Performance Influence: Roofing Assemblies’ Interface With Decks

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**Abstract**

With all the outside forces affecting building construction design, such as the International Code Council (ICC), economic changes, and green standards, to name a few, it is no wonder that some decking material has conflicted with interfacing of roofing assemblies. Though these materials are permitted by the building code, the failure of the material to hold a fastener or adhesive for roofing can jeopardize the expected performance of the roofing assembly. To avoid concerns about long-term performance, it is important to understand the types of decking materials, their limitations, and how to improve architectural specification wording to meet code requirements.

**Speaker**

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BRIAN CHAMBERLAIN has been with Carlisle Construction Materials since 1987. He graduated from the University of Wisconsin at Milwaukee, earning a bachelor’s degree in the science of architectural design. Chamberlain has been assisting architects, consultants, and specifiers with assemblies, focusing on performance and sustainability. He is part of a team responsible for assemblies, details, and code testing. He has presented technology information throughout the U.S., Canada, and overseas, offering information on unique design issues.
With all the outside forces affecting building construction, such as the International Code Council (ICC), national and local economic changes, and the push for green standards, to name a few, it is no wonder that some chosen components for decking have conflicted with proper interfacing of roofing materials. Though most of these chosen materials are permitted by the building code and can be installed to meet the calculated structural pressures, the weakness of the material to hold a roofing system fastener or adhesive for substrate connection jeopardizes the expected performance of the roofing assembly.

Though this presentation will focus on decking materials and methods of interfacing or securing the roofing materials, the author is taking the liberty of assuming that all decks discussed have been designed and installed to meet the building code and minimum loads of ASCE 7 (Minimum Design Loads and Associated Criteria for Buildings and Other Structures).

**CERTIFICATION**

In the roof assembly certification process referenced in the International Building Code (IBC), the roofing assembly must have been tested by an independent testing laboratory to meet or exceed the allowable uplift pressures calculated by following ASCE 7. To know the allowable uplift pressures that the assembly must meet or exceed, the uplift pressures need to be determined for comparison with any test results. As an example, using ASCE 7-201010 for cladding and components and the allowable stress design (ASD) uplift pressures, the approximate parameters of a building would be as follows (see Table 1):

<table>
<thead>
<tr>
<th>Location: Houston, TX</th>
<th>Importance Factor: Category III/IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Design Wind Speed: 145 mph</td>
<td>Enclosed</td>
</tr>
<tr>
<td>Exposure C: Open terrain</td>
<td>Building Height: 40 ft.</td>
</tr>
<tr>
<td>Zone 1 = -34 lbs./sq. ft.; Zone 2 = -57 lbs./sq. ft.; Zone 3 = -86 lbs./sq. ft.</td>
<td></td>
</tr>
</tbody>
</table>

Once the test has been completed, the roofing assembly is given an uplift rating in pounds per square foot (lbs./sq. ft.) that can then be listed as certification of this uplift rating.

**LISTINGS**

In the roofing industry, there are now (November 29, 2017) over 988,000 recorded combinations of roofing materials that have been tested and rated in RoofNav4 alone. Even so, what is listed does not include every possible combination that could be developed in the industry. Even without the new products and methods of installation introduced on a yearly basis, the eventual combination of existing roofing materials could create millions of listings.

With all these assembly options, one might think every combination should be tested and the results listed by independent sources. However, one of the limiting factors for roof material manufacturers, who are responsible for this testing, is cost. Everyone wants the biggest bang for their buck, so they will survey trends within the market to determine how they can offer assemblies with as few tests as necessary. What this creates is the potential for confusion when a designer attempts to be creative, which makes the odds of finding test results for his or her exact material combinations even more difficult. Changes in the market of decking material have added to an already complex situation.

**COMMON TESTING DECKS**

The most commonly tested decking materials by membrane manufacturers are cast-in-place concrete, 22-gauge or heavier steel decking, new lightweight insulated concrete (LWIC), and cementitious wood fiber. Other decks have been tested, such as existing gypsum decking, and 19/32-in.-or 23/32-in.-thick plywood, but they are very limited on tested ratings and options.

Though there have been articles about decking material, the trend is to focus more on wind loads on roof assemblies affecting steel decking securement, the concerns of moisture migration from LWIC, and standard/lightweight structural concrete.

**STEEL DECKING**

Steel decking has become more difficult to specify because of concerns about the deck’s securement to structural members and the overall uplift loads of the roofing assembly (Figure 1). This is complicated when we start to look at the performance characteristics of steel deck, 22-gauge to 16-gauge in thickness; tensile strength of the decking, such as Grade E (80 ksi) or Grade C (33 ksi); and the joist spans (4 to 6 ft.). Added to this, one must consider the method of securement of the deck to the joists, whether the deck was screwed or puddle-welded, and the size of the puddle weld (Figure 1). Unfortunately, if all these specifics are not listed on the structural drawings, most roofing estimators under pressure of the bidding cycle default to worst-case construction, which is 22-gauge,
Grade C (33 ksi), with 6-ft. spans to determine what assembly should be installed. Not knowing the specifics of the deck installation limits the possible roofing assembly options and could increase the overall cost of the project.

Though adhered assemblies with substrate boards fastened have been reported, for the most part, not to be an issue, the overriding concern within the industry is for the most part, not to be an issue, the substrate boards fastened have been reported, of the project. Not knowing the specifics of the deck installation limits the possible roofing assembly options and could increase the overall cost of the project.

One solution is to reduce the sheets’ width-of-field to not exceed the span between joists in order to spread the load of the roofing system more appropriately to the construction. Though this is interesting in theory, I have not found any empirical evidence, such as physical failures, that this is truly an issue. Mechanically secured membranes have been installed for decades without any evidence that the roofing assembly might over stress the deck securement. In one case in the northeast of the U.S., it was assumed the roofing had overstressed the securement method of the deck (Figure 3). Miami-Dade County supports this and has restrictions regarding the width and fastening density of the application sheet, unless an engineer does complete calculations showing that the system will not over stress any of the components.

In Mark Graham’s article “The Situation with Steel Decks,” he offers an interesting discussion on this concerns regarding adhered (uniform uplift loading) or mechanically attached (nonuniform uplift loading) membrane assemblies. In this article, he compares standard structural analysis of steel deck construction to the uplift load characteristics of both types of assemblies. He shows that where joist spans and the layout of roofing membrane securements run parallel to each other, the uplift performance of the roofing membrane may overstress the securement method of the deck (Figure 2). Miami-Dade County supports this and has restrictions regarding the width and fastening density of the application sheet, unless an engineer does complete calculations showing that the system will not over stress any of the components.

The timing of the deck installation and the time it takes to dry out, depending on the environmental conditions, can cause heartburn to the general contractor’s building schedule. The question that still has not been answered by the industry is when will the concrete be ready for the installation of the roofing assembly? Problems have been reported about substrate boards not staying adhered because of interply failure of the insulation facer adhered directly to the deck. Others have mentioned issues with attempts to fasten boards directly to a concrete deck that has not reached a cured state. And, of course, one of the biggest issues is condensation under the membrane and how it might be detrimental to the overall performance of the roofing assembly.

Though studies, discussions, and new products are being presented, the industry has not been able to come up with a consensus standard as guidance. In my paper titled “Moisture Migration: Causes and Cures,” I offer a few suggestions on what might be done. Over the last two years since I wrote that paper, the most acceptable option has been to install a vapor retarder—not using it as a temporary roof, but to install the complete roof assembly once the concrete has cured and the surface is dry. The vapor retarder could be adhered, or the first layer of insulation secured (Figure 4) through the vapor retarder into the deck. This way, the vapor retarder will stay warm and stop the humidity in the concrete from condensing under the membrane.

### Lab Testing of different securement methods of steel decks

<table>
<thead>
<tr>
<th>Steel Deck Attachment Method</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>5/8-inch Puddle Weld</td>
<td>722.4-lbf</td>
</tr>
<tr>
<td>5/8-inch Puddle Weld with Washer</td>
<td>1586.2-lbf</td>
</tr>
<tr>
<td>3/4-inch Puddle Weld</td>
<td>1068.6-lbf</td>
</tr>
<tr>
<td>Tek5-4 / Tek5 (Traxx 4 / Traxx 5) Fasteners</td>
<td>1081.8-lbf</td>
</tr>
</tbody>
</table>

**Figure 1** – Lab testing of different securement methods of steel decks.
as the primary securement for their insured buildings, but require securing into the structural members.

Even so, there are many who feel fastening directly into the metal roofing should work fine. Since we are now relying on the metal panel itself without any laboratory testing, we need fastener resistance field-testing to confirm uplift performance. Field-testing pullout resistance has been reported using a #15 fastener between 300 to 400 lbf for 26-gauge metal roofs, with 400 to 480 lbf for 24-gauge metal roofs. One could work out the math to determine the expected uplift pressures, but once determined, the designer of record should investigate the securement of the metal panel to the structure. These pullouts may offer an acceptable method for attachment of an adhered membrane roofing assembly with the substrate boards secured, but a mechanically attached membrane system may have different issues from the membrane’s dynamic movement through wind events. This movement may transfer the forces onto the engagement of the fastener and slowly cause loosening, potentially reducing the assembly’s long-term performance.

Another option might be adhering the insulation to the metal roof panels. If the building is FM Global insured, they state they will not allow adhering insulation to a metal panel substrate because of a historical incident on a project where asphalt adhesive was used to adhere insulation to a steel deck. Unfortunately, an internal fire happened, causing the asphalt to soften and drip into the building, adding to the fire. Today, we do not use asphalt to adhere insulation to steel decks, but some owners and designers would prefer to use adhesive, such as two-part urethanes. These urethane adhesives, once set, are a solid and cannot be softened through heat. These products are the same base product as polyisocyanurate insulation, which has been traditionally used and accepted directly over steel decks without a thermal barrier.

As an example, a building located in Chicago, IL, was insured by FM Global and needed to be reroofed. The owner wanted the existing roof material removed and a new roof installed without any insulation fasteners into the deck. The owner was concerned that the fasteners would create steel shaving from the deck, contaminating his product below. The contractor knew of a product that was allowed by the manufacturer to adhere insulation to metal decking. FM Global pushed back, and after many months of back and forth, the owner learned of a research test report by FM Global showing the strength of the adhesive to a steel deck would meet the specified uplift pressures. In the last meeting with the FM representative, it came down to the owner stating that either FM Global allow adhering of the insulation to the deck, or the owner would look for a different insurance carrier. FM Global then allowed the insulation, along with a cover board and membrane, to be adhered to the metal panel (Figure 5).

In another example, a building owner of a standing-seam roof had electrical conduits running under or nearby the structural purlins. In this case, the owner did not want to take the chance that a fastener would hit one of the conduits and shut down his manufacturing process. The contractor suggested adhering the insulation into the flutes and then adhering a cover board and membrane. The building owner approved the option, but once FM Global heard, the project came to a standstill and went back and forth for months. Eventually, the building owner told FM Global if they were going to make the contractor install the roof into the purlins, and if the contractor hit any of the conduits, that FM Global would need to pay for the repair of the conduit and compensate the building owner for the lost time, wages, and profit of not allowing the insulation to be adhered. FM Global then allowed the insulation, along with a cover board and membrane, to be adhered to the metal panel (Figure 5).
LIGHTWEIGHT INSULATED CONCRETE (LWIC)

Roofing membranes installed over new LWIC have not been too great an issue, since these assemblies have been tested following ANSI/FM 4474. The larger concern with this material has been when the roof needs to be replaced where there are issues with the existing LWIC. If the top layer of LWIC over the insulation is too thin, fasteners may not hold; or if the material has been compromised by moisture infiltration, the installer is left with securing the roof boards through the material into the structural deck below. Though at times one will come upon a concrete deck with LWIC placed on top, most often it seems that the LWIC is installed over metal decking or pans. Typically, these decks are less than 22-gauge, and fastener engagement can be limited. Certification of the roof assembly uplift performance is difficult because testing of these metal decks has been limited.

Even so, the uplift characteristics of the assembly can be determined by doing field-testing through pullouts of fasteners, and those results can be compared mathematically with the density of the securement. Field-testing results with a #15 fastener have ranged from 300 lbf to 575 lbf.

NON-LABORATORY DECKS

Most wood deck materials and newer decking materials, such as panel concrete decking, high-performance engineered panels, and cross-laminated timber, have yet to be tested. If these decking materials are chosen, the designer of record should not expect to find a listing or test report. Assessment of these decks through field-testing could assist in making sure the assembly meets the uplift pressures and the building code.

PANEL CONCRETE

These decks have been installed in several locations within the U.S. Testing with fasteners has shown very weak securement, where the typical pullout values have been around 300 lbf (Figure 6). Even so, a better option would be to adhere the insulation, which has been tested in the lab with results of over 200 lbs./sq. ft. of uplift. The failure mode of this assembly so far has not been adhesion to these boards, but the securement of these boards to the supporting structure.

WOOD DECKS

Common wood decks that have been specified are wood plank, plywood, and oriented strand board (OSB). We have not seen many issues with interfacing with wood plank boards. The use of wood plank as a roofing deck can be found mostly in existing structures. It is rarely used in new construction. Inexpensive materials such as plywood and OSB have been used much more.

Plywood can be found in different board thicknesses (typically ¾-in., 5/8-in., or ½-in.) and plies (3-ply, 4-ply, or 5-ply). Laboratory tests have shown that different results would be achieved using the various thicknesses of ply combinations (Figure 7).

Though these tests were performed in the lab and provide a good idea of the physical characteristics of a new board, it has been found that field-testing with the same fastener typically shows less pullout resistance (Figure 8), possibly due to weather events. An article by L.D. Hogan, “Roof Decks A to Z Part IX: Oriented Strand Board,” discusses the nature of OSB decks to expand from the effects of environmental conditions, such as prolonged exposure to rain.

Comparing the pullout resistance from lab results and field-testing, we see a decrease in deck strength of approximately
17%. As in any reroofing project, complete assessment of the deck condition should be made.

Though typically not specified, a viable option for these decks would be using insulation adhesives such as two-part urethane, because they have shown great attachment capabilities to a wood surface. Two cautions to keep in mind with these adhesives are that they are distributed as a liquid and could seep through the seams in a wood deck, entering the building; and field testing until failure on the actual installed decking might cause the securement of the deck to be jeopardized, since the minimum uplift criteria for roofing (60 lbs./sq. ft.) might be greater than the structural criteria for the deck.

**TREND IN WOOD STRUCTURES AND DECKS**

One of the most prominent trends occurring in the industry is wood structures. They are now being heavily promoted by “green” initiatives, offering materials that are renewable, sustainable, and meeting all the building codes associated with fire and wind. In addition, they are resilient to weather, mold, and rot. Right now in Portland, Oregon, the Framework (Figure 9) is being built as the tallest wooden high-rise in the U.S.

An article by Kenneth E. Bland, “Updating Code Conforming Wood Designs,” discusses how these materials will meet the IBC 2015 building code, but does not address attachment of roofing systems. Even so, it suggests that cross-laminated timber (CLT) (Figure 10) should be strong enough to hold fasteners or adhesive. Until actual laboratory testing can be determined and completed, the only way to verify the uplift performance of one of these decks is through field-testing.

Another type of wood deck that is becoming more prominent is high-performance engineered panel, which is an alternative to plywood and OSB. These decks look like OSB (Figure 11), but are created by using advanced resin technology. Preliminary pullout results of fasteners have shown very strong securement (450 lbf with a #15 fastener), though additional testing and data collection must be completed.

**UNFORTUNATE SITUATIONS**

Even with improvement of wood decking material, we all have dealt with or been confronted by the term “value engineering.”

Value engineering (VE) is a systematic method to improve the “value” of goods or products and services by using an examination of function. Value, as defined, is the ratio of function to cost. Value can therefore be increased by either improving the function or reducing the cost.\(^2\)

As defined, this thought process seems like it makes sense. If a designer were looking at the potential cost of CLT, he might look at 5/8-in. plywood deck as a viable and cost-effective option. But, if cost becomes a factor, could the 5/8-in. plywood be value-engineered to a thinner product, such as ½-in.-thick plywood? Then what if someone presents the cost-effectiveness of an OSB as a lower-cost option? All four materials can be shown to meet the building code criteria relative to structure; so if they meet the code and reduce the cost, are we not offering a value-engineered option by that definition?

Case in point: It has been reported to me that a project in the Northeastern U.S. was value-engineered to a 19/32-in. OSB decking. The contractor was to install an adhered roofing assembly that would need...
to meet a 120-lb./sq. ft. uplift criteria. As a line item in the contractor’s bid, he presented an overall cost savings if the deck was returned to 5/8-in.-thick plywood. Though the OSB decking did cost less than the plywood and both met the minimum criteria of the building code, the contractor presented cost differences for installing upon each of these decks. To install the specified roofing assembly to meet the uplift pressures based on typical pullout resistance of each deck, the OSB deck required an increase in the number of fasteners, and the labor increased the cost of the total installation as opposed to installing over the plywood deck. Since the contractor could show that this was no longer a savings in cost with the OSB deck, the specifier relented and switched the deck back to the originally specified 5/8-in. plywood, where the overall savings was found in the installation of the roof assembly.

In another project in Las Vegas, the specifier wanted a mechanically attached roofing membrane to be secured to a wood deck, but had switched the deck out from the specified plywood deck to OSB for the same value engineering reasons. Then the contractor presented to the specifier his concern about meeting the building code uplift pressures of 60 lbs./sq. ft. Based on the estimated pullout fastener resistance of the two types of wood decks, the mathematically calculated uplift performance of the roofing system could be determined by taking the pullout results and dividing them by the force distribution points by multiplying the sheet width and the fasteners’ spacing within the seams (see Table 2).

With this information, a designer of record can compare the cost of the roof installation over both decks and determine where his or her true value engineering might be found—in the installation of the roof or the choice of the deck.

CONFIRMING BUILDING CODES

So how does one confirm the building code uplift performance if an assembly is installed over a less-than-22-gauge metal deck, untested wood decks, and OSB?

As shown in the previous discussion about value engineering, when presented with what would need to be done to spread the load out correctly, we can review the pullout resistance of the fastener and calculate expected uplift results.

The first step would be to assess the existing roofing decking material by following a set of procedures listed in the ANSI/SPRI IA-1, which provide instructions on how to perform the field testing. Once the testing is completed, one could take this empirical information and use it to calculate the expected uplift of the roofing assembly.

As with the mechanically attached membrane system, for an adhered membrane system, we need to determine the expected uplift performance by dividing the pullouts by the force distribution, based on board size and the number of fasteners (see Equation 1).

As an example, an existing wood deck in Texas had pullouts completed and was submitted for review, where the average pullout resistance was 360 lbf. The goal was to install a new adhered roofing assembly, so by using the following formula, we could determine the expected uplift performance of the assembly (see Equation 2).

Using the pressures listed in the example at the beginning of this paper, the results of 90 lbs./sq. ft. exceed the calculated pressure per ASCE 7 in the corner -86-lbs./sq. ft. The fastener density would meet the field (Zone 1), the perimeter (Zone 2), and the corners (Zone 3). No additional securement should be necessary to meet building code for this roof deck located in Houston, TX.

CHECKLIST

When attempting to take an untested decking material and interface with the roof assembly, the designer of record should

<table>
<thead>
<tr>
<th>(Pullout value ÷ [rows of securement in ft. x securement spacing in ft.])/2</th>
<th>result in lbs./sq. ft.</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 23/32-in.-thick OSB: #15 fastener resistance of 225 lbs.</td>
<td>o 4-ft. field sheets: [225 lbs. ÷ (3.5 ft. x 0.5 ft.)]/2 = 64 lbs./sq. ft.</td>
</tr>
<tr>
<td></td>
<td>o 2-ft. perimeter securement rows: [225 lbs. ÷ (2 ft. x 0.5 ft.)]/2 = 112 lbs./sq. ft.</td>
</tr>
<tr>
<td>• 5/8-in.-thick plywood: #15 fastener resistance of 360 lbs.</td>
<td>o 6-ft. field sheets: [360 lbs. ÷ (7.5 ft. x .5 ft.)]/2 = 65 lbs./sq. ft.</td>
</tr>
<tr>
<td></td>
<td>o 3-ft. perimeter securement rows: [360 lbs. ÷ (3 ft. x 0.5 ft.)]/2 = 120 lbs./sq. ft.</td>
</tr>
</tbody>
</table>

Table 2

(Pullout value ÷ [(size of board in feet ÷ number of fasteners per board) x2] = result in lbs./sq. ft.

Equation 1
follow some simple steps to make sure no conflict with specification/building code performance and materials occurs:

1. Determine the allowable uplift pressures for the specific roof area for the roof assembly using ASCE 7.
2. Confirm that the roof assembly meets these pressures through formal testing. If no available formal testing, then go to step 3.
3. Field-testing must be completed through pullout testing following ANSI/SPRI IA-1 testing procedure.
4. Based on pullout resistance, determined in step 3, calculate the uplift and, if necessary, increase fastening/securement to meet or exceed the results from ASCE 7, but not less than 60 lbs./sq. ft.
5. If field testing shows marginal to below pullout results (275 lbf or less) for the expected uplift requirement, a review of decking material, such as possibly increasing thickness or strength of roof deck materials, could be considered to avoid unexpected roofing installation expenditures.

**CONCLUSION**

Manufacturers have tested almost every promoted roofing product that they have manufactured or purchased to incorporate into their assemblies. These products are tested following the ANSI/FM 4474 uplift procedures, but only over specific and tested decks. Manufacturers have great confidence that the fasteners, adhesives, and methods of installation can be assembled to resist the highest uplift pressures calculated. But when weak or untested decks are used with proven assemblies, in many ways the deck becomes the weak link. The decking limits the roofing assembly’s uplift performance. As specifiers continue to ignore the interfacing of the tested and proven roofing material to decking materials, the certification of the roofing system for uplift performance is difficult to predict and certify. This usually becomes an issue once the deck has been installed and the interface with the roofing material becomes a concern to all parties based on specified code performance criteria. In the end, no one can feel comfortable and confident until definitive field testing can be completed that would assist in proving the uplift performance with engineering calculations.

**REFERENCES**

8. General Motors Hydramatic Plant, Livonia, MI.