August 16, 2011

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Via email: mark.bromiley@roxul.com

**Re: Roxul – ComfortBoard Insulating Sheathing (IS) Deflection Testing**

## *Background*

As society demands more energy efficient buildings, codes and builders are responding by increasing the R-value of the building enclosure, in particular the above-grade wall. Given than the cavity of the standard 2x6 wood frame wall used in low-rise housing is already filled with insulation, the clear path forward to higher R-values is to add layers of exterior insulation. Although other solutions are possible, exterior insulation layers have the benefits that:

1. At thicknesses of up to 1.5", exterior insulation has long been used by the industry, and hence there is experience with its installation and detailing,
2. Thermal bridging through framing members, floor joists, lintels, etc. is very significantly reduced, increasing the wall R-value significantly,
3. The risk of cold-weather condensation within the moisture-vulnerable wood framing is significantly reduced, and potentially eliminated,
4. A range of target R-values can be easily reached as similar details can be used for the design of walls that have 2, 3, 4 or even 6" of insulation,
5. The marginal cost of increasing framing thickness and/or building double-walls usually outweighs the marginal cost of adding insulating sheathing layers.

Highly-permeable insulation like Roxul has the added benefit that it allows very fast outward drying during cold weather: this dries the wood-frame cavity very quickly, even if the framing is wet from construction or becomes wet because of incidental water leaks.

A major impediment to the wide-spread adoption of exterior sheathing behind direct applied claddings such as vinyl, wood, fibre cement, stucco and adhered veneer, is the lack of information about the structural performance of claddings installed over insulating sheathing. Foam plastic insulations, which have much higher compressive strengths (often 15 to 25 psi @10% deformation) than most Roxul products (often 1 to 5 psi) are seen as better products for this application. The concern is that the insulation is not stiff or strong enough to suspend claddings and deformations may occur causing cracking, and other issues.

Very little testing has been conducted to show the strength and stiffness of insulation supporting cladding and few testing results of Roxul insulation are available.

The most common method of attaching cladding over thick insulation is to use wood furring (strapping) attached with screws through the insulation to the framing as shown in Figure 1.

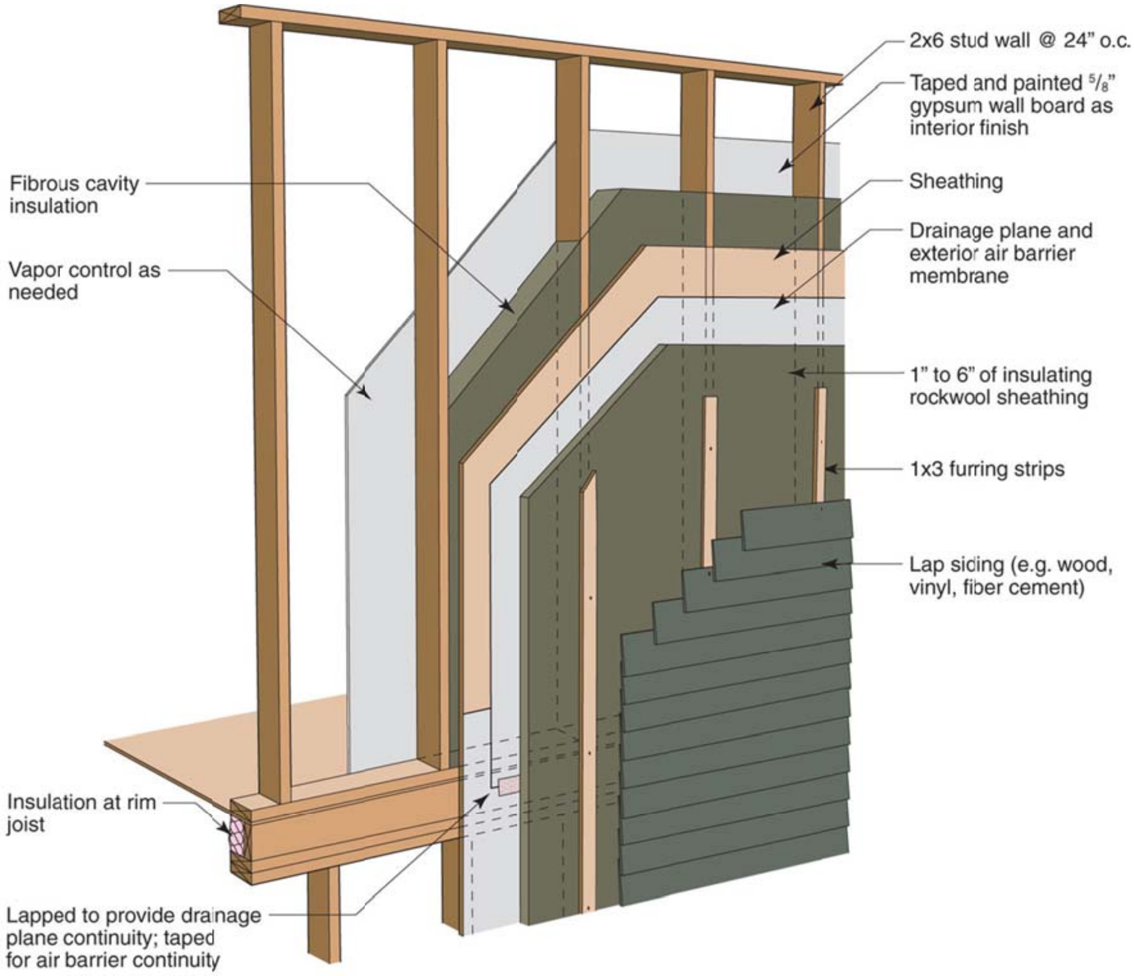



**Figure 1 : Typical application of semi-rigid Roxul insulation over wood framing**

## *Objective*

The objective of this study is to quantify the relationship between cladding gravity loads and deflection under cladding weights of up to 30 pounds per square foot. These results are intended to be used to provide guidance to designers, builders, and code officials involved in projects using Roxul brand semi-rigid rockwool sheathing.

This series of tests differs from the first series of tests (Final Report dated March 3, 2011) in that only ComfortBoard IS is used as the exterior insulation. Four specific questions will be addressed by this testing.

1. How repeatable are the results between the first and second series?
2. How much does it matter if the strapping fasteners miss the framing with respect to short term displacement of the strapping?
3. How do nails perform as strapping attachment compared to screws?

4. What is the improvement in performance when the screws are improved to a #10 diameter from a #8 diameter?

## Scope

This report summarizes the results of load deflection testing of strapping over two thickness of ComfortBoard IS. This testing was conducted following a previous round of testing on several different types of insulation (Report dated March 3, 2011). These walls were tested on 24” oc framing, with 1x3 nominal SPF wood strapping attachment screws at vertical spacings of 16” oc (Table 1). Other variables such as 16” oc framing, and screw spacing attachment were outside the scope of the testing program. This study was designed to simulate walls providing the least support practically likely (thin screws wide spacing of studs and fasteners) and hence the highest likely deflections. If improved construction standards are used, such as stronger screws and/or more frequent screw spacing, the amount of deflection would decrease. This is meant to be a type of worst case, yet realistic, scenario.

**Table 1: Roxul insulation types to be tested**

| Test Number | Insulation | Framing | Sheathing | Fastener | Fastener Embedment | Fastener Spacing |
|---|---|---|---|---|---|---|
| 1 | 1.25" ComfortBoard IS | 24" oc | OSB | #8, 3" wood screws | all embedded in framing | 16" |
| 2 | 1.25" ComfortBoard IS | 24" oc | OSB | #8, 3" wood screws | none embedded in framing | 16" |
| 3 | 1.25" ComfortBoard IS | 24" oc | OSB | #8, 3" wood screws | top and bottom plate only | 16" |
| 4 | 1.25" ComfortBoard IS | 24" oc | OSB | #10, 3" wood screws | all embedded in framing | 16" |
| 5 | 1.25" ComfortBoard IS | 24" oc | OSB | 16d, 3.5" common smooth nail | all embedded in framing | 16" |
| 6 | 3" ComfortBoard IS | 24" oc | OSB | #10, 5" wood screws | all embedded in framing | 16" |

## Testing Apparatus

To conduct the testing, a 2x4 wall frame with 24” stud spacing was securely fastened to a concrete block wall in the laboratory. OSB sheathing and a house wrap were installed over the sheathing. The Roxul insulation were installed over the house wrap, and held in place by screws driven through nominal 1x3 strapping (actual dimension ¾”x 2.5”) connected directly to the wood framing (Figure 2). The strapping was attached with screws spaced vertically at 16” oc (including top and bottom plate). Given the 24” spacing of the framing, this is 2.29 square feet per fastener (or about 4.7 connectors per square meter).

Figure 3 presents photographs of the screws used for strapping attachment for both 1.25” thick insulation and 3” thick insulation during both the first and second series of tests. To attach strapping over 1.25” thick insulation, 3” #8 zinc-coated construction screws were used. The test of 3” thick insulation used #10 x 5” wood screws.

**Figure 2 : Roxul insulation attached to wall frame ready for test**

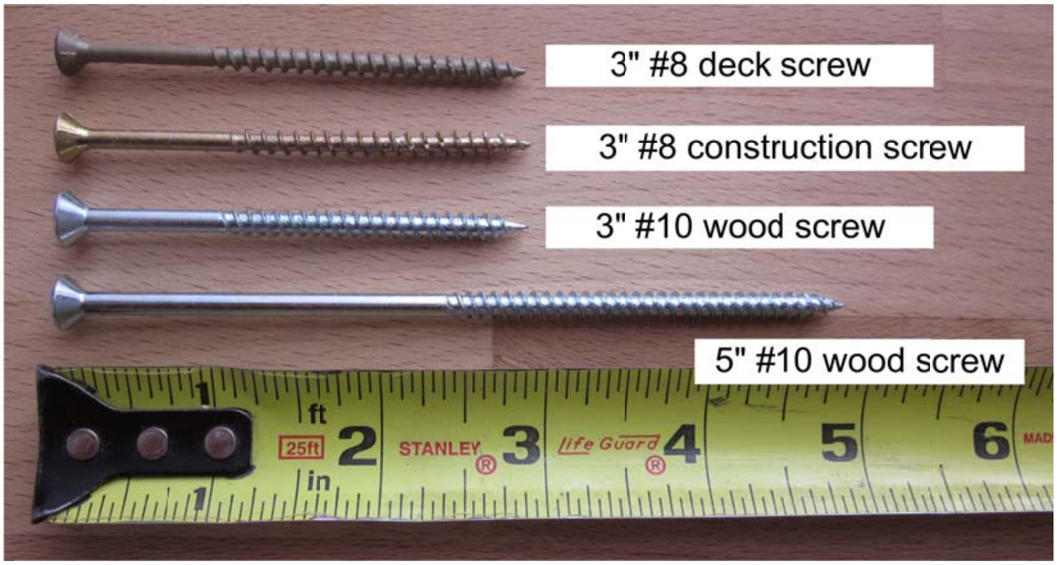



**Figure 3 : Strapping attachment screws**

A 2 tonne-capacity hydraulic ram was used to apply force to a metal angle in contact with the bottom edge of both strapping pieces (Figure 4). To measure the applied force a 1000 lbf (4500 N) strain gauge load cell (with ±0.4 lbf rated accuracy) was placed between the angle and the ram.

Deflection gauges (with a resolution of 1/1000" or 0.025 mm) were used to measure the movement of the wall sheathing and the strapping on both the left and right side. Metal clips were attached to the strapping to allow deflection gauges to measure the strapping movement.

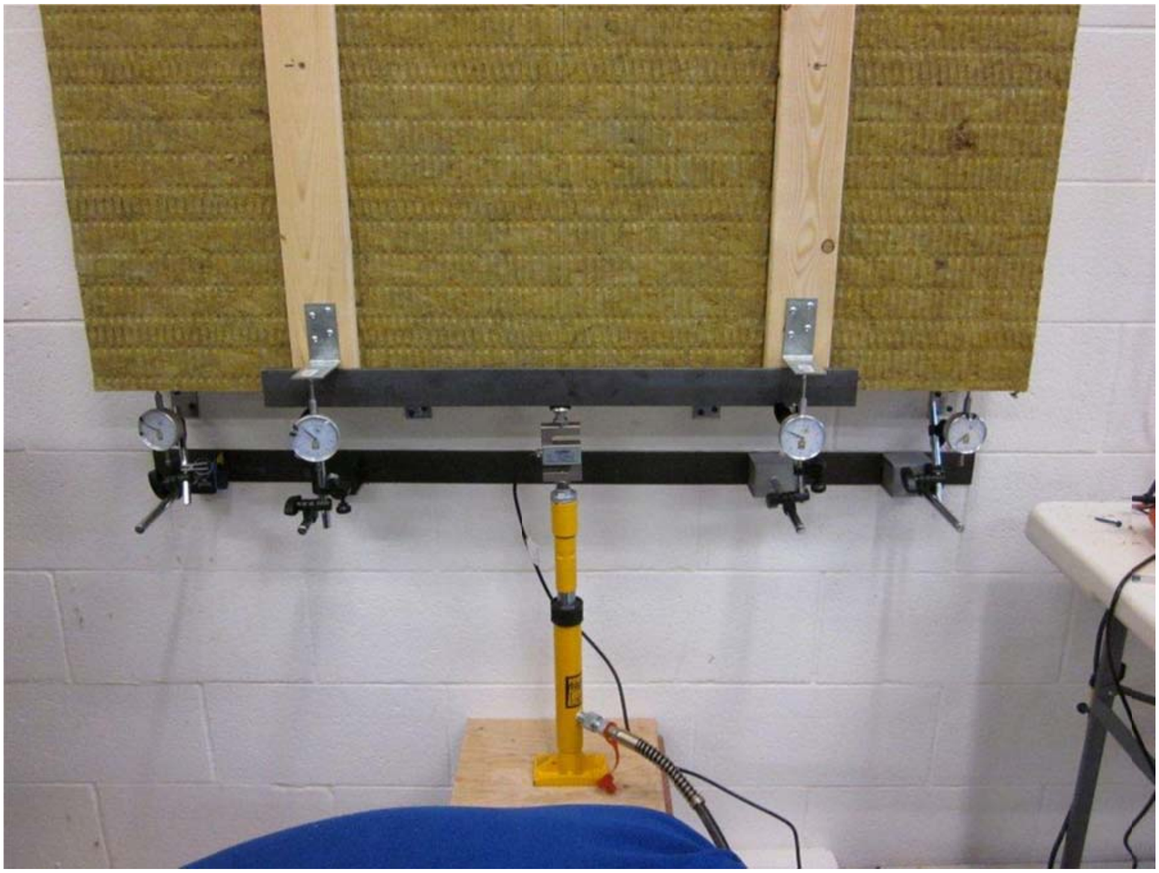


**Figure 4: Hydraulic Ram with load cell and deflection gauges measuring strapping movement**

Loads were applied in increments of 100 lbs between 100 lbs and 1,000 lbs. The four deflection readings were recorded at each increment. Each load increment was applied over about 30 to 60 seconds and the readings taken within 30 seconds. All of the tests were conducted three times on the same test specimen. The wall was loaded to 1000 lbs, unloaded, and reloaded two more times.

## *Results and Analysis*

The average deflection was calculated by determining the average of the deflection of the right and left strapping pieces and subtracting any movement measured in the wall frame. In general, the framing moved very little (about 10% of the total deflection).

For all of the specimens, the first time the wall was loaded the deflection was significantly larger and then the subsequent two tests. The second pair of tests showed good repeatability. It is assumed that this behavior is due to the wall assembly "seating" itself or "settling in". The amount of seating could be increased by attaching the initial torque during installation of the screws: controlling the amount of screw torque was a challenge as it was not always easy to achieve perfectly plumb strapping. For these tests the frame movement was limited and measured separately.

The results of load and deflection can be compared to spatial mass density of typical claddings shown in Table 2. These weights are meant to be representative of all similar claddings although some cladding types might be outside of the range listed. The testing was conducted to exceed the weight of the heaviest cladding in the table, adhered stone veneer, although there is a large range of weight of adhered veneer cladding depending on the specific type selected. These ranges of cladding weights are shown in the analysis graph as shaded areas in Figure 5.

**Table 2 : Approximate cladding weights**

| Cladding Type | Typical mass density range (psf) | Equivalent weight for 4'x8' test panel (lbs) |
|---|---|---|
| Vinyl siding | 0.6-1.0 | 20-32 |
| Wood siding | 1.0-1.5 | 32-48 |
| Fiber cement siding | 3-5 | 96-160 |
| Cement stucco | 10-12 | 320-384 |
| Adhered stone veneer | 17-25 | 544-800 |

Figure 5 plots the load-deflection curves for 3" ComfortBoard IS. As this graph is representative of all of the insulations tested, the remaining load-deflection graphs are attached in the appendix, and the results are summarized in Table 3. As can be seen, the load-deflection curve has a degree of curvature to it, but it largely linear for the first 100-200 pounds (eg. the load imposed by lap siding).

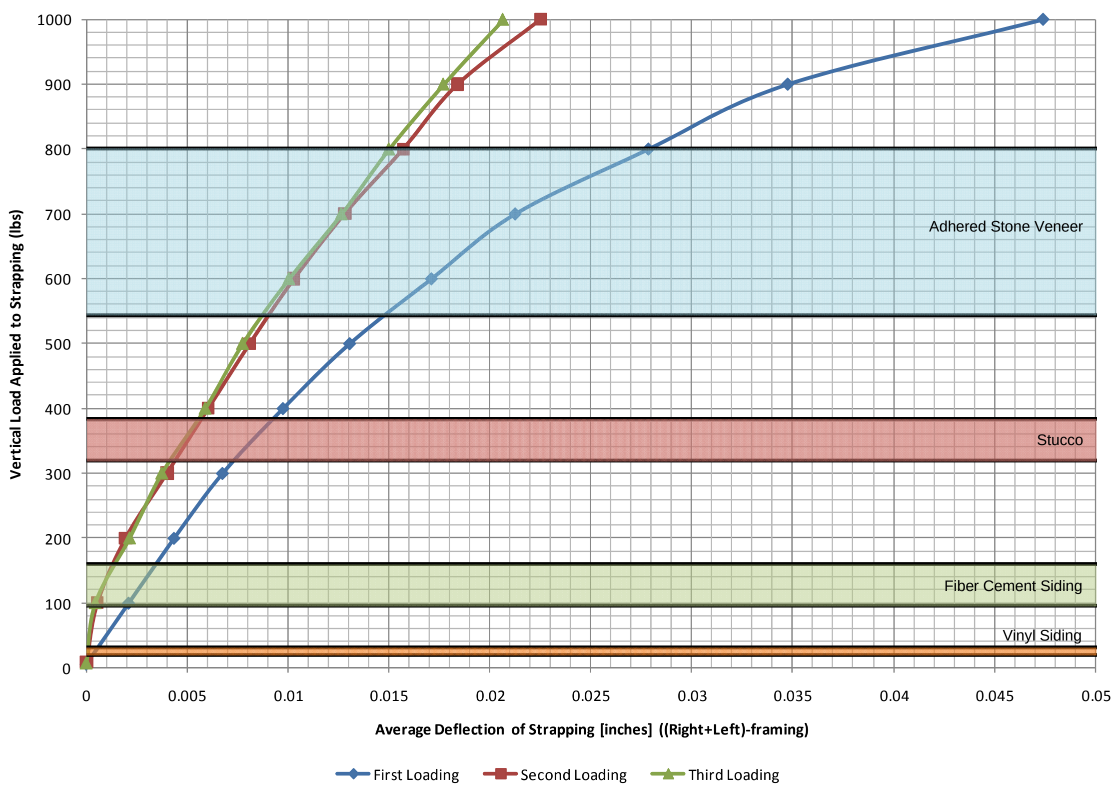



**Figure 5: Deflection Testing of 3" ComfortBoard IS**

Table 3 shows the deflection results for all three 1000lb loadings on each test system.

**Table 3 : Summary of Deflection Results at 1000 lbs**

| Test Series # | Test Description | 1st Loading [inches] | 2nd Loading [inches] | 3rd Loading [inches] |
|---|---|---|---|---|
| 1 | 1¼" ComfortBoard IS, #8 3" screws, all embedded in framing | .034 | .018 | .019 |
| 2 | 1¼" ComfortBoard IS, #8 3" screws, none embedded in framing | .050 | .026 | .026 |
| 3 | 1¼" ComfortBoard IS, #8 3" screws, embedded in top and bot plate | .090 | .036 | .032 |
| 4 | 1¼" ComfortBoard IS, #10 3" screws, all embedded in framing | .030 | .016 | .016 |
| 5 | 1¼" ComfortBoard IS, 16d 3.5" nails, all embedded in framing | .043 | .026 | .027 |
| 6 | 3" ComfortBoard IS, #10 5" screws, all embedded in framing | .047 | .023 | .023 |

Table 4 summarizes the measured data into what is a more useful format. For each of the product types the initial deflection measured is used to predict the deflection in service for three typical cladding types. Given that measurements of less than 0.010" are difficult to measure repeatedly or reliably, and that such a deflection is negligible in service, any deflections of less than 0.01" (0.25 mm) have been simply entered as "<0.01" in the table. None of the walls tested in this study exceeded 0.01" of deflection at 12 psf (384 lbs total), approximately equal to the typical weight of ¾" stucco cladding.

**Table 4: Estimated Deflection (inches) in Service for Typical Cladding Loads**

| Test Number | Vinyl Siding (1 psf) | Fiber Cement Siding (4 psf) | Stucco 3/4" (12 psf) |
|---|---|---|---|
| 1 | <0.01 | <0.01 | <0.01 |
| 2 | <0.01 | <0.01 | <0.01 |
| 3 | <0.01 | <0.01 | 0.01 |
| 4 | <0.01 | <0.01 | <0.01 |
| 5 | <0.01 | <0.01 | <0.01 |
| 6 | <0.01 | <0.01 | <0.01 |

Note: Assumes studs at 24" o.c., and fasteners at maximum 16" vertical spacing through nominal 1x3 furring strips. Deflection is based on the initial loading, and assumes that no creep occurs over long-term. It is important to note that wind suction pressure may control the design of the fastening in high wind areas, not the vertical deflection assessed in these tests

## Repeatability

Two of the test series (1 and 6) were included to test the repeatability of the load deflection testing compared to the previous testing program. Figure 6 shows the comparison of the initial loading, between similar tests of 3" ComfortBoard IS from previous and current testing. The curves are nearly identical to approximately 600 lbs of total load. At 800 lbs, the difference is an insignificant 0.006", and at the final load of 1000lbs, the difference is 0.05". Even at 1000lbs, the difference in testing results is small, and could be caused by the uncontrollable slight variability in construction. This shows that at the lower more reasonable weights, the measured performance was repeatable, and even at higher loads (800-900 lbs) the differences in performance are not significant.

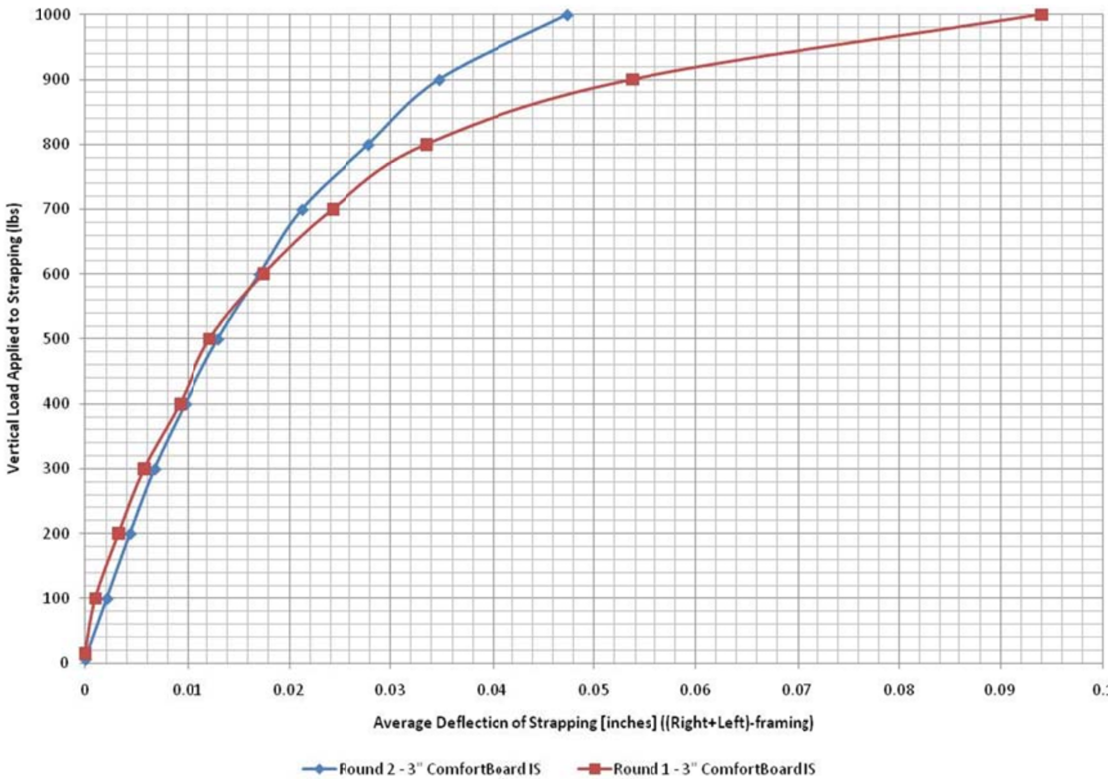



**Figure 6 : Comparison of 3" ComfortBoard IS testing from Series 1 and Series 2 testing**

Figure 7 shows the comparison of the initial loading for two tests of 1¼” ComfortBoard IS. There is a little more variability for the lower weights of the 1¼” testing, than the 3” testing. It is hypothesized that this difference may be due to the fasteners that were used for strapping attachment. In the previous testing, 3” #8 deck screws (Figure 3) were used to attach the strapping (Figure 7, red line). For the current testing, 3” #8 construction screws (Figure 3) were used (Figure 7, blue line). This was the only difference in construction technique between the two tests. Even so, both of the tests experienced deflections that differed by 0.01” or less at 12psf (equivalent to ¾” stucco), so differences in results must be kept in perspective.

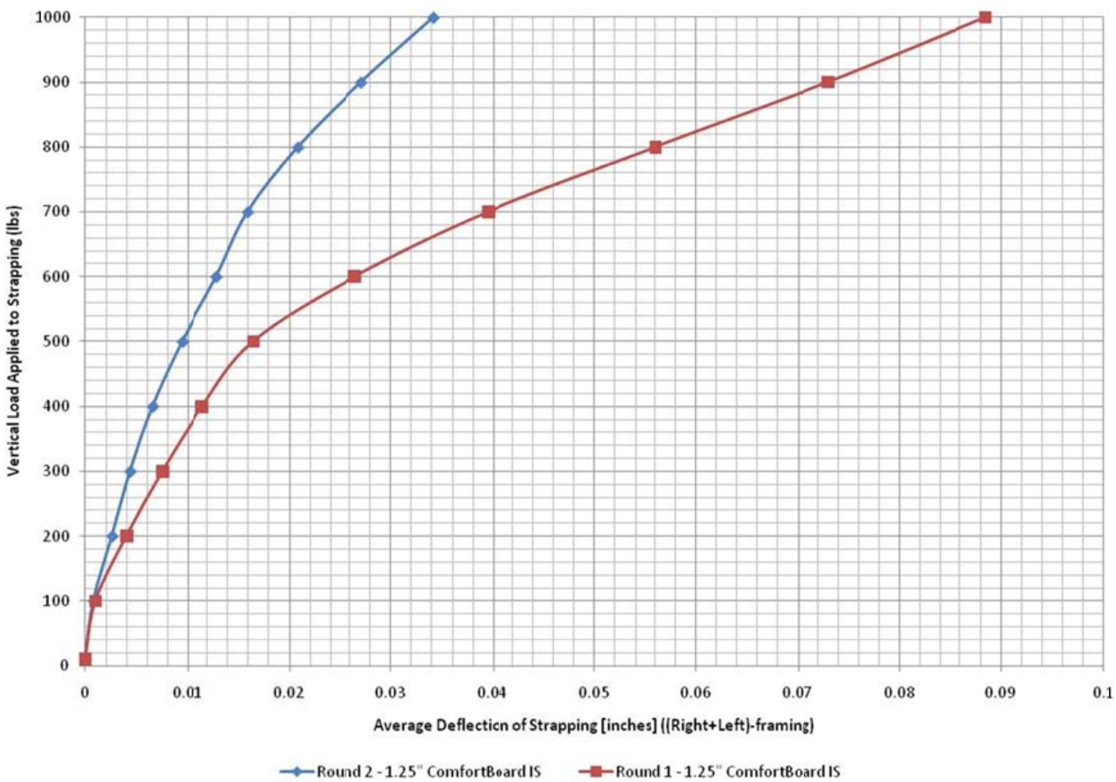



**Figure 7 : Comparison of of 1.25" ComfortBoard IS testing from Series 1 and Series 2 testing**

## Fastener Embedment

A comparison was conducted that examined the performance differences in initial loading based on the embedment of the screws that attach the strapping to the enclosure. During construction, it is unlikely that all of the screws used to attach the strapping are embedded in the wall framing. In reality, it is likely that most will likely embed in the framing, and some will embed only in the OSB sheathing. For Test 1, all of the screws were embedded in the wall framing. For Test 2, all of the screws deliberately missed the framing and were only attached to the OSB. For Test 3, the strapping was attached to both the bottom plate and top plate, but the rest of the screws were only embedded in the OSB sheathing.

Figure 8 shows the intial loading curves of test series 1, 2, and 3. Test 1, with fully embedded fasteners had the least amount of deflection of all three tests, but the difference in deflection between the three tests, especially at a lower load representative of typical cladding, is not large. At 600 lbs of total load, the difference in deflection between the best and worst case scenario is only 0.009”. All three tests have 0.01” deflection or less at 12 psf which corresponds to the weight of typical ¾” stucco cladding. There was no significant difference in deflection until the loads exceeded the weight of adhered stone veneer (>800 total lbs).

The test with the greatest amount of deflection is Test 3, with embedment in the top plate and bottom plate, but only OSB between the top and bottom. Intuitively, the wall that was hypothesized to have the greatest deflection was Test 2 with screw embedment in the OSB only. It is unclear why Test 3 had the greatest deflection.

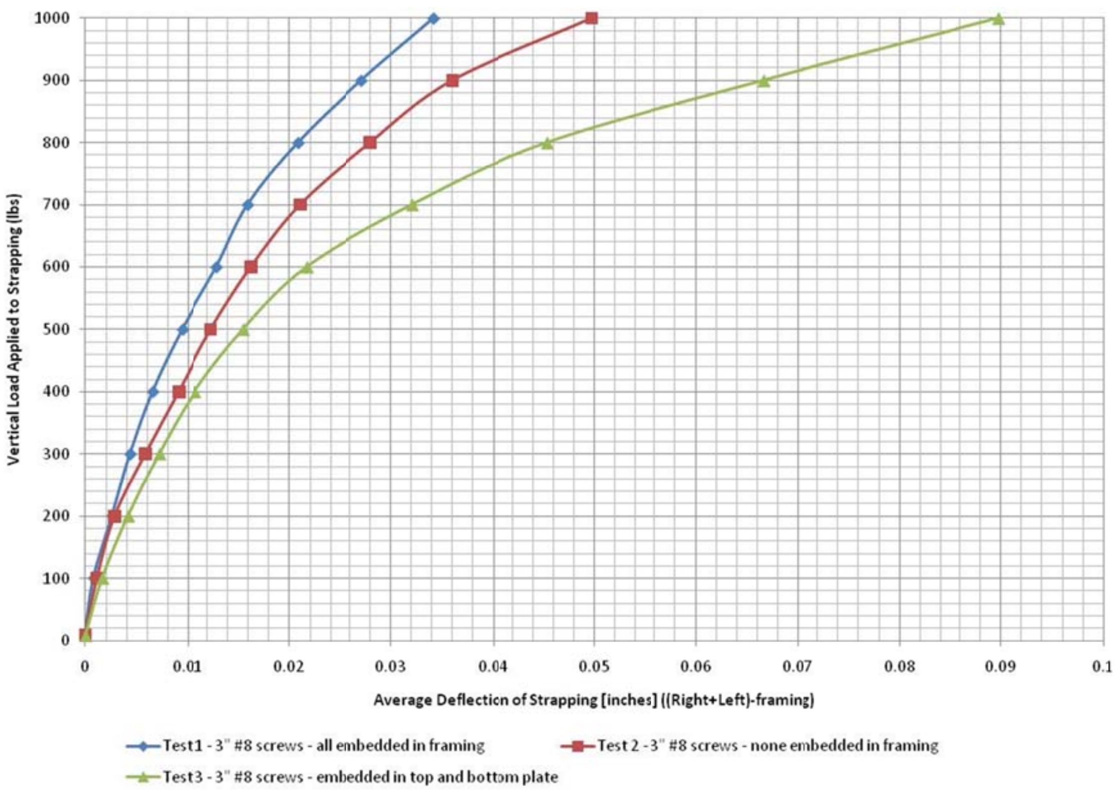



**Figure 8 : Performance comparison of fastener embedment**

## Attachment with Nails

A comparison of initial loading performance using 3” #8 screws (Test 1) and 16d 3.5” smooth nails (Test 5) was conducted to quantify any performance differences between the two attachment methods. Figure 9 shows that there was slightly more deflection with the nails, during the entire test, but that the difference was small. Both of the tests experience less than 0.01” of deflection at 12 psf which correlates to the approximate weight of ¾” stucco.

Practically speaking, there was more difficulty installing the nails near the ends of the strapping without the strapping splitting, and even though smooth nails were tested, the wind loading requirements should be checked, and ring shanked nails may be preferred because of their significantly higher pullout loads.

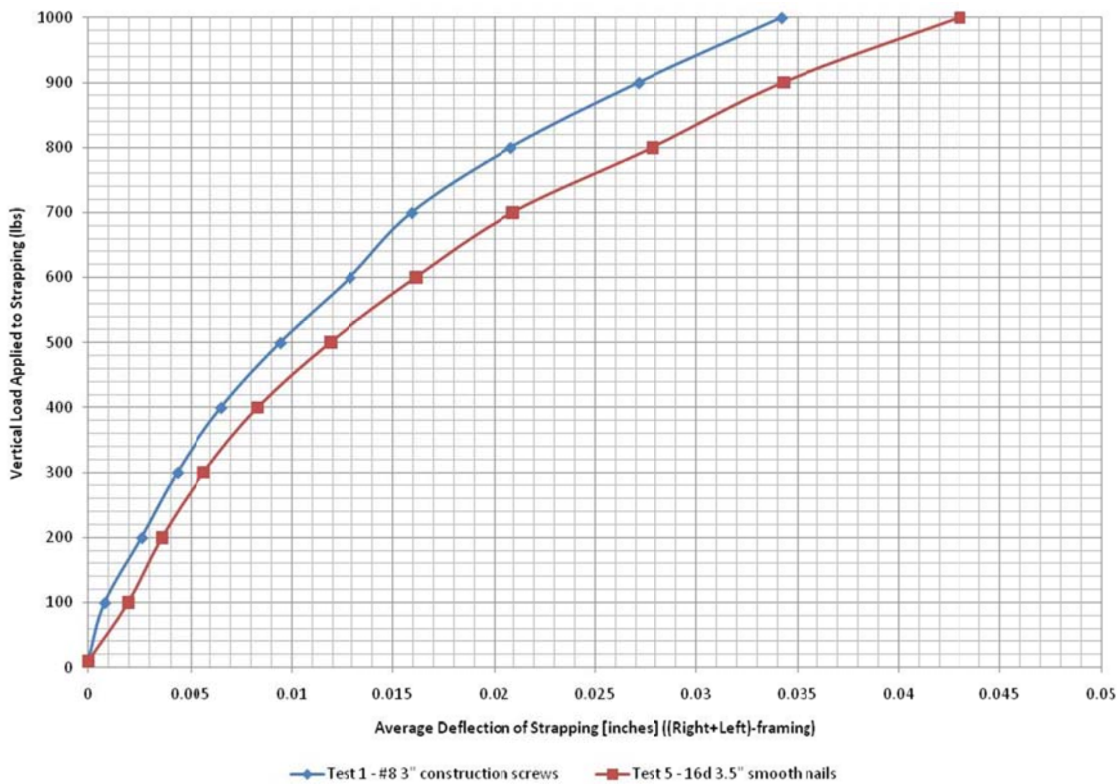



**Figure 9 : Comparison of the initial loading curve with #8 screws and 16d nails**

## Screw Diameter

A comparison of performance using 3” #8 screws (Test 1), and 3” #10 screws (Test4) was conducted to quantify any performance improvements. Figure 10 shows nearly identical performance until 800 lbs of applied load, and even at 1000lbs, the difference in deflection was 0.0045”, which is an insignificant difference.

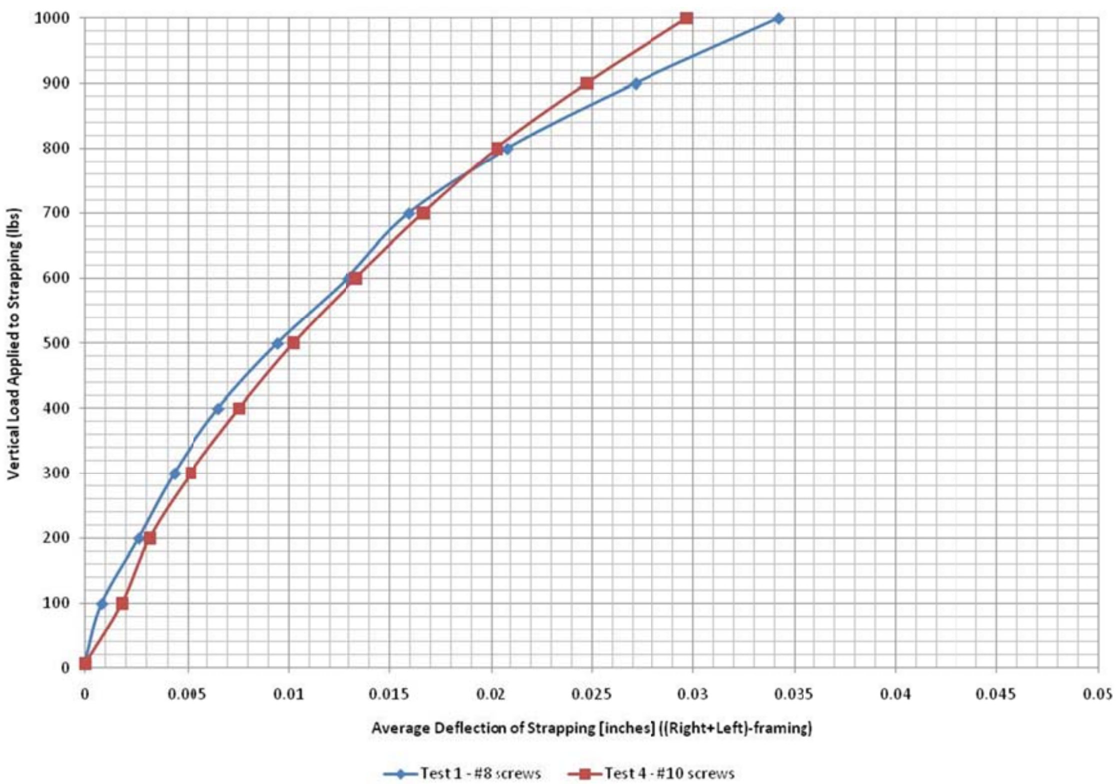



**Figure 10 : Comparison of deflection using #8 screws and #10 screws**

## *Summary and Conclusions*

- All of the insulations tested showed very little deflection (less than 0.01” or 0.25 mm) at the loads imposed by lap siding (of wood, vinyl, or fiber cement)
- The 3” ComfortBoard IS testing showed repeatable results between the first series of testing (final report dated March 3, 2011) and this testing, but there were some differences in the repeatability testing of 1.25” ComfortBoard IS (mostly at the higher loads), that could have been caused by the slightly different screws.
- Testing with various fastener embedment (in framing, in OSB, or a combination) showed no significant differences at loads less than approximately 20 pounds per square foot cladding weight.
- There was no significant performance difference in initial loading between 3” #8 construction screws, and 16d 3.5” smooth nails. At very high loads, screws appear to be stiffer and are known to have more resistance to pullout.
- There was no improvement in performance when #8 3” construction screws were replaced with #10 3” screws.
- If the strapping and insulation are not attached tightly to the wall sheathing, the initial deflection can be expected to be larger than if the insulation is firmly clamped, and the cladding is attached with nail guns or other techniques that caused initial deflection during “seating”.

- All six materials tested resulted in very similar patterns of deflection. The first loading produced the largest amount of deflection for each wall, and the second and third tests were very similar and repeatable with much less deflection, approximately half as much as the initial loading.

Note that these tests were conducted to simulate some of the worst-case realistic scenarios for deflection (i.e., 24” o.c. strapping, and 16” vertical spacing between screws). This is equivalent to only 4 fasteners per square meter. Also, the screws used were the lowest quality, length and thickness that would be reasonable for this application. Using more screws, at a closer spacing would likely decrease deflection, but more testing is required to determine the amount that the deflection could be decreased.

## *Recommendations*

It is recommended that field trials be conducted to gain feedback from installers. It was noted that some care was required when installing the screws to attach the fastening so as to ensure a plumb strapping: excess or insufficient screw torque could cause the strap to be bent.

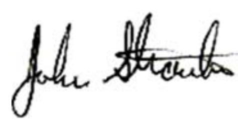
In practice, recommending screw attachments at 12” o.c for 24” o.c framing and 16” for 16” o.c framing would provide some additional safety factors.

To confirm the very favourable results achieved, it is recommended that field testing, in a test facility or on a jobsite, should be conducted to assess the potential for stucco or adhered veneer cracking over a 1-2 year test period before proceeding with wider deployment.

Long term deflection testing in a laboratory setting may give a better indication of performance with sustained loading that simulates cladding, but field testing is preferred.

If you have any questions or comments about any part of this report, please do not hesitate to call or email.

Sincerely,



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