The Journal of RCI

interface

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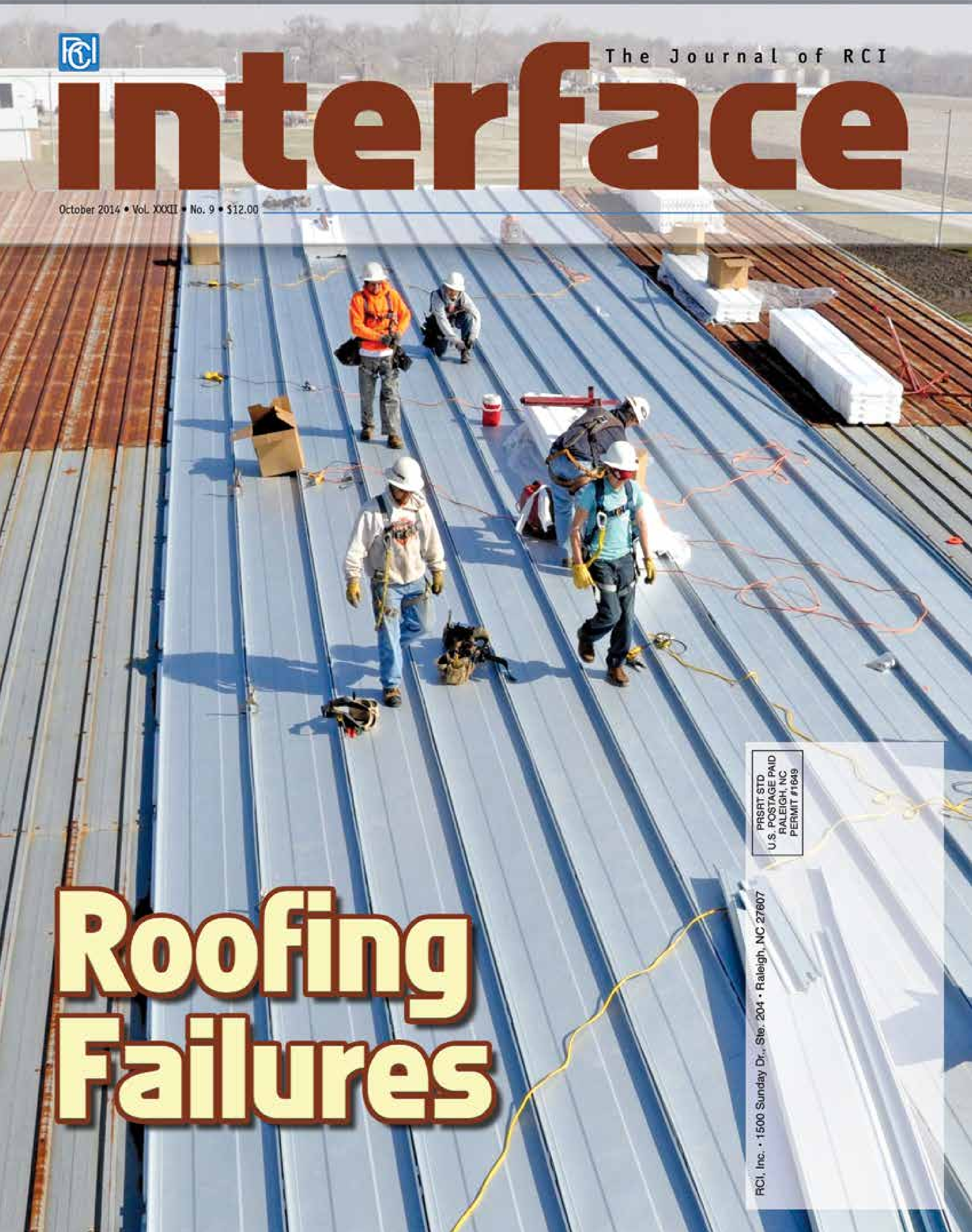
Roofing Failures



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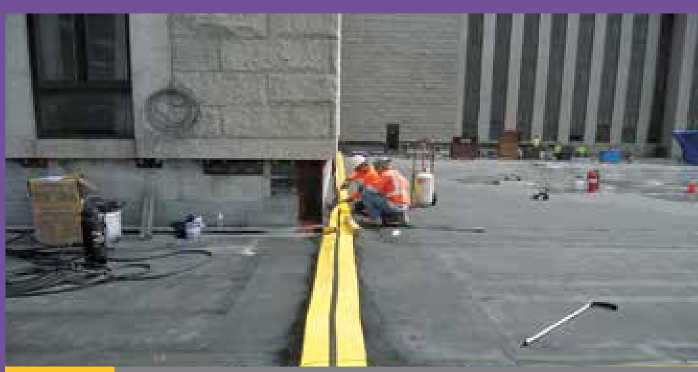

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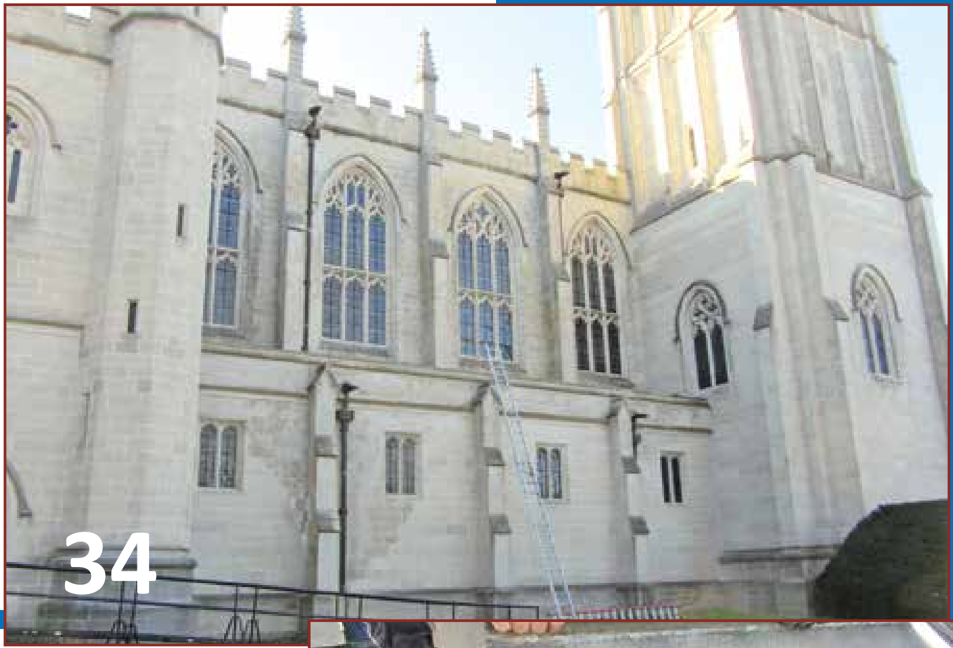
Scan this QR Code to find out more about RCI, Inc.

RCI was chartered, in part, to bridge the gap between the seemingly disparate elements of the roofing profession. It later expanded to include issues of waterproofing and of the entire building envelope. The goal of *Interface* is to connect these elements, educate and inform about related topics, establish a common ground for discussion, promote Association programs, and reach out to the industry at large. The articles contained in this publication are intended to provide information that may be useful to readers of *Interface*. RCI does not necessarily endorse this information. The reader must evaluate the information in light of the unique circumstances of any particular situation and independently determine its applicability.

Interface is a vital source of information written for and by building envelope experts. Featuring a paid circulation of 3,000, it is commonly circulated intraoffice among multiple colleagues, creating a total estimated readership of 9,000 per issue. If you would like more information about advertising in *Interface* or marketing to RCI members, contact Director of Marketing Communications William Myers at wmyers@rci-online.org.

special interest



departments

In This Issue: We examine various roof failure issues, including uplift-compromised adhered single-plies, compromised R-panel metal roofs, and failed restoration of an historic chapel.

On the Cover: Three aging T hangars at Lafayette Regional Airport, Lafayette, LA, were recently reroofed with symmetrical standing-seam roofing panels. Photo courtesy of McElroy Metals. See article, page 21.

Sidney I. Hankins, RRC, AIA
President

Inquiring Minds Want to Know: "WHAT IS THE BUILDING ENVELOPE SYMPOSIUM, and WHY SHOULD I ATTEND?"

Recently, I heard an RCI consultant refer to himself as a "skin consultant." Obviously he was subjected to jokes, laughs, and ridicule; but in retrospect, I have to admit that exactly describes a building's envelope. In simplest terms, the envelope is the building's skin. So, if the skin of a building interests you, the RCI Building Envelope Symposium (BES) is a great opportunity. It is not just for RCI members and registrants. Anyone in design, construction, sales, product development, or research of building materials should attend. Geared towards building envelope professionals, this program will be invaluable to all who are involved with building envelope systems.

According to *Webster's Dictionary*, the RCI BES meets the definitions of a "symposium":

- A social gathering at which there is free interchange of ideas. ✓
- A formal meeting at which experts deliver presentations on a topic or related topics. ✓
- A collection of opinions on a subject; especially intended to share ideas and encourage discourse. ✓

So, that is the RCI BES: pure, undiluted, cutting-edge technology; challenging your knowledge and opinions; offering the opportunity to meet one-on-one with other professionals from across North America; and providing ideas to help you in your field.

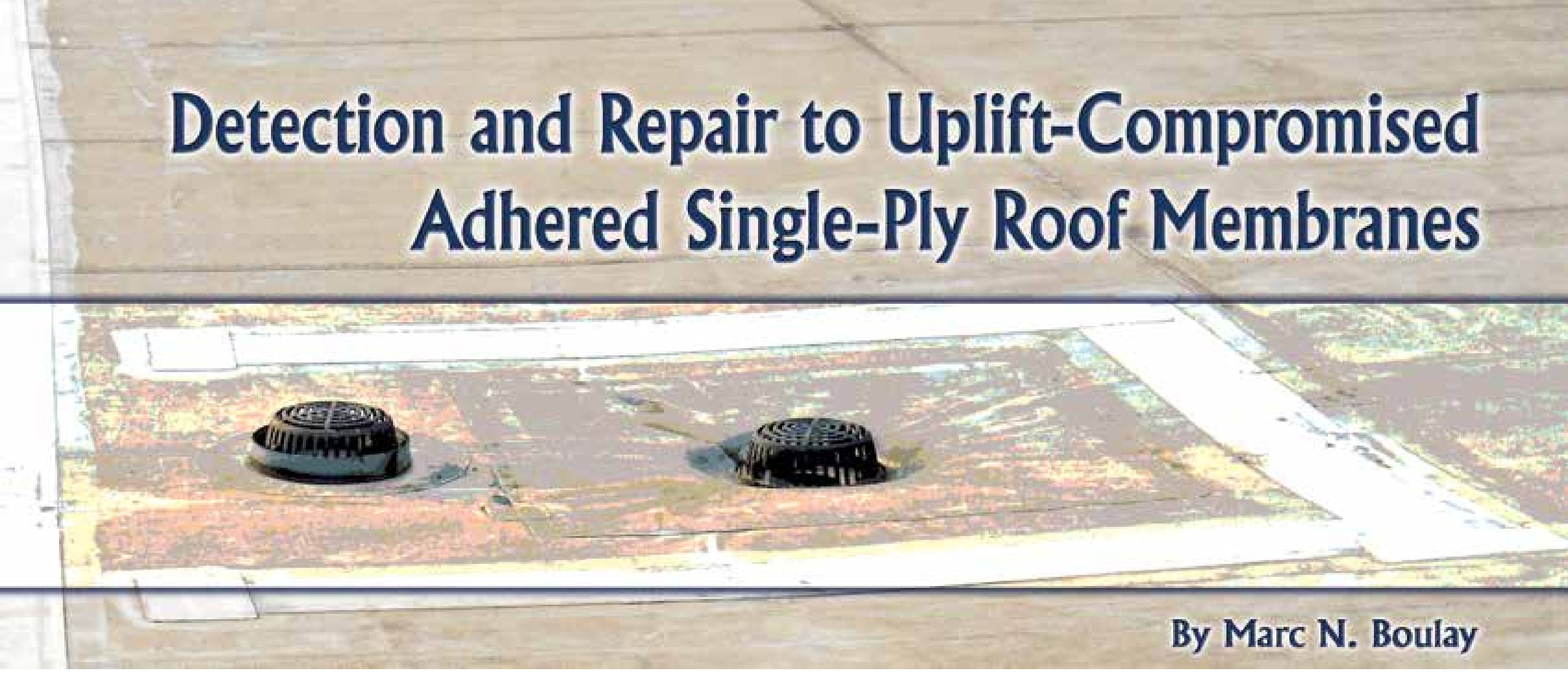
Since its beginning in 1994, the BES has steadily grown in its scope and prestige. The scholarly articles and presentations are selected by rigorous peer review during a multistep process. The competition for selection is intense, with 48 papers being submitted this year for the 12 available spots. The BES Committee, led by Mike Violette and Karen McElroy, has done an outstanding job to ensure that the Symposium upholds tradition and meets all expectations.

Why attend the 2014 RCI BES? Consider these reasons:

- The real advantage in attending the BES is enhancing one's understanding of the current and future role of technology in design, construction, and management from industry experts.
- The assemblage of world-class speakers promises to challenge the imagination. The BES pulls together the best of the best in topics and speakers.
- Earn up to 12 continuing educaton hours, including AIA Health, Safety, and Welfare (HSW) credits.
- The presentations are a two-way dialogue with plenty of time for interactive Q&A, agreements, disagreements, and discussion.
- Location, location, location. Tampa, Florida, is an easy destination to reach, the climate is great, the city is fun, and the food is inviting.
- The BES offers the chance to rub shoulders with colleagues in an informal setting. It affords attendees the rare opportunity to network with researchers; practitioners; building developers; vendors; IT professionals; educators and students; those working in architecture, engineering, construction, and facilities management; and leading manufacturers and service providers.

As you know, a building envelope is the physical separation between the conditioned and unconditioned environment of a building. It is the building's resistance to air, water, heat, light, and noise. We know that the building envelope must be carefully designed with regard to climate, ventilation, and energy consumption. It also includes structural support, controlling moisture and humidity, regulating temperature, and controlling airflow. More than just physical qualities, it must also address aesthetics, quality of life, social consciousness, and security; and the latest challenge is the current demand for intelligent buildings. So that is what the BES is about. I know you will find it beneficial and leave with something new to consider. And who knows, you might become the next skin consultant!

Please join me at the 2014 RCI Building Envelope Symposium in Tampa on October 20-21. See you there!



Detection and Repair to Uplift-Compromised Adhered Single-Ply Roof Membranes

By Marc N. Boulay

ADHERED ROOF ASSEMBLY OVERVIEW

Adhered roof assemblies have been a popular method of attachment for single-ply membranes for over 30 years, and the popularity of these systems continues to grow despite increasingly stringent regulations on the volatile organic compounds (VOCs) used in bonding adhesives. While the vast majority of these systems perform adequately for extended periods of time, a number of adhered systems experience uplift compromise ranging from limited areas of failure to complete failure. The overall integrity of an adhered single-ply system is only as strong as its weakest links, which, in the case of these assemblies, are sections of less-than-optimally bonded membrane.

ADHERED ROOF UPLIFT FAILURE

Reasons for uplift failure of an adhered single-ply membrane include the usual suspects of substrate compromise involving foam core collapse, facer delamination (usually in high-traffic areas), moisture compromise of wood fiberboard, and— to a lesser degree—moisture-compromised hardboard cover panels.

Moisture compromise of the adhesive bond can be the result of leaks and/or elevated levels of interior moisture that migrate up and erode the adhesive bond, as most adhered roof assemblies presently in service did not employ an air or vapor barrier, and more often than not, used a single layer of insulation—all contributing factors to compromise of the bonding adhesive. There are a number of other factors in the equation that result in an increasing number of failures of adhered single-ply roof systems. They include compromise of the bonding adhesive itself due to substandard manufacturing, inadequate storage, incomplete mixing of the adhesive prior to installation, and application during weather conditions outside the design parameters of the adhesive.

The primary external force involved with the failure of adhered roofing systems is negative air pressure, which is created

Figure 1 – The roof drain and cast-iron leader were dislodged by the uplift pressure on this roof system.

Figure 2 – Uplift damage to adhered PVC roof assembly.

as the wind passes across the roof surface. Such uplift pressure can be sufficient to pull the membrane free of a properly adhered insulation stratum firmly attached to a structural, poured-in-place concrete roof deck. An example of such a condition is shown in *Figure 1*, where the roof drain and the cast-iron leader were dislodged by the uplift pressure (this on a roof system less than four years old and only in a select, middle area of that roof system—nowhere near a roof edge). Concrete pavers in the image were taken from another portion of the building and relocated beside the damaged area to temporarily stabilize the membrane until the permanent repairs could be performed.

Adding to the uplift pressure on some buildings is positive air pressure, ranging from minimal added pressure created by mechanical equipment to extensive air pressure created when wind enters a building through openings in the sidewalls. This condition is most prevalent on large warehouse buildings where the percentage of wall openings can approach and exceed 50%, which will dramatically increase the overall uplift pressure on the roof system. Another component of increased uplift failure scenarios is the increase in severe weather attributed in part to climate change, which is being experienced in geographic areas not typically exposed to such weather and the higher intensity of these storm events.

The result is an ever-increasing number of uplift failures on adhered single-ply roof systems. To put the condition into perspective, the author's office has experience with over 1.6 million sq. ft. of uplift-compromised single-ply roof systems involving both EPDM and PVC roof membranes from differing manufacturers, in various geographic locations, and atop varying roof decks, from corrugated steel—where positive air pressure introduced through large wall openings was a notable contributing factor, to poured-in-place structural concrete—where positive pressure was a nonfactor. In these cases, a number of failures were noted as having commenced along the roof edge (as shown in the PVC roof system failure in *Figure 2)* to select areas of the roofs that were nowhere near a roof edge and that had occurred at a relatively lower wind speed (45 to 65 mph) than we would have anticipated.

This PVC roof uplift damage occurred while the building was still under construction, without the building envelope being sealed, and with temporary coverings on walls and door openings. After occurence of numerous uplift-compromised areas in the field of the roof and away from a roof edge, a series of investigations were conducted to closely examine all conditions and factors contributing to the uplift failure of this particular roof system, which over a number of years had increased to affect over 400,000 sq. ft. Testing included placing anemometers about the roof to record wind speeds in random locations; creation of a scaled model of the large, uniquely shaped building; and wind-tunnel testing, each of which failed to provide a definitive reason for the routine uplift failures.

An extensive series of test cuts were taken throughout the roof, which revealed the insulation facer firmly attached to the polyisocyanurate insulation foam core, turning the focus to the bonding adhesive. Test cuts in failed areas, as well as at still-adhered sections, were taken and shipped to a well-known testing lab for analysis. In this particular instance, the culprit was identified as substandard bonding adhesive, which was embrittled and unable to adequately restrain the membrane when exposed to moderate levels of uplift pressure.

Disbonded single-ply membrane areas are apparent when the roof is noticeably elevated in what appears from a distance to resemble the top of a large balloon such as the EPDM and PVC roofs seen in *Figures 3* and *4*. Other failures are detected by the sound of flapping membrane and/or leakage at compromised membrane areas.

Damage to roof systems attributed to

Figure 3 – Uplifted EPDM at compromised area.

Figure 4 – Uplifted PVC roof at compromised area.

uplifted single-ply membranes can include roof drains, as can be seen in *Figure 5*. In this example of a dislodged roof drain on an EPDM roof system atop a corrugated steel roof deck assembly, the PVC piping fractured and the membrane tore free of the building, resulting in widespread leakage and interruption to the building operation.

Unreinforced EPDM membrane—the predominant single-ply sheet for adhered roof systems—tears relatively easily in contrast with scrim-reinforced single-ply membranes, which do not easily rupture and, as such, tend to magnify the extent of uplift damage to drains and rooftop penetrations, distorting and even fracturing lateral rooftop gas lines and conduit.

As part of roof maintenance, a cursory inspection may be performed on a suspected

Figure 5 – Dislodged roof drain on uplifted EPDM area.

Figure 6 – Disbonded EPDM membrane area in foreground; adjacent area in background is still bonded.

Figure 7 – Disbonded EPDM membrane with iso facer adhered to underside, pulled free of the foam core.

uplift-damaged, adhered roof system during a period of elevated wind conditions (20 to 25 mph), which is sufficient to allow an observation and identification of disbonded areas that will elevate, billow, and flutter to a degree commensurate with the size of the disbonded areas. Scrim-reinforced membranes do not billow to the extent that an unreinforced EPDM sheet does; and as a result, it is slightly more difficult to detect smaller areas of disbonded membrane in comparison with an unreinforced EPDM sheet. An adhered EPDM roof membrane with a fleece or felt backing, and those adhered to alternately secured insulation (hot-asphalt bitumen or adhesive-grade, low-rising polyurethane foam) without plates and screws, have a smooth appearance, making it difficult to determine areas of disbonded membrane. On these roofs, carefully dragging a shoe heel will reveal a disbonded roof membrane. Alternatively, use a plunger to test a suspected loose area. Adhered systems with unreinforced EPDM membrane with insulation secured with plates and screws will telegraph on the roof surface.

On such assemblies, disbonded areas are easily detected during inspection. An example of a disbonded EPDM area with a smooth surface that peeled away from the insulation facer is shown in the foreground of *Figure 6*, while the adhered plates of the solidly adhered membrane area are shown in the background of the same image.

Uplift damaged or disbonded EPDM membrane areas where the insulation facer pulled free of the foam core and remains adhered to the backside of the disbonded membrane have a very distorted surface appearance, as seen in *Figure 7*. Once disbonded areas of an adhered single-ply membrane are identified, remediation work should commence in a timely fashion to halt the size of uplift-damaged areas.

REPAIR OF UPLIFT-COMPROMISED AREAS

If emergency repairs are initiated when the membrane is actively lifted, extreme care must be exercised to ensure personnel are not injured. A billowing single-ply roof membrane is capable of lifting a person off the roof deck. Therefore, we recommend that repair personnel move about a billowing membrane area in a relatively tight cluster of three or four persons to create a point load that is sufficient for people to remain firmly atop the roof surface.

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David Vokey, PEng – Detec Systems, LLC, Bellingham, WA

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Mathew Dupuis, PE – Structural Research, Inc., Middleton, WI

Fan Pressure Testing for Large, Complex Buildings
Terry Brennan – Camroden Associates, Inc., Westmoreland, NY

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Lurita McIntosh Blank, REWC, CDT – Walter P. Moore Associates, Inc., Kansas City, MO

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Detailing in Transition: Hybrid Walls and the Evolution of Terra Cotta Detailing
Edward Gerns, RA, LEED AP and Rachel Will, PE – Wiss, Janney, Elstner Associates, Inc., Chicago, IL

The Energy Penalty Associated With the Use of Mechanically Attached Roofing Systems
Simon Pallin – Oak Ridge National Laboratory, Oak Ridge, TN
Nonpresenting coauthors: André Desjarlais and Manfred Kehrer

Onshore vs. Offshore Curtain Wall Systems
Brian Hubbs, PE, BEP – RDH Building Engineering, Ltd., Vancouver, BC

Reducing Condensation Risk in Buildings
Amir Hassan – Read Jones Christoffersen, Ltd., Edmonton, AB

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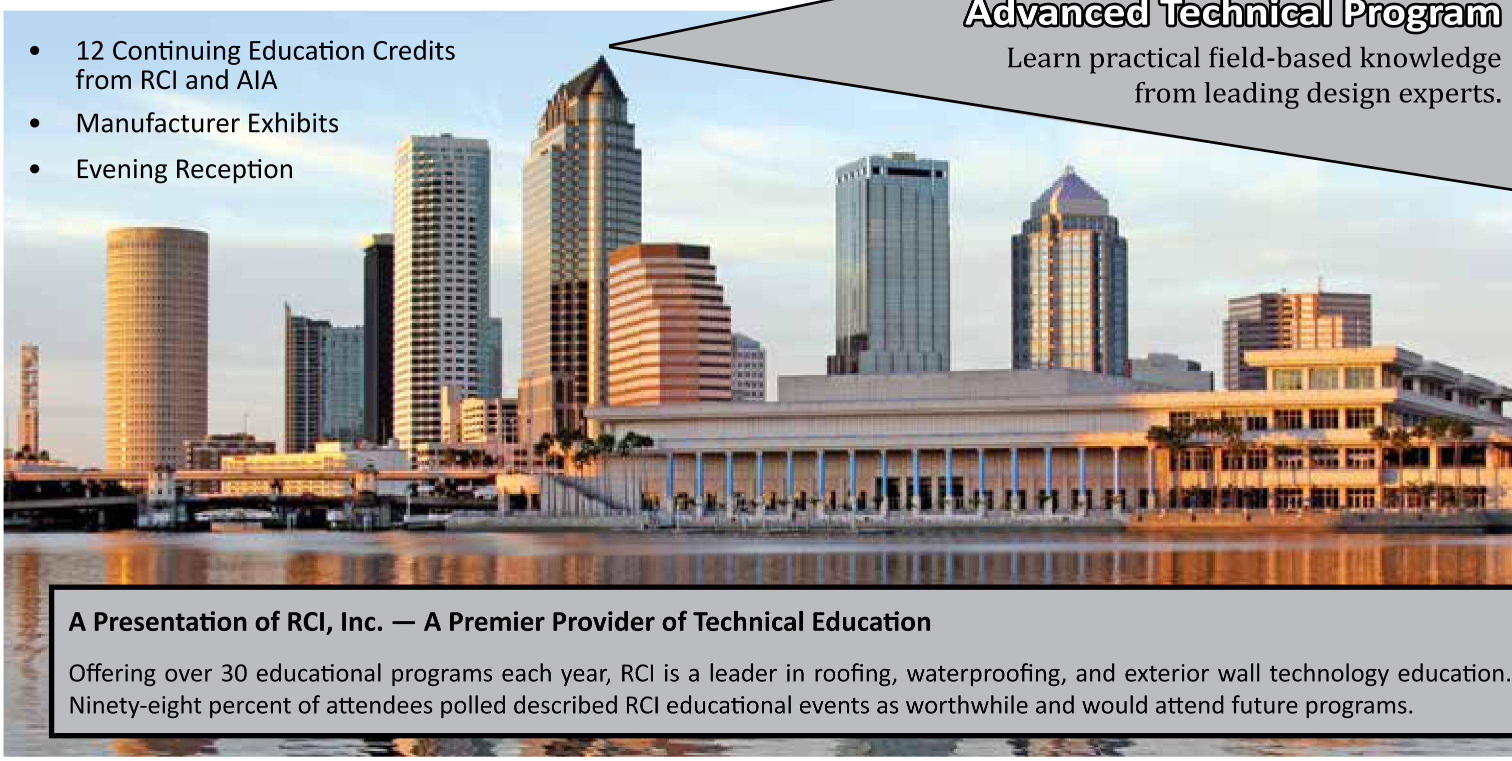

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ing area, carefully cut a round, 6-in. hole in the roof membrane, leaving no sharp or trailing edges (most critical on the unreinforced EPDM membrane, which will tear wide open along any sharp edge). Once the membrane is cut, install plate and screw fasteners positioned 36 to 48 in. away from and around the membrane opening, using four to six fasteners. These new membrane openings should be covered as soon as possible with a larger-diameter (6-in.), spun-aluminum, one-way air vent in order to return the cut areas to an effective, watertight condition.

Figure 8 – One-way air vents installed along edge of disbonded EPDM membrane area.

Plates and screws should be covered with appropriate new membrane patches, installed using recommended application procedures for the respective roof membrane being patched. Weight is also typically deployed to secure the loose and billowing membrane; however, caution must be used to ensure the proper type of weight is used. Concrete pavers used atop a billowing roof edge without battens or air vents have resulted in the pavers being tossed over the roof edge. Rubber tires spaced atop a large disbonded single-ply roof area without the benefit of air vents also have resulted in billowing membrane, lifting the tires and allowing them to roll about and even off of the low-profiled roof edge. The use of sandbags—while effective in a point-loading capacity—is only to be used as a short-term remedy. Long-term UV exposure tends to erode the integrity of the bags, resulting in the bags breaching and depositing sand and gravel atop the roof surface. If sandbags are deployed in a cold-weather climate, repetitive freeze/thaw cycles may compromise the bags and result in the same outcome, with aggregate atop the roof surface.

Once the excessively billowing, disbonded, single-ply membrane areas are addressed (and if areas are manageable without cutting pressure-relief holes), then the perimeter of the disbonded areas should be mechanically secured to contain the uplifted areas and prevent them from expanding. Securement on a scrim-reinforced membrane may be performed with plates and screws or with batten strips, while all unreinforced EPDM membrane areas should employ a batten strip. Metal battens may be used if they are the only battens available—metal is not the optimal component, due to issues with thermal expansion and bridging—instead, polymer battens are preferred for such work. Securement into a composite decking will require appropriate auger-style fasteners, while concrete decks should be secured with heavy-duty screw fasteners, as drive pins are difficult to remove and will complicate the eventual reroofing project.

Concrete pavers may be used in rows and in select locations, positioned atop appropriate slip sheets to augment membrane restraint. Before permanent repairs to uplift-damaged areas are initiated, a fair amount of data must be collected, including the type and age of the roof system, the manufacturer, and if any warranty coverage remains on the assembly. If warranty coverage is in effect, check the wind speed limitation and compare it against the closest weather station for the highest recorded wind speed and gusts experienced during a recognized storm event or going back over a number of weeks or even months in order to locate the elevated wind conditions that resulted in the uplift damage. If the uplifted area was detected during a rooftop inspec-

Figure 9 – Tightly clustered batten securement of an uplifted, fiberglass-reinforced PVC membrane area.

tion and/or during a period of a lower wind speed, establishing the date and time of the uplift damage may not be easily determined. An easy method of locating wind speed documentation is online at websites that include archived weather data, such as Weather Underground. If it is possible to determine the wind speed at which the roof failed, and it is below the wind speed coverage on the warranty, repair to the uplift damage may be covered under the warranty/guarantee.

Regardless of whether the damage occurred below or above the wind speed limitation on an active warranty, the roof system manufacturer should be notified in a timely fashion with as much detail of the failed area as possible. The building insurance carrier should also be notified of the roofing system loss, typically by the building owner. Depending on the particulars of the insurance policy, including deductible, permanent repair/replacement work may be dictated by the insurance company or the owner. Options always include full removal and replacement of the failed area; however, there are instances when an owner wishes to obtain additional service from an uplift-damaged/disbonded single-ply roof membrane area—e.g., if he or she is self-insured and/or the affected areas are relatively sound.

In such an instance, the disbonded roof area should be examined to determine the feasibility of repairing the areas and converting the system into a hybrid mechanically attached assembly with a series of batten strips and one-way air vents. Proceeding with a repair project involves installing the battens around the perimeter of the uplifted areas, around roof drains, and at set intervals through the body of the uplifted areas, positioned perpendicular to the steel deck direction. Once battens are installed atop an EPDM membrane, the areas should be properly cleaned with a weathered EPDM cleaner, then primed and covered over with a semi-cured EPDM/butyl tape membrane. New one-way air vents should then be installed along the roof area perimeter at intervals of 20 to 30 ft. and about the body of a larger uplifted area, with the number and position to be determined by the field conditions and the size of the area involved. The air vents act as purge valves, minimizing the uplift pressures on the membrane by providing a means of egress for positive air pressure on buildings with large wall openings and on buildings with a mostly enclosed envelope, allowing negative air pressure to act as a downward force on the membrane.

Disbonded single-ply roof areas that were repaired using this combined method of battens and one-way air vents have been in successful service for upwards of ten years on various assemblies. An example of one of the roofs repaired in this manner is on a building on Long Island, NY, shown in *Figure 8*. Note that this hybrid repaired area is positioned nearly 50 ft. high and with open exposure due to the surrounding low terrain. It has, over the years, successfully weathered a series of subsequent high-wind events that resulted in uplift damage to other, lower portions of this same building without any issues on the repaired area.

Repair to uplift-damaged PVC roof membranes is similar to that of EPDM roof systems, in that the disbonded membrane must be secured with battens or plates and fitted with air vents to limit billowing and uplift pressure in the sheet. If the PVC roof membrane used is a fiberglass-reinforced sheet, the battens or plates will require placement at a tighter spacing than if the sheet is a polyester scrim membrane, due to the fact that fiberglass-reinforced PVC membranes cannot withstand routine flexure without compromise.

An example of a tight (3-ft.) spacing of polymer battens on an uplifted, compromised area of a fiberglass, scrim-reinforced PVC membrane is shown in *Figure 9*.

Such extensive batten work is costly, and it may be less expensive to simply replace the membrane area with a polyester scrim PVC membrane for a permanent repair. Temporary repair could have employed battens around the roof drains and at wider intervals, with one-way air vents installed. An example of such a repair is shown in *Figure 10*, with that particular area awaiting installation of the one-way air vents.

Figure 10 – Battens around roof drain on uplifted area.

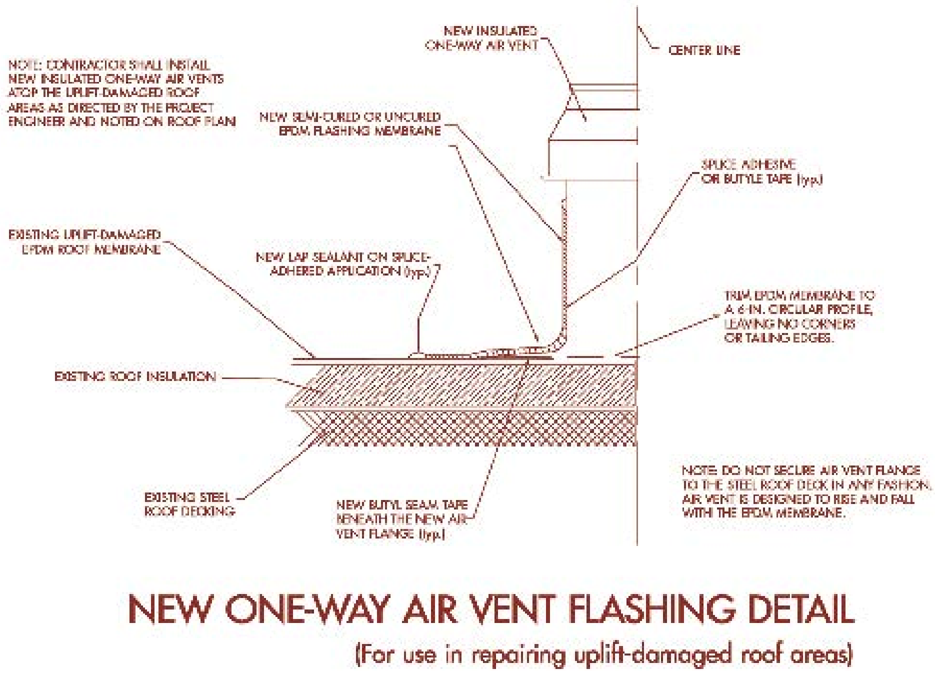


Figure 11 – One-way air vent flashing detail.

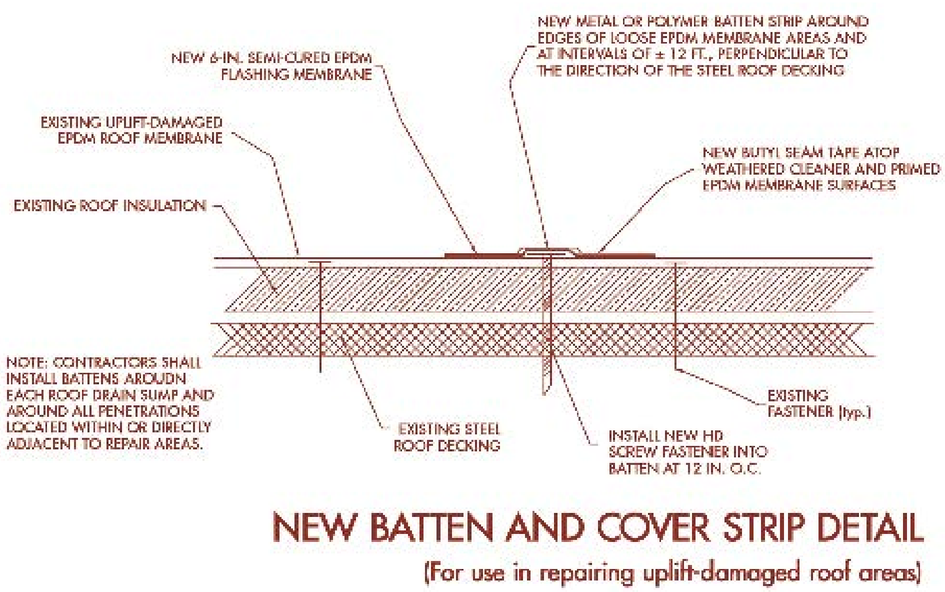
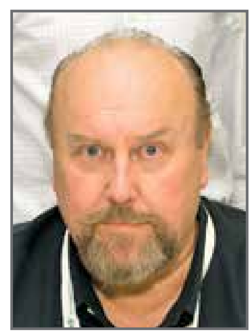


Figure 12 – Batten and cover strip detail.

Cleaning an aged PVC membrane to a level that will facilitate a hot-air-welded PVC membrane cover strip could also prove to be a chore if the surface has microbial growth or particulates that are tightly adhered to the membrane surface.

If a building owner wishes to extend the usable life of a disbonded, single-ply roof membrane area, and the membrane remains mostly sound (simply loose from the insulation substrate), turning it into a hybrid, mechanically attached assembly is a viable option. Such a repair application must be properly designed for field conditions and executed using proper components and time-proven detail applications. The example details provided (*Figures 11* and *12*) are for use in repairing an unreinforced EPDM roof system, but may be readily adapted for use in the repair of an uplift-compromised PVC or TPO roof membrane area.



Marc N. Boulay

Marc N. Boulay is the chief engineer with Northridge Consulting Engineers, Inc., based in Massachusetts. He has been involved with commercial low-slope roofing for 33 years. He has authored numerous articles and manuals and has lectured at seminars on commercial roofing, masonry, and pavement assemblies. Boulay is an active member of ASCE and RCI and serves on the Editorial Board for Interface *journal.*

NIOSH Releases Ladder Safety App

The National Institute for Occupational Safety and Health (NIOSH) has released a new ladder safety app as a free download for iPhone and Android mobile devices. The app is available in both English and Spanish. It features an angle-of-inclination indicator that uses visual, sound, and vibration signals to provide instant feedback on the position of an extension ladder to help workers set the ladder to the optimum angle and can also be used to measure the slope of a steep roof. For more information, visit www.cdc.gov/niosh/topics/falls/mobileapp.html.

Engineered Methods for Reroofing Metal Airplane Hangars

By Charlie Smith

In the 1970s and 1980s, metal became a practical option for constructing commercial and industrial buildings, as well as many types of storage facilities, from simple backyard sheds to large warehouses.

Some of those buildings are in need of repair to remain functional. Leaking roofs caused by age, damage, or other issues have become a common problem for building owners, creating an opportunity for consultants and roofers alike.

LAFAYETTE REGIONAL AIRPORT

Metal buildings remain a popular choice for airplane hangars, small and large. The Lafayette Regional Airport in Lafayette, LA, is home to nearly three dozen hangars, all of which are inspected either annually or semiannually. The man charged with inspecting the hangars (some more than 40 years old) is Ian Brown, project manager at MBSB Group, in Lafayette (*Figure 1*). Over the past dozen years, Ian has witnessed predictable roof failures on quite a few of these structures.

"I've been with MBSB for 16 years," Brown says, "and 12 of those 16 have been dedicated to helping Lafayette Regional Airport inspect and maintain its facilities. Many of these facilities are aging metal buildings with 26-gauge, exposed fastener R-panel roofs." R-panels, a low-profile 36-inch metal roofing (or wall) panel that can be installed over open framing or a solid substrate, remain the standard option for large metal buildings. They are chosen for their low cost and because the wide panels allow installers to cover the building quicker than with narrower panels.

Many times, the older roofs begin to leak at the end laps and where fasteners are installed. Thermal movement helps to elongate the holes where the screws penetrate the panels. Louisiana also receives some of the most intense sun and torrential rains in North America, both of which accelerate aging of all roofing materials.

"Structurally, the buildings remain in good shape," says Brown, "and by employing several different metal retrofit systems, we've been able to avoid the expense of tearing down a building and rebuilding a replacement. We've re-covered more than a dozen hangars and assorted outbuildings over the past 12 years."

EVOLUTION OF THE RE-COVER

"Our job here is to provide long-term value to our client, and our client does not want short-term fixes," Brown says. "Many of these exposed fastener systems have lasted 40 years. If it were not for the end laps and the way these panels were through-fastened to the structure, they would have lasted a lot longer. In our view, coatings or single-ply re-covers are short-term solutions when compared to a metal roof that can last 50-plus years. We re-cover with full-length, structural standing-seam panels that are attached back to the structure."

Figure 1 – Ian Brown going up for a roof inspection.

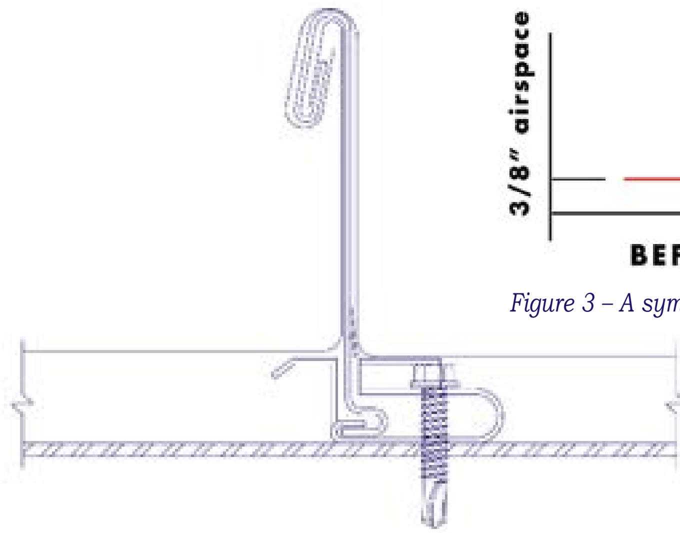


Figure 2 – A standard double-lock, standing-seam metal roofing panel.

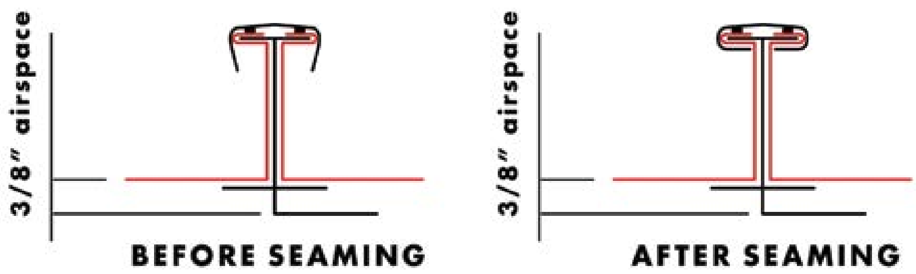


Figure 3 – A symmetrical standing-seam roofing panel.

During the past 12 years, the systems have evolved as improvements have developed, but the basic idea is the same: leave the old roof in place, use full-length panels to eliminate the end laps, and attach the new roof to the structure.

"When we first started re-covering buildings at the airport, we used a notched sub-purlin attached through the old roof into the purlin below and a continuous-length, 2- or 3-in.-tall, vertical-rib, 180-degree, double-folded, structural standing-seam panel," Brown explains. "The two main leak sources in the original roof—exposed fasteners penetrating the roof deck and end laps—are easily overcome by using a free-floating standing-seam system with panels that run full length from top to bottom. This system will have no horizontal lap joints and no exposed fasteners to leak. The 180-degree double-folded standing seams provide the best wind uplift and watertightness available.

"Re-cover is the best option for our tenants because it provides the least disruption to their operation and offers an opportunity for us to add insulation between the new and old roof."

There are other significant advantages to re-covering. While all structures should be inspected by a qualified design professional prior to doing any work of this nature, re-covering over an R-panel does not alter the structural diaphragm, since the exposed fastener panel that remains in place is an integral part of the structure. Also, the system weighs less than 3 pounds per foot, so it falls within the guidelines of the International Building Code (IBC) for existing buildings. The notched sub-purlin provides the most attachment back to the structure; and when used over an R-panel, it will increase the load-carrying capacity of the underlying purlin. In essence, by using a notched sub-purlin, structural enhancement is actually provided while the roof is being re-covered.

"We re-covered 10 to 12 hangars and assorted outbuildings with the notched sub-purlin and double-lock panel and had 100-percent success with the system. We know it will be a watertight solution long into the future," Brown says. "Coatings are temporary fixes, and single-ply re-covers have a much shorter life expectancy than metal. Both end up being more costly, so we won't go that route."

SYMMETRY

About five years ago, Brown was introduced to a two-piece, mechanically seamed, symmetrical metal panel. "It was not hard

Figure 4 – Here, a 5-in.-tall Roof Hugger retrofit purlin and a 130-ft.-long curved symmetrical panel with 100% curved continuous clips were used to solve the problems of wind uplift and leaky transition.

Figure 5 – Finished application showing continuous panel, step-down, and welded stainless flashing.

to see it had significant advantages over the double-lock system we had been using," he says. (See *Figures 2* and *3*.) "First, a symmetrical panel can provide better wind uplift capacity over existing frame spacing, and that is very important here in southern Louisiana. Also, the seam design on a symmetrical panel is more watertight than a double lock because there is no interruption of sealant in the seam at the clip locations. Most importantly, a symmetrical panel can be easily fixed if there is ever damage or a reason to pull a panel out of the roof at a later date. In this hurricane-prone area, the idea of being able to replace an individual panel anywhere on the roof after a storm carrying flying debris is a very big plus."

Symmetrical standing-seam systems do not have male and female seams, but are comprised of panels with matching left and right seams. The panels are joined with a mechanically seamed cap. The panels are nondirectional, meaning they can be installed left to right, right to left, or even from the center out.

Around the same time, the Airport Authority switched insurance carriers to Factory Mutual. This required the use of FM-approved systems, along with having a professional engineer design the re-cover. The most recent re-cover with a sub-purlin installation was topped with an FM-listed 16-in. curved symmetrical panel with 100-percent continuous clips over a 5-in.-tall, notched sub-purlin system. The system met FM 1-195 approval for that construction method.

"On this job, we had a couple of challenges," Brown says. "First was meeting the wind loads on a barrel vault with 5-ft. purlin spacing in a 110-mph wind zone. The corner pressures per ASCE-7 were -78 psf. Second was dealing with a transition between the barrel vault roof and the adjacent shed roof. This transition has been a failure since it was first installed; and over the years, several unsuccessful repair attempts had been made. By using an extra-high-notched purlin, we were able to create a 5-in. drop from the curved roof onto the transition flashing; and by using 100-percent continuous clips with the symmetrical panel, we were able to meet the FM-determined wind loading." (See *Figures 4* and *5*.)

Responsible spenders keep an eye on their budgets, and the Lafayette Regional Airport is a responsible spender. On a recent inspection, Brown became aware of leaking issues on three rows of T-hangars. It was a familiar problem: an exposed fastener R-panel that had endured too much Louisiana rain, heat, and sunshine.

"As we had done so many times before, we proposed installing a notched sub-purlin system to re-cover the T-hangar roofs," Brown says. "Everyone was familiar with the system and knew it worked. We were a little surprised when we were told the budget did not allow for another notched sub-purlin re-cover."

Discussion came back to removing the original R-panel and replacing it in kind, but that would require the building to be cleared during the installation of another R-panel. This method would not be popular with the tenants, but it would be an affordable solution, and it could be done within the airport's budget.

Brown recalled the new frameless re-cover system using a symmetrical standing-seam panel. Instead of using a sub-purlin or hat sections, the system uses tall clips that sit down between the ribs of the exist-

Figure 6 – Installation of the 24-gauge Galvalume symmetrical panels.

Figure 7 – A 24-in.-wide frameless symmetrical re-cover system with wind clamps in corner zone per FM requirements.

ing panel and are attached through to the purlin below. The clips hold the new panel above the ribs of the R-panel, eliminating the need for a sub-frame. Like the system used on the barrel roof, this system can be installed with 100-percent continuous clips to meet the wind uplift at 5-ft.-on-center frame spacing. The use of continuous clips offers nearly three times greater uplift resistance than standard clips. The frameless system eliminates the time and expense of installing sub-purlins and would fall within the parameters of the owners' budget.

The Lafayette Regional Airport Commission submitted the new system to FM for approval, explaining that funds were not available to install the already-approved notched sub-purlin system used on other buildings. FM approved the system for use on the T-hangars with the addition of wind clamps in the corner zones.

Each T-hangar measured 58 x 331 ft., or 19,198 sq. ft., for a total of 57,594 sq. ft. Most roofing panels measured about 30 ft. in length. Like all other re-covers at the airport, the 24-gauge Galvalume panels (*Figure 4*) were polyvinylidene difluoride-coated in "Regal White" to take advantage of that color's reflective qualities. Batt insulation was installed between the original roof and the new system in the fields, and a polyiso insulation was added on the perimeter. The rigid insulation provided additional support at the roof edge.

"The new system went up very fast," Brown says. "The panels were 24 in. wide, so the installer could really move. Panels run continuously from the eaves to a double row of vented ridge caps."

Crown Architectural Metal installed the roof panels on the three hangars in less than two months. Project Manager Jerry Hiltibidal estimated the project could have taken almost twice as long if they had installed sub-purlins and a new standing-seam re-cover system. To execute a complete tear-off and reroof would have been even longer and, again, an inconvenience to tenants.

"This was definitely the quicker and more economical system install," Hiltibidal says. "The continuous clips allowed us to achieve the wind uplift requirements and install the panels without sub-purlins. The clips run alongside the panels and serve as a base for the panels. They attach to the original existing purlins of the metal building.

"The other big advantage to installing this frameless symmetrical panel system is that it provided a safe platform to work on. Tearing off a roof and working on open purlins is definitely a safety challenge."

"This new frameless system made everyone happy," Brown says. "The elimination of the sub-purlins saved time and expense on installation. We kept the occupants and contents of the buildings covered with minimal disturbance, and we came in well under budget."

Charlie Smith

Charlie Smith, national re-cover manager at McElroy Metal, founded Architectural Building Components in 1989, purchasing the equipment of a small Houston, Texas-based metal roofing manufacturer. Over the next 23 years, the company grew to be an industry-leading metal roofing and wall system solution provider specializing in metal re-covers of existing low-slope roofs. In 2012, the company became a part of McElroy Metal, enabling Smith to focus on educational and product development efforts. He recently cowrote the new RCI Metal Roofing course with Brian Gardiner. He is a member of RCI and NRCA.

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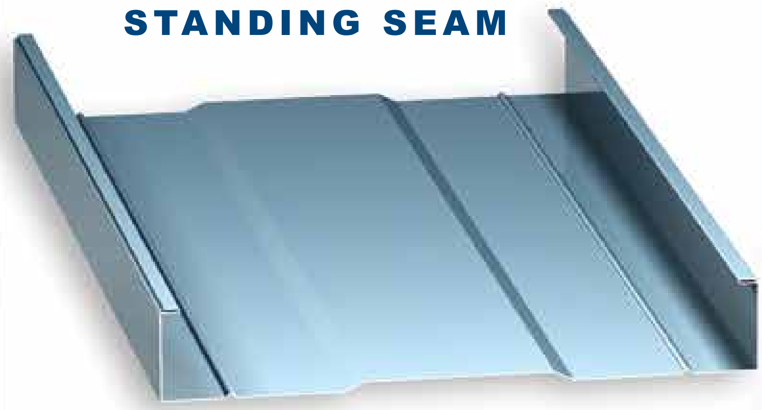

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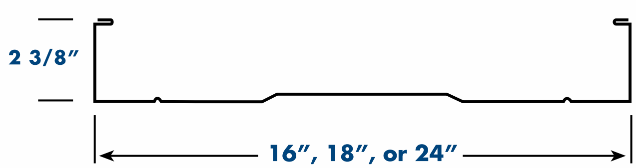

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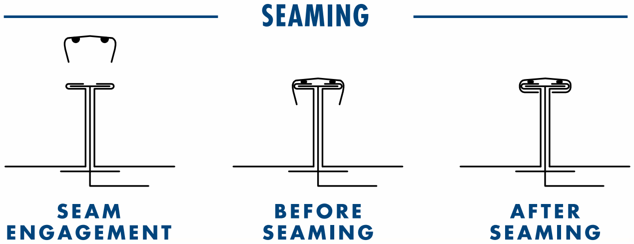

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Is It Just Me, or Does Every Building Leak?

By David Leslie, RWC

It was August, and I had just finished presenting "Design, Material, and Installation: The Three Facets for an Integrated Weather Barrier" to the Austin, Texas, chapter of the Building Enclosure Council (BEC). As my presentation implied, my goal has always been to positively change our industry and to give insight into why buildings leak. Anyone who knows me or has seen me present knows that I am very passionate about the building envelope industry and believe to my core that there is no good reason why a building should leak. The audience's reaction was overwhelmingly positive, and there was an enthusiastic understanding, which is usually the case. However, something different happened after that presentation, and it became the impetus for this article. I was asked a very poignant question: "How do we change the industry?"

Buildings that have environmental intrusions (air, thermal, and water leaks) are the number-one cause for unusable occupied space for building owners. In my research, I discovered that roughly 90% of litigation with architects involves leaks in a building. Additionally, the number-one problem for general contractors in closing out a building involves building leaks and is the primary reason for specialty subcontractors being called back. Consequently, the greatest source of liability for building weather barrier system manufacturers is, again, leaks in the building. Buildings that leak are a big problem, and that problem is growing as technological advances increase the complexity of designing and constructing buildings. The fact that the issue continues to grow is the reason that organizations like the American Institute of Architects (AIA) have started the BEC, the reason that RCI has developed a Registered Building Envelope Consultant® (RBEC®) registration, and the reason continuous air and weather

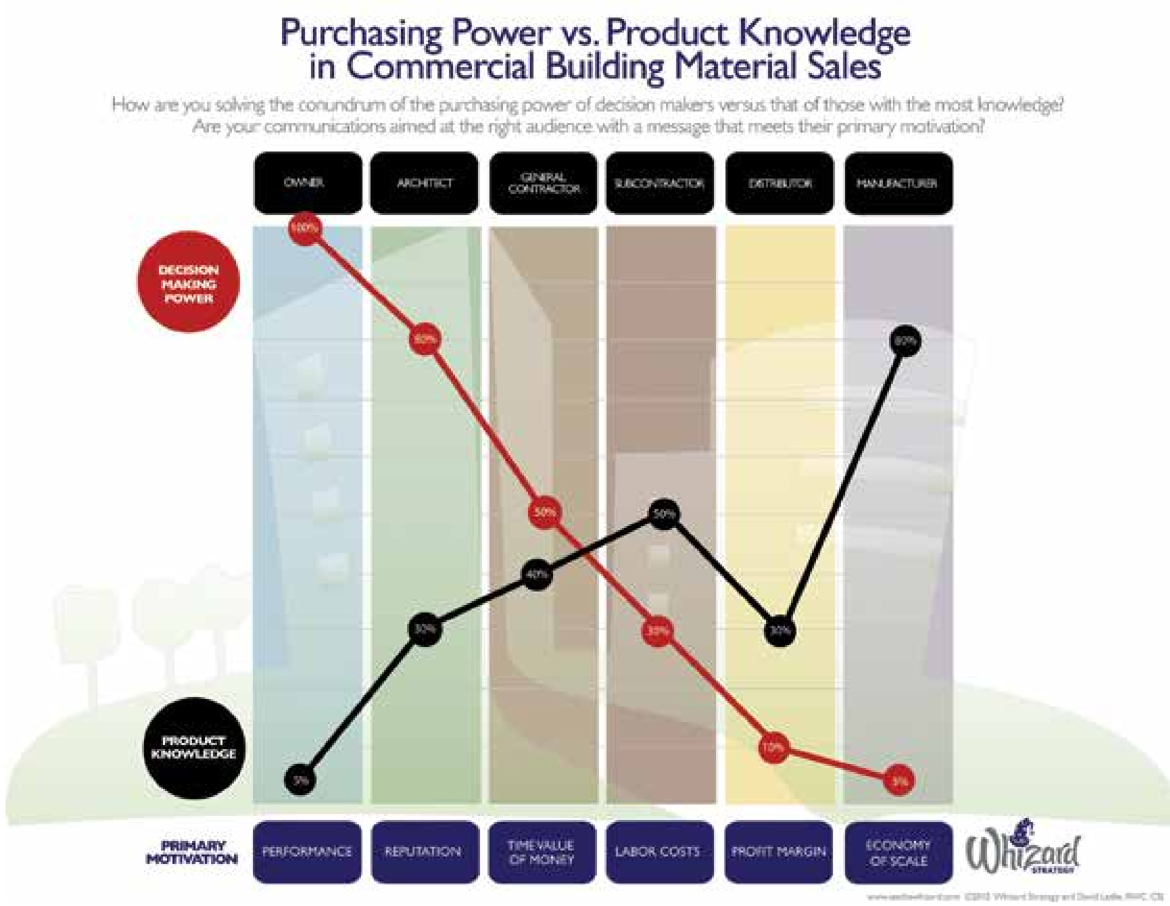

Figure 1 – Power purchasing vs. building material product knowledge.

barrier and other ASTM building envelope standards are being written into all of the building codes. The need for these new designations is a clear indication that many people are asking that same question: "How do we change the industry?"

The person who asked that pivotal question at the Austin BEC was John Posenecker of Chamberlin Roofing & Waterproofing of Austin. We have been friends for years and frequently discuss how to improve our industry. But his query hit close to home for me because it begs the question: What good is a consultant if he tells you what the problem is but doesn't tell you how to fix it? In the presentation, I defined five primary objectives that establish a process of creating integrated weather barriers (i.e., buildings that don't leak); however, these processes don't have the breadth or width to impact the industry as a whole because they are simply tasks.

In order to change the industry, there has to be a universal vision and relevant and consistent message to effectively communicate the vision that leak-free buildings are attainable, and it has to be relevant to the stakeholders involved in constructing buildings. What is most interesting is that the very thing needed to focus the vision—and therefore define the message—is actually in the presentation itself and is captured in the Purchasing Power vs. Product Knowledge graphic (*Figure 1*). This simple graphic is a powerful tool that creates insights into the dynamic workings of our industry's purchasing chain and into the mechanisms of how buildings are constructed.

I have 25 years in the roofing and waterproofing industry and have been blessed with a wide array of life experiences, but in college, I actually majored in baseball. Being an athlete teaches many fantastic things, but a lesson that has served me well beyond sports is that having good fundamentals is the key to reaching maximum performance, and understanding those fundamentals is critical to knowing how to improve. Before we can develop a vision and, ultimately, the message to change the industry, we must first agree upon the fundamentals for constructing buildings that perform as intended. Following are the universal fundamentals that I believe are key to achieving those results:

- Amazingly enough, it is frequently overlooked that the primary reason for constructing a building is to provide shelter for human activity. When this concept is forgotten, grave mistakes are often made during construction related to the building's weather barrier systems. **The building's primary purpose is to keep the outside environment out and the inside environment in.**
- Because the building's primary purpose is to serve as shelter, it has to be viewed as a whole and not just a sum of its parts. The reality is that 90% of all environmental intrusion occurs in less than 1% of the building surface.[1] That 1% area includes the terminations, penetrations, and transitions for the weather barrier systems. This basically means that leaks occur where one weather barrier system stops and another one begins. **For any building to perform as intended and to be leak-free, all of the weather barrier systems have to function together to create an integrated weather barrier.**
- Creating an integrated weather barrier does not happen by chance—it must be planned. Regardless of what is being constructed, there are three facets to the process:
  1) Design (the prescribed plans for moving an idea from vision to tangible)
  2) Material (the physical products chosen to move the vision from intangible to reality)
  3) Installation (the process of assembling the materials to bring the vision to fruition).

  These components are intimately intertwined, inseparable, and interdependent. A flaw with any one of them can result in poor performance, and a flaw in all three will cause significant failure. **Design, material, and installation create a prism, and through this lens, we can project an image of how to construct buildings that are leak-free and view ways to correct existing buildings that are not.**

The question then becomes, if we know these fundamentals, why do buildings leak, and how do the fundamentals relate to the information in *Figure 1*? To better understand how the graphic functions and relates

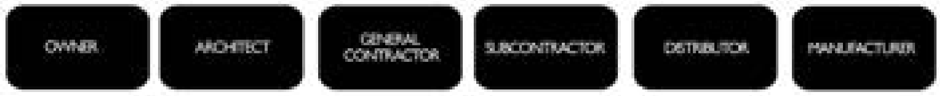

Figure 2 – The purchasing chain.

to the three fundamentals, it is helpful to know why the graphic was developed. Some years ago, while working as the technical services manager for a building weather barrier material manufacturer, I was performing a training class for some newly hired employees. During the class, I posed the question, "Who is our customer?" Someone in the class responded, "The contractor." My reply was, "That answer is the very reason that our industry has a poor reputation and why buildings leak." Ultimately, the customer for everyone involved in constructing buildings is the building owner. To illustrate the concept, I wrote on the white board what I called the "Purchasing Chain" (*Figure 2*).

Regardless of where you fall in the chain, it is easy to forget that the person everyone is working for is the building owner, who sits at the top of the chain. This is an especially difficult reality for groups to the right of the general contractor, because they virtually never have direct dealings with the owner. I then expanded the concept

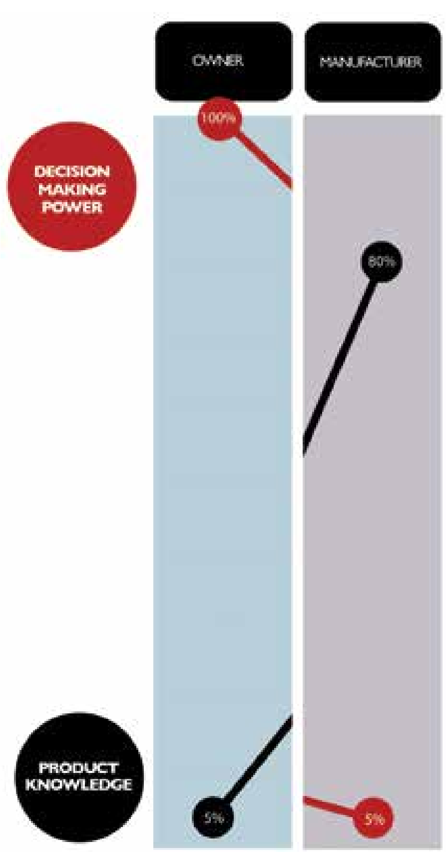

Figure 3 – The decision-maker power vs. product knowledge.

by plotting the points for the Purchasing Power vs. Product Knowledge graph (*Figure 1*) and the stark realization that the person with the most power has the least knowledge, and the person with the most knowledge has the least power (*Figure 3*).

What is even more telling, however, is that the purchasing chain also reflects the sequence for actually constructing the building; and conclusively, this is where the three fundamentals become relevant. The general chronological process of actual construction is:

- Owner hires an architect to design a building.
- The architect's design documents are issued for bid from general contractors.
- The general contractor then selects specialty contractors who purchase the weather barrier manufacturer's products from a distributor.

When this sequence is viewed in relationship to the Purchasing Power vs. Product Knowledge graphic (*Figure 1*), we realize that the reverse relationship with power and knowledge carries throughout the entire graphic. Because design, material, and installation are intertwined, inseparable, and interdependent for constructing leak-free buildings, the fact that an architect is designing a building with only 30% product knowledge creates significant opportunity for flaws in the weather barrier systems for the entire duration of the product.

This is not to say that all issues belong to the architect. Nothing could be further

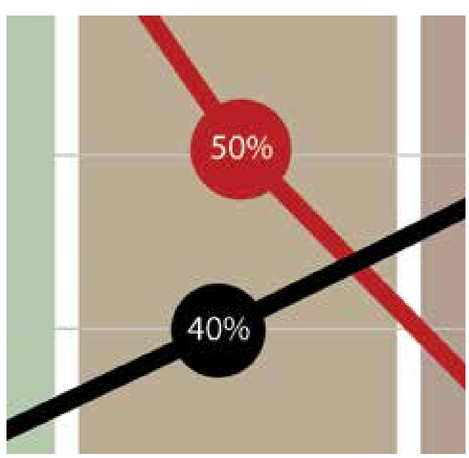

Figure 4 – The general contractor.

from the truth because there is no possible way for the architect to know all the available weather barrier products for the building envelope, and the architect is not actually installing the products. Due to this reality, many of the critical details of the termination, penetrations, and transitions (where 90% of all leaks occur) are deferred to the general contractor via shop drawings from the specialty subcontractor and during actual construction. There was an era when this process was practical because the general contractor had many of the specialty subcontractors in-house, and everyone involved understood that they were constructing the building as a whole. With the purpose of optimizing production by everyone becoming a specialist, the current business model is for the general contractor to function as a project administrator and utilize specialty subcontractors who have a very narrow focus of a single discipline, such as roofing. Unfortunately, specialization—the very thing that has helped us advance as a society—has become a hindrance to constructing buildings that don't leak. Few people know how to install terminations, penetrations, and transitions properly; fewer manufacturers make all of the products for them so that they are compatible; even fewer people know how to design them so they don't leak; and virtually no one takes responsibility for them. Because of this fact, the vast majority of the time, the final decisions for how the building is constructed fall on the shoulders of the general contractor, who has 50% of the purchase power and 40% of the product knowledge (*Figure 4*).

Ultimately, due to the process of constructing buildings, often the primary reason we are building it in the first place gets lost, and we wonder why virtually all buildings leak.

Mark Mitchell, author of *Building Material Channel Marketing* and owner of Whizard Strategy (www.seethewhizard.com), used *Figure 1* as the centerpiece for a chapter in his book to illustrate how the Purchase Power vs. Product Knowledge concept can help marketing be more effective. However, the same core principle found in the primary motivation of the graphic that makes product placement messaging effective is also applicable to that message for positively changing our industry (*Figure 5*).

For true change to be accepted and sustainable, it has to be beneficial to all of the stakeholders; but even more important,

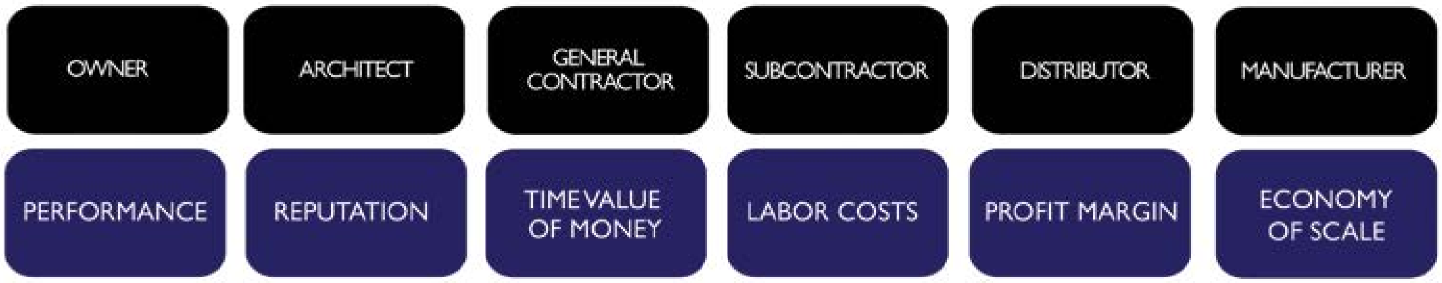

Figure 5 – Project stakeholders and their primary motivation.

it has to be practical for everyone. An integrated weather barrier producing a leak-free building obviously would be beneficial for everyone, but if the process does not provide value for any one stakeholder, it will not be followed. Regardless of who you are, value is only created by a combination of three things: wants, needs, and budget. When I say there is no good reason for buildings to leak, I mean exactly that: no good reason. The designs, materials, and installation processes all currently exist to produce an integrated weather barrier and would not require any additional cost. Sadly, as I stated before, the current process of constructing is not conducive to making buildings that don't leak.

Unfortunately, the wholesale process of constructing buildings that don't leak does not exist, and I don't know exactly what it is going to look like, but it will require a paradigm shift with all of the stakeholders participating. However, in the meantime, the industry is not doomed to producing leaky buildings. The workaround is to have a dedicated person working outside of the current process, functioning as the integrator from the very inception of the building until fruition.

How do we change the industry? Honestly, we just have to remember that we construct buildings to keep the outside out and the inside in. Just as there needs to be a vision to bring the weather barrier components to work as a single unit, so there needs to be a vision to unify the stakeholders to construct the building as a whole.

FOOTNOTE

1. Michael T. Kubal, *Construction Waterproofing Handbook*, Second Edition, 2008 (New York: McGraw-Hill), p. 1.12.

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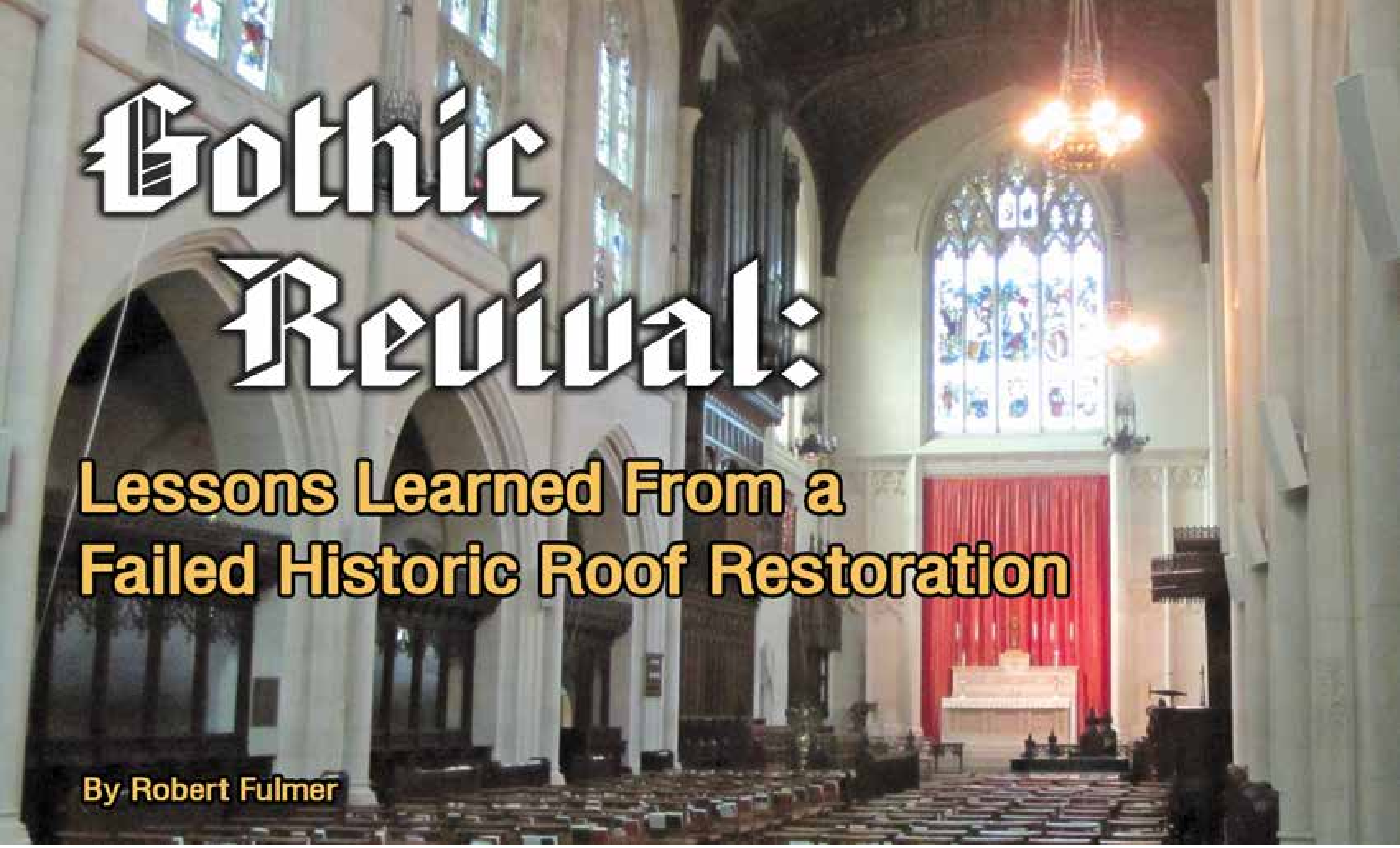
David Leslie, RWC

David Leslie, RWC, is the director of Building Science & Technical Services for the Henry Company. Over the last 25 years, Leslie has been involved with building envelope consulting; development and production of building envelope products for various manufacturers, including four patent applications; and management of major roofing and waterproofing construction projects nationwide. He is a seasoned presenter, having taught numerous AIA CEU classes, and has been a speaker at RCI and National Facility Management & Technology conventions. Leslie is an active member of RCI with his RWC credential, is an ABAA Licensed Field Auditor, and is a member of CSI.



Gothic Revival:

Lessons Learned From a Failed Historic Roof Restoration

By Robert Fulmer

INTRODUCTION

Recently, a private school in Boston, Massachusetts, commissioned the building envelope restoration of its campus chapel. Noted Boston architect Henry Vaughn originally designed the chapel circa 1899 in the Gothic Revival style.

The 2000 restoration project incorporated a mix of historic and contemporary materials and processes in the design and installation of a new copper roof, flashing, and roof drainage systems, as well as the cleaning and restoration of the chapel's limestone exterior. Although traditional building materials with an 80-year service life were specified, the restoration failed within two years of completion due to design and workmanship errors. The result was over $150,000 in subsequent water damage to the building and the requirement to redesign and replace the 2000 restoration just 11 years later, in 2012, at a cost of $1.5 million.

This case study illustrates how a combination of failed design elements and nonstandard workmanship resulted in the systemic exterior restoration failure of a noted historic building. The failed restoration, however, would provide an opportunity, 11 years later, to design and construct exterior building systems using a combination of both historic and contemporary materials and technologies. The end result would be extended service lives of exterior systems that would provide improved thermal efficiencies while enhancing building performance. Some of the challenges encountered included ventilating Gothic architectural roof system spaces; modern insulation considerations for historic structures; proper thermal-dynamic design of copper roof systems; as well as field research, testing, and use of contemporary building technology and materials in historic structures to improve thermal efficiencies and address thermodynamic issues. Lessons learned also highlighted the requirement to fully qualify all contractors and underscored the need for thorough and extensive project management to ensure a positive project outcome.

Gothic Architecture Characteristics and Challenges

The first recorded example of Gothic architecture occurred in 1140 with the construction of the Abbey of St. Denis in Paris. The original, true Gothic order officially ended during the early to mid-16th century with buildings such as Henry VII's Chapel at Westminster.

Far from dying out in the 16th century, original Gothic architecture was recognized as one of the primary structural systems of institutional construction. Its incorporation of the use of masonry structural members "in compression" enabled the construction of tall, buttressed structures with interior load-bearing masonry columns and structural vaulted ceilings. This style of construction is ideal for cathedral and institutional structures with large open spaces and tall stained-glass windows. The ornate Gothic order survived and flourished over the centuries under a number of transformations and movements such as Early English, Norman, French Neo-Gothic, Venetian, and, more recently, Vernacular and Carpenter revival movements.

The Gothic Revival movement (also referred to as Neo-Gothic or Victorian Gothic) began in England in the mid-1700s as a response to renewed interest in the "High" or "Anglo Catholic" church. The movement's popularity was exported to the United States in the early 1800s and reached a peak of interest in the early 20th century.

The subject property of this case study was designed by noted Boston architect Henry

Photo 1 – Chapel west elevation.

Vaughn in 1898-1899. Vaughn was born in Cheshire, England. He moved to Boston in 1881 to bring the English Gothic style to the Anglican (Episcopal) community in the United States. He became one of the most influential proponents of the Gothic Revival movement there. Vaughn's notable projects in the United States include the Cathedral of St. John the Divine in New York City; Searles Castle in Windham, NH; the Washington National Cathedral in Washington, DC; as well as numerous college and private school cathedrals and chapels, including the subject property in this case study.

In 1898, when Vaughn began his design of this chapel (see *Photo 1*), he viewed his work in the same perspective as Gothic architects had centuries before him. He incorporated high-quality materials with extensive service lives. He specified a solid masonry structure with substantial brick and veneer walls stabilized by flying buttresses. The brick core (4-ft.-thick at grade) was faced with 8-in.-thick local limestone blocks, which constituted both exterior and interior ornately finished façade surfaces. Solid structural masonry columns "in compression" anchored ribbed vaulted ceilings that supported the large, open roof areas. This construction type provided the large, open interior spaces desired for worship and a venue for rows of ornate stained-glass window panels, exceeding 25 ft. in height.

Photo 2 – Original scupper drain with 2000 retrofit gutter.

Vaughn protected the structure with a copper roof and drainage system, utilizing both standing-seam and flat-seam copper panels. The low-slope roof areas are found on the bell tower and semitransept roofs, as well as all flat gusset areas between the crenelated parapet and the foot of the steep-slope roof sections. These areas received fully soldered flat-seam, 16-oz. natural (red) copper panels. The steep-slope roofs on the nave, nave-aisle, and sacristy roofs received double-lock, standing-seam panels of the same material. The roof drainage system is a combination of historically accurate, copper-lined "gargoyle" scuppers (*Photo 2*) and copper downspouts.

Vaughn had specified the roof system components with a 70- to 80-year service life. As with other architectural genres, Gothic architecture, by its defining characteristics, presents its own unique design challenges.

For example, a principal Gothic architectural characteristic is the use of crenelated parapets that incorporate the decorative merlon stones, punctuated by crenel openings defining the upper termination of exterior walls or battlement. This detail is problematic in cold-climate zones, creating waterproofing issues during periods of ice and snow accumulation. Like his peers throughout the centuries, Vaughn neither specified nor designed for any insulation or ventilation considerations. It was believed that these large, open interior spaces were "self-ventilating," and any heat loss above the lower third of the structure was not recoverable or useful. When these substantial structures are restored, however, the modern design must address these and other building performance issues.

The application of contemporary building principles and technologies must be carefully considered and designed as requisites for successful historic restoration projects.

Photo 3 – Chapel interior (note inscribed limestone blocks).

2000 Chapel Restoration

As the building envelope systems of the chapel began to deteriorate over time, water infiltration began to occur throughout the roof, drainage, and exterior wall flashing systems. Over the years, numerous repair attempts were made, from the construction of steep-slope roofs over chronically leaking low-slope roofs and gussets, to the prodigious use of asphalt cement. Most of the repairs were incompatible with the original architectural style or materials, and none had compatible service lives.

In the 1970s, a slate roof was installed over the ailing standing-seam copper nave roof. This attempt eventually failed, as did the use of a BUR roof system to replace the original flat-seam copper gusset. After an extended period of interior water damage, in 1999, the board of trustees voted to perform a restoration of the building envelope that would include the use of the original copper roof and flashing materials specified by Vaughn. The process of design team selection began. After much research and due diligence by the trustees, the design team finally included a Boston architectural firm noted for its work in historic preservation. Also included were an historic architectural consulting firm, two engineering firms, and a landscape architect. With the respected and qualified team in place, the design work began. In the late winter of 2000, a contractor was selected and the contract awarded. The chosen firm was selected based on references of other notable historic restoration and copper roofing projects. They were not

Photo 4 – 2000 gusset installation in 2011, with deteriorated framing from solder seam failure and condensation.

the low bidder.

By May of 2000, the design team and contractors were waiting for the June project start date when the students left campus for the summer. Based on the request of the board of trustees and the recommendations of the historic consultants, the design team had included much of Vaughn's original intent into the envelope restoration. The existing slate roof was to be removed and replaced with a new standing-seam and flat-seam copper roof system. The interior limestone walls had been inscribed over the years with the names and class years of notable alumni, in addition to ornamental moldings and school insignia (see *Photo 3*). Years of water infiltration had left the limestone heavily stained with contaminants and efflorescence. The exterior limestone walls had also been affected by environmental surface contaminants and efflorescence. Consequently, the repointing and cleaning of both the interior and exterior limestone façade were included in the scope of work. The design team also incorporated design changes to take advantage of contemporary building technology and materials. For example, ice and snow accumulation within the low-slope gusset areas behind the crenelated parapets had been a long-standing source of water infiltration. Consequently, an extensive heat-trace system was specified behind all parapets and roof drain scupper locations through the parapets.

Most of the cast gargoyle scuppers were replaced with Gothic drain tail pieces fabricated in natural copper, diverting roof run-off into copper conductor heads and downspout assemblies (*Photo 2*). The parapet heights from the gusset to the crenels varied from 36 to 40 in. In an effort to reduce snow build-up at this detail, the decision was made to elevate the gusset by fabricating a new wood-frame gusset, approximately 18 in. above the original. (The original gusset was located on the roof rafter tails at the parapet sill plate.) The new gusset framing was installed at all parapets on all elevations along the 135-ft. building length. All roof drainage occurred via steel "bowl drains" located within the flat-seam copper gusset areas behind the parapets. Rainwater then passed through 4-in.-diameter cast pipe beneath the gussets and exited through the parapets at the copper drain tailpiece, finally coursing through the new copper conductor head/downspout assemblies. This 2000 detail created a continuous unventilated and uninsulated cavity along all parapets that would later become a source of significant deterioration within the gusset assembly (see *Photo 4*).

Another design addition was made to the roofing underlayment system. After demolition of the existing roofing material down to the tongue-and-groove roof sheathing on all low-slope and steep-slope surfaces, a continuous, fully adhered layer of .060 ethylene propylene diene monomer (EPDM) was applied to all sheathing surfaces as an underlayment. The design theory was to provide a durable, waterproof underlayment to protect the structure while work was in progress, at a reduced cost compared to a conventional self-adhered, high-temperature, ice- and water shield product.

The chapel had originally been constructed with a decorative interior and vaulted oak ceiling ornamented with hand-carved oak icons. A cavity space of two to three feet exists between the ceiling and roof sheathing. This space below the roof was never insulated or ventilated. The 2000

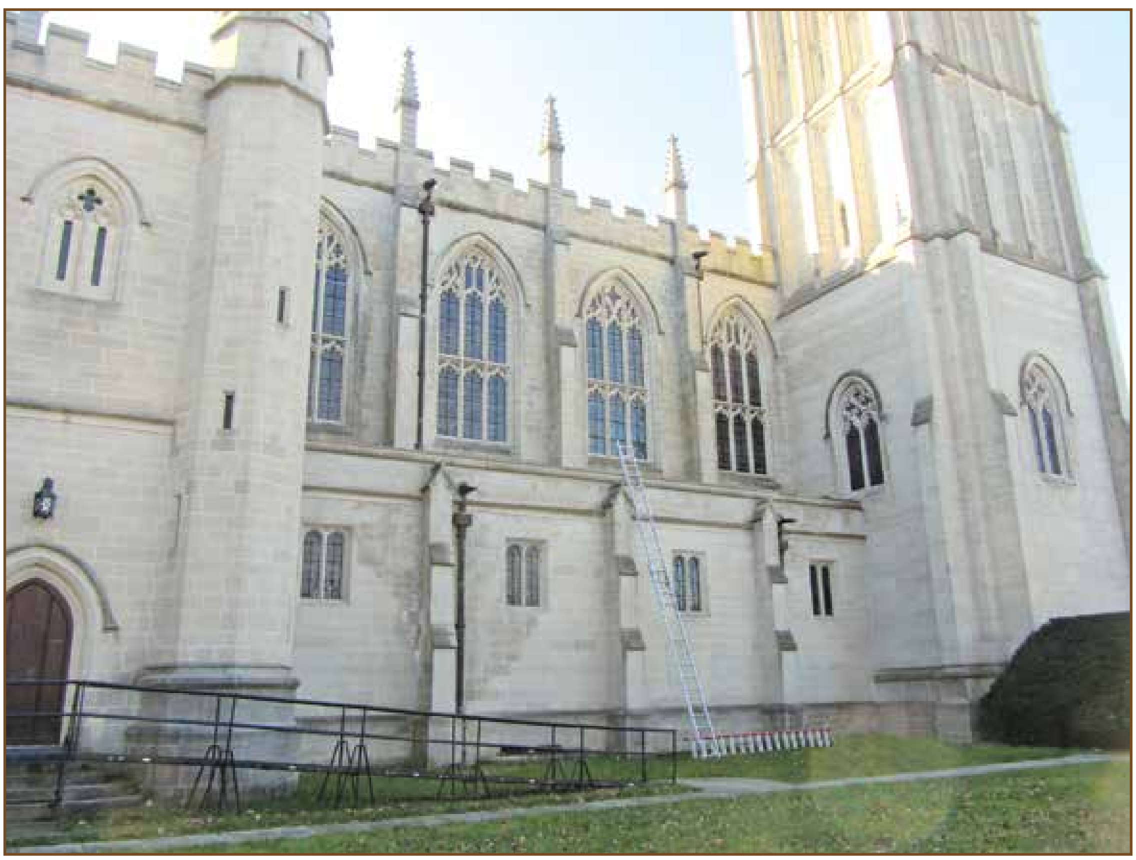


Photo 5 – Chapel north elevation (note area of saturation on limestone).

design did not address or alter these systems.

Based on these and other design alterations, construction began in June of 2000. The chapel was recommissioned five months later for a total restoration cost of $1.6 million.

Post-Construction Issues

In the spring of 2001, the first water infiltration issues began to occur. The inscribed limestone block in the north elevation nave aisle area became saturated below the parapet/gusset area. This area had just been cleaned, so staining was obvious. The contractors were contacted and responded to find several failed solder seams in the flat-seam copper gusset above. These seams were subsequently resoldered. Approximately six months later, the previously repaired area began leaking again. In addition, several other areas of water infiltration were observed on the north and south elevations of the upper nave roof and at the north elevation semitransept roof. The leaking areas of the nave roof were all located within the flat-seam copper gussets in the vicinity of the roof drains and crenelated parapet.

The water infiltration within the semitransept roof was located at that roof's intersection with the north elevation nave exterior wall. The leakage at this location was of particular concern, as the chapel's large and ornate pipe organ was housed directly below. A cycle of repairs and callbacks with the contractor began and extended over a period of several years. Most of the repairs involved the resoldering of failed solder seams, which at the time were attributed to poor workmanship. While new leakage occurred within the roof system, older leaking areas went unresolved and persisted. The volume of water infiltration within the semitransept roof over the pipe organ continued to grow. This low-slope roof section is not visible from the ground, and in an effort to curb restoration costs, the design team had specified a fully adhered EPDM roof system both there as well as on the bell tower and sacristy roofs. The potential for damage to the pipe organ was so great that the contractor built an "interior copper duct" system to divert the leakage away from the organ loft and into the chapel's interior drainage system.

Meanwhile, the area of leakage continued to grow and encompassed an area approximately 25 ft. long along the interior limestone wall of the north elevation nave aisle. This wall had been recently cleaned and restored during the 2000 project at a cost of $65,000.

Several years after project completion, water infiltration issues continued to multiply. Most problems were occurring within all parapet/gusset areas and were noticeably worsened by accumulation of ice and snow. The residential-grade heat-trace system began to fail periodically, compounding the leakage and forcing members of the facilities staff to shovel ice and snow off of the flat-seam copper-gusset areas. A cabled fall-arrest system was installed at all parapets to enhance the safety of the snow-removal process.

While repairing failed solder seams in the spring of 2004, workers began to notice small "tears" or "splits" in the flat-seam copper panels. These were occurring at the soldered corners of the panels and at brake-formed "pitch changes."

Frustrated, the owner summoned the original 2000 design team to inspect and specify a remediation process. A building envelope consulting firm was retained by the original architects to perform inspections and make recommendations.

In spite of the fact that flat-seam copper gusset areas were approximately 8 ft. wide at the parapet/steep-slope juncture and continued the length of the building, no expansion joints had been designed or installed throughout the extensive copper roof system during the 2000 project. The building envelope consultants identified the lack of expansion joints as an issue and designed the retrofit of their installation. The original roofing contractor performed the installation during the summer of 2006. During the following winter, water infiltration continued unabated.

In the spring of 2007, additional failed solder seams and damaged copper panels were observed throughout the flat-seam copper installation. When the original roofing contractor was contacted to return yet again, it was discovered that the firm had been purchased by a national roofing franchise. The new entity refused to honor or assume liability for the former company's work.

Over the next several years, two roofing firms attempted to perform remediation to stop the persistent water infiltration. They resoldered failed solder seams, some as many as four times. They caulked other seams and applied EPDM patches to dam-

Photo 6 – Nave roof (note temporary gusset repairs).

aged copper details. Limestone details were beginning to spall from freeze/thaw cycles (see *Photo 5*). Still, the remediation efforts failed and water infiltration continued.

Unable to remediate the persistent roof problems, the building envelope consulting firm recommended covering the entire (ten-year-old) copper roof system with an acrylic coating product, stabilized with a polyester mat. The product was guaranteed to "restore" metal roofs for 20 years. The manufacturer of this product had been in business for four years. Completely frustrated, the owners were considering the option. They now demanded to know how this could have happened. They had done their due diligence and hired a reputable architectural firm, which in turn had recommended two reputable consulting firms. They had added two prominent engineering firms to complete the design team. They had hired a contractor who was not the low bidder, had good references, and had demonstrable experience with similar projects. They had installed the specified roof system that they were told had an 80-year service life, and had paid $1.6 million for it.

The reality was that water infiltration had occurred throughout the building within months of project completion. Years of repairs have not solved the leakage problems. They had hired a new building envelope consulting firm and two new roofing contractors who could not diagnose or remediate the systemic issues. Ten years after construction, the owner was left with a leaking historic building that had accumulated over $150,000 in water-related damages.

Premature Systemic Failure

In the spring of 2011, my firm was retained by the owner to perform an existing conditions survey (ECS) to determine the extent and nature of the systemic failures on the chapel. The survey began with a series of forensic inspections to determine material and assembly conditions, as well as the confirmation of as-built details and water infiltration sources (see *Photo 6*). The ECS revealed the following design and workmanship errors.

It was observed that a number of flat-seam copper panels on the gusset (abutting the standing-seam copper installation) were oversized. Industry standards specify a maximum panel size for flat-seam copper installations to be approximately 24 x 18 in., prior to forming the panel locks. The panel sizes observed within the low-slope gusset area varied from 24 x 18 in., up to 96 x 24 in. The larger panel sizes create "oil canning" and stress on the copper panels, as well as excessive thermal movement within the flat-seam system.

Industry standards require that flat-seam copper panels be attached to the roof deck with copper clips, having two copper nails per clip for adequate attachment. The copper clip is subsequently folded over the nail heads. The copper clips observed within the existing low-slope copper roof system test areas had one 1¾-in. copper nail per clip without the "finish" fold on the panel attachment clips. In addition, a single steel nail was observed in some copper clips. In this dissimilar metal condition, copper occupies a higher position than steel on the galvanic scale, resulting in the corrosion of the steel nail in the presence of an electrolyte (moisture). This condition could compromise the panel attachment if it occurs frequently enough.

The existing copper panel edges were not pretinned with solder prior to forming the panel locks. Proper soldering technique dictates that all flat-seam locks be formed with panel edges that have been fully "pretinned" with solder prior to forming. Pretinning allows the solder to be completely distributed throughout the multiple folds of the soldered lock when sufficient heat is applied, thereby ensuring the integrity of the solder joint.

The solder joints exhibited an abnormally high failure rate throughout the flat-seam system. The principal reason for the premature failure of the soldered seams was due to the lack of pretinning of the panel edges by the installers prior to forming the panel locks. In addition, the solder application was inconsistent, with an inadequate volume of solder applied on many seams. This was a result of the installers performing only two rather than the three soldering "passes" required to finish each seam. Numerous seams exhibited evidence of insufficient heat applied during soldering, producing

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Photo 7 – 2000 EPDM underlayment assembly.

Photo 8 – Merlon stone attachment inspection (note 1-in. pin pipe).

a "cold" seam. As a result, the solder was not fully distributed throughout the panel lock.

There was no allowance or compensation for material stresses caused by thermal elongation (contraction and expansion) within any of the copper systems. Despite the size of several copper installations (up to approximately 135 ft. long, with widths of 6 to 10 ft.), the 2000 design included no requirements or specifications for expansion joints. In addition, oversized flat-seam panels on the low-slope portion of the copper gussets create excessive thermal movement, oil canning, and panel stress throughout the system.

Several expansion joints were observed but were not part of the 2000 installation. They were installed as a postconstruction remediation attempt after stress failures were observed within the copper flat-seam panel roof system.

The retrofitted expansion joints were nonstandard in both configuration and installation, as well as insufficient in number and size.

The underlayment for the steep-slope and low-slope copper roof sections on the nave and nave aisle roofs, gussets, and drainage systems, was a combination of loose-laid and fully adhered .060 EPDM. A fully adhered EPDM system was installed below the existing low-slope, flat-seam copper gusset area, in the location of the original roof drainage system. This detail created a "double vapor barrier" condition within the large, uninsulated and unvented cavity space beneath the redesigned gusset sections. EPDM is not designed as an underlayment material and does not provide a waterproof seal around the shanks of fasteners that penetrate the material.

Using EPDM as an underlayment throughout the roof system constitutes a nonstandard material application (see *Photo 7*).

The roof drains located within the gusset area were improperly installed. No drain sump was created; instead, the drain bowl flanges protruded ¾ to 1 in. above the roof panel surface, thereby creating standing water surrounding the drains.

Standing water was observed beneath the redesigned copper gusset roof deck within the unventilated cavity space. Ponding water existed within the original gutter, directly adjacent to the drains. The EPDM membrane in the original gutter location was damaged (punctured) in several locations, apparently during installation. The presence of standing water at the punctured membrane on the nave aisle roof at the parapet scupper/drain was the probable leak source that damaged the inscribed interior limestone wall directly below.

At locations where the copper drain tailpiece exited through the exterior wall, a small weep "slit," approximately ⅛ in. wide by 3 in. long, provided an intended exit point for condensate and other moisture accumulating within the open cavity area under the gusset. This weep drain configuration was insufficient to allow proper drainage during freezing weather and was susceptible to blockage by debris. The adjacent heat-trace system did not directly contact the weep location and, consequently, did not prevent the weep from freezing. Standing water was observed adjacent to several nonfunctioning weep details.

No ventilation or insulation provisions were designed for the large (approximately 7-ft.-wide x 18-in.-deep) area beneath the redesigned flat gusset deck. This open cavity created a continuous air space along the length of the building on both the north and south elevations. This space is subject to heat loss from the uninsulated attic space below and cold material temperatures from the roof and adjacent parapet during the winter months. Within proper relative humidity and temperature parameters, dew point is reached with condensation forming within the unventilated space. The gusset sheathing and framing consists of ¾-in. CDX plywood over untreated 2- x 4-in. framing. These details were saturated and observed in various states of decay. Mold growth was observed on the underside of the plywood sheathing, and 100-year-old steel 8d-framing nails were observed to be rusted through.

At the crenelated parapet, a continuous copper through-pan flashing extended horizontally across the crenel and beneath the merlon stones. When removing merlon stones to confirm as-built attachment methods, it was observed that the workers had installed the specified stainless steel pins to anchor the merlon stones, but had only installed them 1 in. above the through-pan flashing. The ⅝-in. stainless steel pins were epoxied into the parapet, wrapped in copper, and soldered to the through-pan flashing. The 1-in. pin height was insufficient to anchor the stones in place. Under a side load of snow and ice in the gusset area, the merlon stones could easily become dislodged (see *Photo 8*).

SUMMARY OF INVESTIGATION FINDINGS AND CONCLUSIONS

Based on data collected and observations made during the ECS copper roof system inspection of the chapel, the following conclusions were formulated.

As a result of a combination of both design and installation issues observed during our inspection, the flat-seam copper roof systems on the gusset areas of the chapel had prematurely failed. Properly designed and installed, a comparable copper roof system should have an expected service life of 75 to 80 years with no significant scheduled maintenance requirements.

As a result of the prematurely failed performance of the roof system, as well as the systemic issues observed, it was recommended that the entire copper roof and drainage systems on the chapel be redesigned and replaced. Immediate short-term remediation was recommended as a priority maintenance requirement, with the expectation and intent to prevent further water

Photo 9 – Nave parapet wall vent construction in 2012.

infiltration into the building within the next (one) year. The short-term repair objective was achieved by applying a strip cover to all solder joints and material gaps within the low-slope copper gusset system, using a methyl methacrylate-based (MMA) system, using a copper primer, mat, and coating process. The short-term repairs were not considered a permanent solution, as only a full roof system replacement would provide the service life and performance of the originally intended system.

The presence of significant moisture at various locations within the copper roof and gusset systems promoted mold growth and deterioration of wood components within the substrate system. For this reason, it was recommended that permanent remediation (and the resultant drying of the roof substrate) should occur within one year.

A complete roof and drainage system replacement with both 20-oz. copper standing- and flat-seam systems was advised, based on the performance, service life, and low maintenance requirements of copper systems.

In addition to performance advantages, the copper systems are compatible and representative of the historic fabric and architectural style of the chapel.

It was further recommended that the replacement system be properly designed and specified in accordance with all considerations and standards of copper roof and drainage systems. The installation of the system would be performed only by prequalified, competent tradesmen familiar with industry standards pertaining to copper and with demonstrable experience in working on projects of similar size and scope. In the new roof design, the 2000 flat gusset (and cavity) area would be eliminated, reverting back to the original gutter and roof drainage configurations.

Based on the results of the ECS, the owner commissioned a "basis-of-design" document from our firm that would outline new design elements and a scope of work that would address the systemic failures. Having been through a ten-year remediation process, the owner was skeptical of a redesign that would incorporate the same historic copper systems and improve overall building performance. In January of 2012, the decision was made by the owner to replace all copper roof, flashing, and drainage systems on the chapel. Our firm was awarded the contract to redesign, specify, and manage the construction process. The owner's expectation was that water infiltration issues would be eliminated and appropriate system service life would be attained, with improvements in overall building performance.

Although the copper systems were only 11 years old at this time, the 2000 installation was unable to be salvaged or warrantied. With a new budget and approximately $150,000 in damages to the building, a new envelope redesign began for the chapel.

2012 CHAPEL REDESIGN

The 2012 redesign of the chapel building envelope system restoration began by acknowledging the owner's intent to use the original materials and configurations specified by Henry Vaughn, the original architect. Where possible, the owner wanted to enhance building envelope performance by incorporating contemporary materials and technology. In new construction, the building is designed with consideration of modern materials and technologies. In historic restoration, the designer must work within the parameters of an existing building or architectural style. Gothic architecture presents some unique challenges to the modern designer. For example, decisions must be made to ventilate or insulate a building that historically may have had neither system. Providing enhancements to thermal performance in buildings with large open spaces; columnar supports with ceiling heights in excess of 50 ft.; solid masonry walls; large areas of single-pane, uninsulated stained-glass panels, etc.; all require careful consideration by the designer. Even one of the most prominent features of Gothic architecture—the crenelated parapet (or battlement)—provides a challenge to utilizing the "passive roof ventilation" system so common in modern design. Contemporary materials and technologies can enhance the performance of historic structures, but the designer must perform due diligence to avoid costly design mistakes. The following are some of the design challenge issues addressed in the 2012 redesign of the chapel subject property.

Copper Roof System Insulation and Ventilation

Many traditional Gothic structures had neither roof ventilation nor insulation systems as a part of their original design. These buildings had various heating systems for the occupants' comfort, but air-handling ductwork to support those systems was the extent of passive air handling within the structure. The decision to insulate the roof system should be based on careful thermal and dew point calculation, as well as return on investment (ROI), but should also be supported by common-sense justification. After all, insulating a roof above a 50-ft. ceiling supported by solid masonry walls that contain hundreds of square feet of single-pane, uninsulated stained glass, will not likely make a large reduction in the owner's heating costs.

However, the decision to insulate (and ventilate) the roof systems of the chapel was

Photo 10 – 2012 vented and insulated roof assembly.

based on other performance considerations. While adding R-value to the roof system was calculated to produce slight reductions in heating costs, the cost of design and installation of those systems produced an extended ROI. The owners were skeptical. However, a more significant consideration than the reduction of heating costs was the moderation of the roof and “attic” temperatures. This was accomplished by designing a both ventilated and insulated roof assembly (see *Photo 9*). Such an assembly reduces the extreme temperature operating parameters to which the original system was exposed.

Thermaldynamics are one of the most important design considerations in copper roof systems. The cyclical thermal elongation and contraction of copper assemblies occurs on a daily basis. When material and substrate temperatures reach extremes, so do the thermal stressors on the copper components. Although adequate expansion provisions (i.e., expansion joints) are an essential component of the copper design process, moderating the temperature variations the system is exposed to reduces dynamic stresses on the copper components. The combination of mechanical expansion provisions and assembly temperature moderation result in extended system service life and reduce the potential for premature material failure.

The same principles were also applied to the decorative wood ceiling below the nave roof. The ceiling material is 1¼- x 6-in. red oak and is located approximately 18 in. below the roof sheathing. This “cavity” space is empty, with no insulation. Measured thermal parameters indicated summer temperatures in the 115 to 142° daytime range. The oak ceiling below the cavity space is ornamental, with hand-carved icons. An inspection revealed the drying effects of cavity temperatures on the ceiling and icons in the form of excessive cracking and splits within the wood assembly. Moderation of the substrate and cavity temperatures will benefit the ceiling assembly, as well.

The decision was made to incorporate the insulation and ventilation systems into a single assembly located above the roof deck. A waterproofing layer was required for tong-term protection of the building interior. As the chapel is located in cold Climate Zone Six, the waterproof “air barrier” was required to be installed on the roof deck, under the insulation. The design concerns were how best to insulate above the roof deck and provide passive ventilation when all roof eaves terminated at the crenelated parapet/gusset detail.

A system was designed utilizing a “faced” polyisocyanurate (iso) product manufactured by a prominent insulation manufacturer. This “ventilated” system was specified to incorporate two layers of 2½-in. iso with top panels “faced” with ¾-in. CDX plywood bonded to 1½-in. “biscuits.” These biscuits provide a 1½-in. omnidirectional airflow space between the CDX and top layer of iso. The system is vented at the ridge with a conventional copper ridge vent. Venting the parapet (eave) of the passive system required the design of a ventilated wall assembly. This system incorporates a continuous vertical wall vent, providing contiguous airflow from the elevated wall vent into the 1½-in. insulation panel vent, resulting in the requisite air intake at the eave with the exhaust at the ridge.

Dew point calculations for the assembly

were performed, and airflow calculations for this system indicate positive dynamic pressures within acceptable CFM displacement parameters. The system is constructed of composite framing materials and covered with copper. The roof-waterproofing layer is comprised of two layers of a self-adhesive ice and water shield applied to the sheathing surface. This "ventilated insulation" assembly was installed at all roof surfaces and parapet walls (see *Photo 10*). In order to ensure system performance during periods of snow and ice accumulation, a commercial-grade heat-trace system was installed at the intake of the ventilated wall assembly, as well as at the adjacent copper gusset.

Materials Testing and Due Diligence

Most architectural designers are constantly searching for ways to improve the efficiencies of their designs and assemblies. Technological development in the construction materials industry within the last 25 years has moved forward at an unprecedented rate. The results have been mostly positive, but not all new products are appropriate for every application. As designers, it is incumbent upon us to perform our own due diligence. Slipsheets under metal roofing have been used since the mid-18th century. Surprisingly, they have evolved very little from their organic, cellulose composition. "Four-pound rosin paper" has been a standard specification under metal roofing for a long time.

When a colleague told me about a "new" synthetic, highly permeable (but waterproof) underlayment for metal roofing, I was anxious to try it on this project. I read the cut sheet and material safety data sheets (MSDS) but had questions. I called the manufacturer and asked (among other things) about the melting point for the product. I informed the "tech rep" that I wanted to use it under flat-seam copper roofing that would be soldered. The rep stated he didn't know but would look into it. He contacted me and stated that he didn't know the "melting point," but the product was formulated to be used under copper to be soldered. I then contacted a local distributor who informed me that "this product has a higher melting point than high-temperature ice and water shield." We decided to perform our own testing. We ordered a roll of the product, built a mock-up, and applied flat-seam copper pans to be soldered on top of the "new" underlayment. When the soldering iron touched the copper, the new product instantly melted. We added a layer of 30# felt, and it still melted. We added a second layer of 30# felt and a layer of rosin paper over the new product, and it melted again, although not as severely. I then called the president of the company, who after doing some "research," informed me that the product melting point was 330 degrees. When I stated that the melting point for 50/50 solder is 365 to 419 degrees, he suggested I only use it under standing-seam copper. Had we not performed our own testing, the product failure while work was in progress could have resulted in a significant change order—or worse, could have gone undetected. As designers, it is essential that we research and test products with which we are unfamiliar (see *Photo 11*).

Photo 11 – 2012 semitransept roof flat-seam copper installation.

Photo 12 – Nave aisle roof gusset expansion joint and wall vent assembly (2012 installation).

Thermaldynamic Considerations for Copper Systems

One of the most important components of a functional copper roofing design is the allowance for cyclical thermal movement within the entire system. If this movement is not provided for in the design documents, the resultant material stresses can cause premature failure of the copper and its components. The 2000 design of the flat-seam copper roof system of the chapel did not call for any expansion joints. The two largest systems are approximately 135 ft. long and 8 ft. wide. Utilizing a generic thermal movement calculator, each system will migrate approximately 1¾ in. longitudinally and ¼ in. vertically every 24 hours. Thermal elongation forces are omnidirectional, and they occur in cyclical progression. These forces are created mostly by solar gain and are affected by temperature extremes, speed of temperature transition, and asymmetrical temperature exposures (i.e., snow load on a copper roof on a sunny winter day). The flat-seam copper gusset roofs on the chapel require a large "box-type" expansion joint every 33.5 ft. These box expansion joints are framed into the roof deck and extend from the gusset to the through-pan flashing (approximately 36 in. high) and up-rafter to the standing-seam roof transition (established water table) for a length of approximately 7 ft.

The expansion requirements for the steep-slope roof area can be accommodated with expansion locks at the ventilated ridge caps and at the standing-seam eave termination. Expansion joint configuration and spacing requirements are defined by conditions such as square-foot areas and lineal-foot measurements of copper systems, roof pitch, locations, and frequency of through-copper penetrations (including walls and parapets), etc. While there are

Photo 13 – 1935 Aeolian-Skinner organ protected during construction.

standard criteria and configurations for copper gutter expansion joints, the requirements for copper roofing systems or large copper details are more diverse and complex. In large-scale copper design, the various copper organizations are an excellent design resource.

Copper thermal provisions can be simple or complex, and requirements vary by size, configuration, and project. A simple axiom is "if you specify copper, you need to specify provision for its movement" (see *Photo 12*).

Quality Assurance

As specifiers and designers, we have measures at our disposal to ensure a successful and high-quality project for our clients. Quality assurance should extend beyond a "boilerplate" section in the project manual. Some assurance requirements are obvious, such as "contractor qualification" and "project management." However, other project issues require specific consideration. Listed below are several quality assurance measures specified in the chapel project documents.

Pipe Organ

The chapel pipe organ was manufactured by Aeolian-Skinner in 1935. The company was a noted American builder of high-quality pipe organs for important cathedrals across the U.S. The company closed for business in 1972. The instrument is impressive, standing approximately 35 ft. tall, is composed of over 5,500 pipes. The organ loft is housed directly under the north-elevation, semitransept roof. The complete covering of all pipes by a professional organ restoration company was required. The owner inquired about the need for and cost of the covering. They were told that construction dust could damage the organ to the point of requiring rebuilding. The owner was uncertain of the value of the organ, so we commissioned an appraisal. The value was established at $4.1 million for the organ and $750,000 for the console. The estimate to restore the organ if damaged by dust was $175,000 to $250,000. The organ was subsequently protected per our project documents, prior to the project start date (see *Photo 13*).

Mock-Up Process

The mock-up process is particularly useful as quality assurance for a copper roof installation. One of the principal causes of premature failures within copper systems is a failed solder joint. Full-size mock-ups should be created to demonstrate both horizontal and vertical seams, as well as any difficult solder applications, in order to assess the contractor's ability to solder correctly. The seams should be dismantled after soldering to verify adequate coverage of the solder throughout the soldered joints. Mock-ups of all copper details specified should be created as a quality standard for all as-build details.

Water Testing

Prior to the installation of copper, water testing should be performed, where possible, on all waterproof underlayment systems. The gusset areas behind the parapets on the chapel were identified as priorities for water testing. They are also the locations for the roof drains and scuppers. These susceptible areas were specified to receive two layers of ice and water shield. After performing the requisite live-load calculations, water tests were performed after the installation of the first membrane layer by blocking the drains and scuppers. The gussets were then flooded with 12 in. of water. After successful testing, the second layer of ice and water shield was applied just prior to the copper gusset system installation.

Contractor Qualification and Project Management

Thorough vetting of contractors asked to perform "specialty" roofing services is essential. Our qualification statement contains five pages of information relevant to the scope of the work. The information requested includes extensive project-specific references, financial information, and criminal offender record information (CORI) forms for employee background and security checks. Managing the successful contractor during the project keeps everyone on track. Meticulous project records and documentation are essential. "Specialty trades" require above-average skill sets. The essential quality of the work varies among companies and employees within the same company. Watchful oversight can benefit the owner and contractor, as well.

Peer Review

Peer review of design work is an often overlooked but critical component of the design and specification process. It can be beneficial (and humbling) to have one's peers review one's work. A "fresh" perspective can lend credibility and integrity to a project. There were four peer reviews of the design work done on the chapel.

SUMMATION

The premature failure of the high-quality building envelope system on the historic chapel in 2000 was both unfortunate and avoidable. Poor design and poor workmanship were equally to blame. While knowledge of some historic materials and processes is both nuanced and specific, there are resources available to designers and contractors alike. Our peers and material manufacturers are good places to begin. When we are challenged by combining modern building technologies with historic applications, we are required to do our due diligence to ensure a successful project outcome. We owe that to our clients and our historic buildings.

EDITOR'S NOTE: This article is republished from the Proceedings of the September 2012 RCI Building Envelope Technology Symposium.

Robert Fulmer

Robert Fulmer specializes in analysis, diagnosis, and integration of historic and contemporary building envelope issues, providing specification and oversight of appropriate remedial solutions. Recognized as an expert in copper and slate roofing, he has consulted on significant projects throughout North and Central America. Fulmer is a published author of trade-specific articles and has lectured throughout the U.S. on historic preservation and building envelope topics. He is qualified as an expert witness in roofing litigation. He is past president and currently on the board of the New England Chapter of RCI. He is the current senior vice president of the National Slate Association.

DUBAI RETROFITTING 100,000 BUILDINGS

Dubai, one of the wealthiest places on the planet, has plans to go green. The Dubai Supreme Council of Energy, in partnership with the Dubai Electricity and Water Authority, has announced plans to retrofit 100,000 buildings. The move is part of a plan to diversify Dubai's energy mix to comprise 71% from natural gas, 12% from nuclear, 12% from "clean coal," and 5% from solar power. The first phase of the private-public project will retrofit 30,000 buildings with green technologies, with total project completion expected by 2030.


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Industry Groups to Coordinate Green Building Standard Development

The International Code Council (ICC), ASHRAE, the American Institute of Architects (AIA), the Illuminating Engineering Society of North America (IES), and the U.S. Green Building Council (USGBC) have announced the signing of a memorandum to collaborate on the development of Standard 189.1, the *International Green Construction Code* (IgCC) and USGBC's Leadership in Energy and Environmental Design (LEED) green building program.

The unprecedented cooperation aims to create a comprehensive framework for jurisdictions looking to implement and adopt green building regulations and codes and/or provide incentives for voluntary leadership programs such as LEED.

The agreement outlines the development, maintenance, and implementation of new versions of ANSI/ASHRAE/IES/USGBC Standard 189.1, *Standard for the Design of High-Performance, Green Buildings Except Low-Rise Residential Buildings,* and the IgCC, which will be combined into one regulatory tool. This agreement also endeavors to align the LEED program with the new code to ensure a streamlined, effective set of regulatory and above-code options for jurisdictions across the country.

"Architects have become the leaders in employing green building techniques; and the IgCC, a valuable regulatory tool, provides support leading to the creation of a sustainable, resilient built environment," said AIA CEO Robert Ivy, FAIA. "This agreement, which underscores the AIA's dedication to sustainable design and construction, should lead to more rapid adoption of responsible approaches by designers, builders, developers, and a host of other building industry groups."

"ASHRAE sees this as a move forward in green building, reducing fragmentation of compliance documents for users who are pressing toward a more sustainable environment," ASHRAE President Tom Phoenix said.

"Working collaboratively with our industry partners is producing real results that will help improve building performance, streamline regulation, reduce cost, and allow us to focus our resources on goals we have in common," pronounced Dominic Sims, CEO of the ICC. "This agreement continues the partnership we began in 2012 and assures that our members and partners have a meaningful role in shaping the future of the built environment."

Rita Harrold, IES director of technology, noted, "IES members will benefit from this alignment of both regulatory and voluntary tools, and we look forward to participating in delivering technical provisions for code-intended adoption."

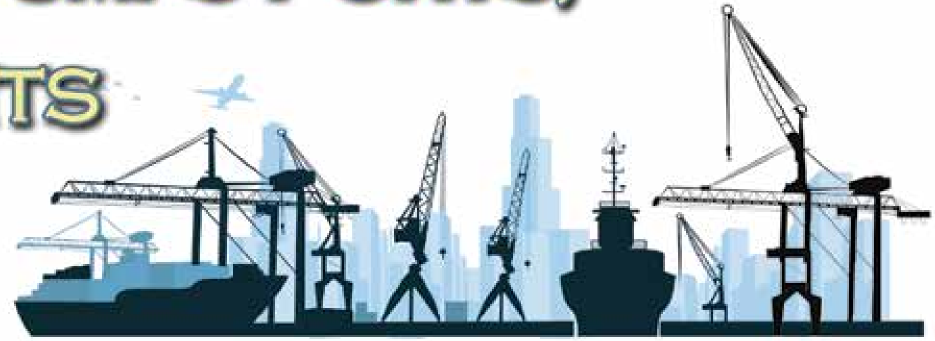
"This landmark agreement will leverage the unique strengths of each of the five partner organizations to deliver a coordinated, integrated suite of green building tools—an ANSI standard as the basis of a regulatory code to push the market and a rating system to pull the market higher," said Brendan Owens, vice president of the USGBC. "We are collectively dedicated to advancing green building practices and to advancing the broader industry's understanding about the importance of green building goals and how to achieve them."

—ICC

CORRECTIONS

The article "ASTM Committee D08 Honors Teitsma, Paroli, and Others at Awards Ceremony," in the August 2014 issue of *Interface*, had several errors—none of them the fault of the author, Walt Rossiter. Jerry Teitsma's last name was misspelled in the head. The caption on Ralph Paroli's photo should have listed his honor as the Distinguished Leadership Award. The cutline on David Vokey should have said he received his plaque of appreciation for leading the development of D7877, *Standard Guide for Electronic Methods for Detecting and Locating Leaks in Waterproof Membranes.* Vokey is not retiring from the committee. Similar errors were made in the related article in RCI's member newsletter, *RCItems.*

Panamax Pumps Ports; Riverfronts Revitalize



By Ken Simonson

PANAMAX PUSHES PORT PROMOTION

"Investment in industrial real estate on the East Coast has soared, particularly near the ports [that] are expected to be able to accommodate the bigger [container] ships, called post-Panamax vessels," after widening of the Panama Canal is completed in early 2016, the *Wall Street Journal (WSJ)* reports. More than 12 million sq. ft. of new industrial space is under construction at eastern and southern ports as a result.

"While construction in Norfolk [VA] has been limited, Baltimore [MD] has 4.9 million sq. ft. of new space on the way. In northern New Jersey, which jointly operates its port with New York, there are an additional 2.6 million sq. ft. of new warehouse space being built," according to Cassidy Turley, a commercial real-estate firm. Though not yet ready, the ports of Houston, TX; Charleston, SC; Savannah, GA; Miami, FL; and the Port of Everglades in Fort Lauderdale, FL, all are expected to be expanded and ready by 2016. "There is new warehouse space under construction in all of these markets," the *WSJ* article stated. In addition, "Houston leads all but three U.S. metropolitan areas in the construction of industrial space, with more than 4.7 million sq. ft. under way."

RIVER REVIVALS

Developers increasingly are looking at downtown waterfronts in small cities such as Cleveland, where prices are still low and returns could be high, notes Christopher Leinberger, a specialist in land-use strategy quoted in the *WSJ*. Plans approved in June by Cleveland's city council for a $700 million downtown waterfront development illustrate trends occurring in many metro areas. The downtown's population has risen by 88% since 2000, according to a Downtown Cleveland Alliance report. "With an office-vacancy rate of 18.5%, Cleveland's developers have chosen to turn old office space into apartments rather than build new construction."

MANUFACTURING MOUNTS

New construction starts for July climbed 6%, while for "the first seven months of 2014, total construction starts… were reported at…a 4% gain compared to the same period a year ago," according to McGraw Hill Construction. "Manufacturing plant construction is seeing the start of numerous chemical and energy-related projects, consistent with the nation's growing energy sector. Commercial building is maintaining its upward momentum from low levels, while institutional building with its up-and-down pattern appears to be stabilizing after a lengthy decline."

DEMOGRAPHICS DEPRESS CAMPUS CONSTRUCTION

Construction at private colleges is being affected by unfavorable demographic and financial trends. Marketplace Radio reported, "In the '90s, birth rates fell nationally. On top of that, lots of people migrated south and west. That all spells a decline in high school graduates in the Northeast and Midwest today," according to Brian Prescott, who directs research at the Western Interstate Commission for Higher Education. Prescott estimates there has been a 7% drop in high school graduates in the middle of the country just over the past six years.

A study by Sallie Mae and Ipsos, "How America Pays for College 2014," states, "Families reported the highest enrollment in two-year public colleges since the survey began [in 2008] (34%, up from 30% last year). In addition, students opted to attend in-state institutions (69%), cut back on entertainment (66%), or live closer to home (61%) or at home (54%), among other cost-saving measures, to help reduce the cost of college." Census Bureau data shows private higher education construction spending dropped 4.2% in the first five months of 2014 compared with January-May 2013, following a 7.6% fall from 2012 to 2013.

Ken Simonson

This series on the economy and its impact on the construction industry is published quarterly in Interface. *The column is prepared by Kenneth D. Simonson, chief economist for the Associated General Contractors of America (AGC). Simonson was the 2012-13 president of the National Association for Business Economics. He may be reached at simonsonk@agc.org.*

Balfour Beatty Spurns Merge Offer

Construction firm Balfour Beatty has spurned a third offer to merge with Carillion after its smaller rival upped the ante with an improved bid valuing the combined company at £2.1 billion. Under UK takeover rules, Carillion will not be able to make another approach until February 2015. Balfour Beatty is the UK's largest construction firm and has reiterated its determination to sell Parsons Brinckerhoff, the U.S. design and consultancy business that Carillion wants to keep in a combined company.

SMACNA Elects Officers

The following officers were elected to serve terms on the Sheet Metal and Air Conditioning Contractors' National Association (SMACNA) board of directors beginning in October: President Tom Szymczak, President-Elect Guy Gast; Secretary/Treasurer Joseph R. Lansdell; Vice President Jack Knox; and Immediate Past President Randy Novak.

ABC Earns Workplace Award

ABC Supply Co., Inc., has been honored for the eighth time with the Gallup Great Workplace Award. It is one of only 36 companies in the world to receive the 2014 award. The award is based on multiple criteria, including response rates, overall engagement levels, and evidence of engagement's impact on performance.

GAF's Habitat Partnership Roofs 700 Homes

GAF, which committed in 2011 to matching its own roofing materials donations with installation services donated by GAF Master Elite and Certified Contractors across the U.S. for Habitat for Humanity (HFH) has reached its three-year mark. The collaboration has contributed to building over 700 homes for families in need. Over 460 of GAF's certified contractors have signed up for the program and are working with their local HFH affiliates.

IKO Opens New Alabama Plant

IKO Industries has announced the official grand opening in October of its newest facility producing asphalt shingles and related roofing materials in Sylacauga, Alabama. The plant is largely automated but has created 50 new jobs. The company now has more than 30 plants in North America and Europe. The family-owned business was established in 1951.

A.C.T. Metal Deck Supply Opens Center

A.C.T. Metal Deck Supply has announced the grand opening of its 13th distribution center, in Albany, NY. A.C.T. Metal Deck has been in business for 42 years.

To submit an industry news item to *Interface*, e-mail it to kammerman@rci-online.org or mail it to RCI, *Interface* Journal, 1500 Sunday Drive, Suite 204, Raleigh, NC 27607

Note: News must fit journal requirements in order to be published.

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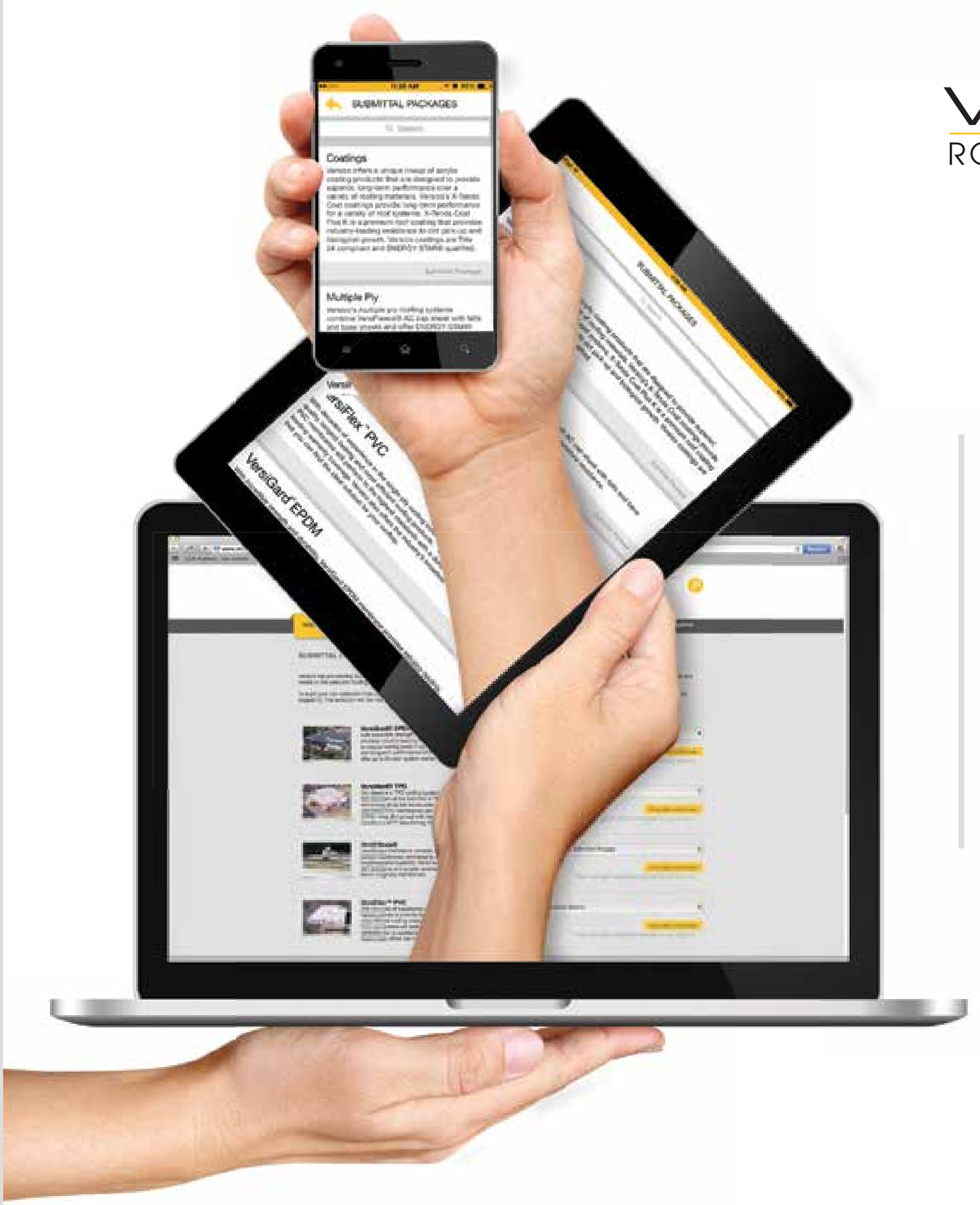
SUBMITTAL PACKAGES
Coatings
Multiple Ply
VersiFlex PVC
VersiGard EPDM

calendar of events

OCTOBER 2014

1-3	Metalcon Info: metalcon.com	Denver, CO
2-3	Waterproofing	New Orleans, LA
4	RWC Exam *(applications due 7/3/14)*	New Orleans, LA
3	Region I meeting	Baltimore, MD
5-6	Symposium on EIFS Info: astm.org	New Orleans, LA
6	Delaware Valley Chapter golf outing	Lopatcong, NJ
9-10	Roof Technology & Science I *Delivered by RCI SoCal Chapter* Info: rcisocalevents.org	So. California
12-15	SMACNA Convention www.smacna.org	San Antonio, TX
16-17	Rooftop Quality Assurance *Delivered by RCI Canadian Prairies Chapter* Info: rcicpc.org	Red Deer, AB
17	Ontario Chapter meeting	Waterloo, ON
20-21	Symposium on Building Envelope Technology	Tampa, FL
22-24	Greenbuild International Conference & Expo Info: www.greenbuildexpo.com	New Orleans, LA
31	Northern Gulf Coast Chapter golf tourney	Pensacola, FL

NOVEMBER 2014

6-7	Leadership Development Workshop	Raleigh, NC
6	Roof Systems Thermal & Moisture Design	Langley, BC
7	RRC Review & Update *Delivered by RCI Western Canada Chapter* Info: rciwesterncanada.org	Langley, BC
7	Chicago Area Chapter meeting	Oak Brook, IL
13-14	Exterior Walls Technology & Science *Delivered by RCI Carolinas Chapter* Info: rcicarolinas.org	Charlotte, NC
15	REWC Exam *(applications due 8/15/14)*	Charlotte, NC
18-19	Roof Technology & Science I	Atlantic City, NJ
20-21	Roof Technology & Science II	Atlantic City, NJ
20-21	Metal Roofing *Delivered by RCI Ontario Chapter* Contact: rci-ontariochapter.ca	Toronto, ON

DECEMBER 2014

3-5	Construct Canada Info: constructcanada.com	Toronto, ON
4-7	Exec. Committee winter meeting	Marco Island, FL
5	*Applications due for 3/6/15 RWC and REWC exams*	
10	Roof System Thermal & Moisture Design	Orlando, FL
11-12	Professional Building Consulting *Delivered by RCI Florida Chapter* Info: rciflorida.org	Orlando, FL
10-11	Professional Building Consulting	San Francisco, CA
12	Vegetative Roofs for the Design Professional	San Francisco, CA
10-12	MRCA Convention & Trade Show Info: mrca.com	Grapevine, TX

Red print:	RCI Education or Registration Opportunity
Blue print:	RCI Leadership Event
Green print:	RCI Region or Chapter Meeting
Black print:	Industry Event

Calendar subject to change without prior notice.
Visit **www.rci-online.org** for schedule updates.

Scan this QR Code to sign up directly for events at rci-online.org

Dis(h) Might Work...

This new and improved way to mount a satellite dish on one's roof was discovered during a routine roof evaluation survey. Too bad the roofer coated it in, allowing water to get below the coating.

Contributed by Timothy W. Thomas, RRO, CAD
T. Brooks & Associates, Inc.
Clovis, California

Readers running across situations that would catch the attention of other building envelope consultants are asked to submit representative photographs and a maximum 150-word summary to Kristen Ammerman, Director of Publications, "Would You Look at That!" column, RCI, 1500 Sunday Drive, Suite 204, Raleigh, NC 27607; or via e-mail to kammerman@rci-online.org.


Some Folks Speak Loud
And Clear. We Listen.
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GAF®
The need for green roofing solutions is growing. GAF is proud to offer environmentally friendly options—from garden roofing to white roof coatings to residential "cool" roofing—that will meet your needs and your budget.
So you'll not only protect your property, you'll also help us to protect the precious creatures who share our planet. It's a win-win situation—after all, working to benefit more "customers" has always been our ultimate goal.
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