw was loaded up to 25 lb (9.1 kg).
- ▶ Fastening only into 3/4" thick plywood sheathing provides similar load-deflection performance to assemblies where screws fasten into the wood framing members.
- ▶ Fastening the strapping to horizontal metal straps attached within the steel-frame wall behind the sheathing provides similar load-deflection performance as fastening to the steel studs, when fasteners are loaded up to 25 lb (9.1 kg).

Note that resistance to other loads such as wind and seismic was not part of this testing work and would need to be evaluated separately.

Refer to the Design Tables at the end of the bulletin for values provided pertaining to wall assemblies based on completed testing by RDH.

Conclusion & Summary

Exterior insulation is continuing to become increasingly more common across North America to achieve higher energy performance targets. Generally, insulation installed continuously on the outside of the primary structure is more thermally efficient compared to insulation placed between studs or inboard of the structural system. Furthermore, exterior insulation provides greater thermal performance if installed with a thermally efficient cladding attachment approach, such as long screws with strapping or hat tracks.

The studies outlined in this bulletin have shown that long screws are also an appropriate structural solution to support deadloads imposed by typical claddings, and when installed with exterior insulation, presents additional enclosure benefits related to water control.

This work has assessed only the ability to support cladding dead loads using long screws with ROCKWOOL and XPS exterior insulation, as well as air and water penetration resistance using the selected cladding support approaches. The methods of installation, types of insulation, and resistance to other loads (such as wind load) was not part of this testing work and would need to be evaluated separately.

Design Tables

Based on the testing work completed and engineering calculations, the following design tables are provided with respect to supporting the dead load of cladding systems installed using long screws through ROCKWOOL exterior stone wool insulation. The design tables assume ROCKWOOL Comfortboard® 80 exterior stone wool insulation with minimum compression strength of 439 psf (21 kPa) at 10% per ASTM C165 testing. Embedment refers to the embedment of the fastener into the stud, excluding the tapered tip of the fastener and the sheathing thickness. Values provided pertain to wall assemblies on low- to mid-rise buildings up to six storeys, built using typical wood and steel stud framing techniques. The higher wind loads expected on larger buildings requires specific structural design.

Exterior Insulation Thickness	Maximum Vertical Screw Spacing	Minimum Screw Diameter	Minimum Screw Embedment	Minimum Strapping Size
16" o.c. Wood-Frame Wall Assemblies				

Light Weight Cladding < 5 lbs/ft²

up to 3"	24"	#10	1-1/2"	3/4" x 2-1/2"
>3" to 6"	16"			
>6" to 9"	16"	#12	1-1/2"	3/4" x 2-1/2"
>9" to 12"	8"			

Medium Weight Cladding 5 lbs/ft² to < 10 lbs/ft²

up to 3"	16"	#12	1-1/2"	3/4" x 3"
>3" to 6"	12"			
>6" to 9"	12"	#14	1-1/2"	3/4" x 3"
>9" to 12"	8"			

Heavy Weight Cladding 10 lbs/ft² to < 15 lbs/ft²

up to 3"	16"	#14	1-1/2"	3/4" x 3-1/2"
>3" to 6"	12"			
>6" to 9"	12"	5/16"	1-1/2"	3/4" x 3-1/2"
>9" to 12"	10"			

24" o.c. Wood-Frame Wall Assemblies

Light Weight Cladding < 5 lbs/ft²

up to 3"	16"	#10	1-1/2"	3/4" x 2-1/2"
>3" to 6"	12"			
>6" to 9"	12"	#12	1-1/2"	3/4" x 2-1/2"
>9" to 12"	6"			

Medium Weight Cladding 5 lbs/ft² to < 10 lbs/ft²

up to 3"	12"	#12	1-1/2"	3/4" x 3"
>3" to 6"	8"			
>6" to 9"	8"	#14	1-1/2"	3/4" x 3"
>9" to 12"	6"			

Heavy Weight Cladding 10 lbs/ft² to < 15 lbs/ft²

up to 3"	16"	#14	1-1/2"	3/4" x 3-1/2"
>3" to 6"	12"			
>6" to 9"	12"	5/16"	1-1/2"	3/4" x 3-1/2"
>9" to 12"	6"			

16" o.c. Steel Stud Wall Assemblies

Light Weight Cladding < 5 lbs/ft²

up to 3"	16"	#12	through stud flange	7/8" x 1-1/4" 20ga hat track
>3" to 6"	12"			
>6" to 9"	10"	#12	through stud flange	7/8" x 1-1/4" 20ga hat track

Medium Weight Cladding 5 lbs/ft² to < 10 lbs/ft²

up to 3"	12"	#12	through stud flange	7/8" x 1-1/4" 20ga hat track
>3" to 6"	10"			
>6" to 9"	8"	#12	through stud flange	7/8" x 1-1/4" 20ga hat track

Heavy Weight Cladding 10 lbs/ft² to < 15 lbs/ft²

up to 3"	12"	#14	through stud flange	7/8" x 1-1/4" 20ga hat track
>3" to 6"	8"			
>6" to 9"	6"	#14	through stud flange	7/8" x 1-1/4" 20ga hat track

Disclaimer

Information provided in this technical bulletin is for general guidance. Design and installation of appropriate cladding support and building enclosure assemblies, both for structural capacity and air/water durability, remains the responsibility of the project team.

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