High Performance Roof Systems: A Standard of Care for Designers and Contractors

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Keywords

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Abstract

High-performance roofing, as the name implies, relies first on a roof system performing. As the roofing industry moves deeper into so-called environmental mandates and new materials have emerged, the “standard of care” required of designers and contractors’ customs and practices have been raised.

This paper will address the increased standard of care for architects and customs and practices for roofing contractors regarding the design and installation required to achieve high-performance roof systems. Examples demonstrating where the standard of care and installations have fallen short and recommend improvements are provided. It often is the smallest detail that results in a roof system’s failure. I will draw on empirical in-field observations to discuss various concerns resulting in roof failure and legal remedies.

Author

Tom Hutchinson graduated from the University of Illinois, Urbana-Champaign, with master's degrees in architecture and civil engineering. Hutchinson is a licensed architect and registered roof consultant, specializing in roof design, contract document preparation, specifications, inspections and determination of moisture penetration and failure of existing roof systems. He has made numerous presentations in Europe, South America, North America and Asia. His topics have included architectural contract detailing for roof systems, roof system removal and replacement, steep-slope roof system design, roof restoration and roof system maintenance. Hutchinson believes in the complete integration of all building components into a roof system design, and his work is noted for its comprehensiveness in design, detailing and specification. Hutchinson currently is a principal in Hutchinson Design Group Ltd.; past president of RCI Inc.; certified energy professional in the City of Chicago; and Secretary CIB/RILEM International Joint Committee on Roof Materials and Systems. He is a member of the American Institute of Architects, Construction Specifications Institute, RCI, NRCA, ASTM international Committee D-8 on Roofing, Waterproofing & Bituminous Materials, past president of the Barrington Rotary and region director of RCI.

Introduction

Architects, roof consultants, manufacturers and roofing contractors who enter the realm of roof system design—whether in compliance with codes, state licensing laws or not—consequently are bound by a "standard of care" that addresses performance and life safety issues. Contractors, as well as installers, are bound by industry customs and practices. Recent observations by this author throughout the U.S. have revealed many are falling short of this standard of care or not living up to these customs and practices—with devastating results: roof deck collapses, roof blow-offs, loss of property and expensive litigation. Many of the shortfalls are what some would consider small concerns that had significant effects. Following are design elements, installation concerns and issues I have observed along with comments and recommendations regarding how these costly errors could have been avoided. As the famous architect Ludwig Mies van der Rohe said, “God is in the details.”

Issues of concern

Moisture drive: There probably is no greater issue currently facing the roofing industry than moisture drive. Air vapor moves from energy high to energy low—that is, warmer air wants to move to cooler locations to equalize. The advent of loose-laid single layer insulations—mechanically fastened and covered with mechanically fastened light-colored roof covers that can billow and draw up warm moist interior air—has resulted in massive condensation issues, including some that have led to the largest roof litigations in the U.S. I have observed ice of up to 1.27 cm (0.5 inches) thick below watertight roof membranes (see Photo 1). It is interesting that this issue—a result of physics—can be traced back to the unbridled endorsement of cool roofs by well-known physicists, including our current Energy Secretary. The rush to be LEED®-compliant (a lemming-like mentality) appears to have resulted in design professionals forgetting that allowing warm, moist conditioned air to move through a roof assembly to a loose façade material that is cold is not a good idea. The additional concern is that the so-called cool roof membranes are cool—so cool they do not warm enough to drive the built-up moisture back to the interior, resulting in a roof assembly that is not self-drying.

Photo 1: Ice below roof membranes, the result of condensation, is a conundrum for architects, contractors and those in the cool roof movement.

Lesson learned No. 1: Remember the laws of physics: Air containing moisture condenses on cold surfaces, regardless of where the cold surfaces are located. Remove the condition that allows air movement (i.e. air barrier), or remove the cold surface (i.e. non-highly reflective surfaces).

Water -based adhesives: As with cool roofing, there has been a rush to change the roofing industry by those who have little or no knowledge regarding roofing and roof system design, have absolutely no investment in the industry, and pay nothing if their mandates fail. Proponents now have come up with the "bright" idea of water-based adhesives. Currently roofing is a 12 month a year activity, with temperatures below freezing in much of December – March in a good part of the country, the use of water based adhesives will prevent many roof systems from being installed during these months. As I write this paper, it is 4 °F outside—so much for winter roofing. The idea of using water-based adhesives that are not water-resistant, freeze-resistant or useable during a good portion of the fall, winter and spring in a major portion of North America for the installation of roofing materials is concerning. Project failures involving frozen and thawed adhesives, partially frozen adhesives, and/or adhesives compromised by moisture (condensation) are on the rise. Although most roofing professionals want to do their part for the environment, they often cannot control the project, and specifying materials that are extremely temperature- and moisture-sensitive, such as water-based adhesives, on a roof is not prudent.

Lesson learned No. 2: Know your climate, project schedule and product's ability to resist temperature and moisture to increase potential long-term success.

Spray foam adhesives: This author particularly likes the potential spray foam adhesives have. Applied correctly, spray foam adhesive is a tenacious adhesive, adhering to insulation, roof membranes, glass, rooftop mechanical equipment, metal flashing, clothing and cars with particular persistence; for that reason, it can provide excellent wind-uplift resistance. The key to the successful performance of spray foam adhesive is full coverage contact between the substrate and roofing materials, proper roof deck preparation, application on level surfaces to which the insulation and/or cover board can be rolled into and adhered, as well as proper temperature and humidity at time of installation. Problems arise when the roof deck surface is not level (undulates), cleaned or properly prepared, the application is poorly specified, and/or installers believe the adhesion is so good that the material can be

Photo 2: For spray foam adhesives to properly secure materials together, the materials need to be compressed through rolling and not rely on gravity and/or foot traffic to do so.

dropped (without properly setting the insulation) in place and they can continue. I have investigated numerous roof system blow-offs in which the roof deck was fully coated with foam adhesive but the insulation board had little or no contact with the adhesive because it never was pressed in place by using a water roller, which is an installation step manufacturers require (see Photo 2). Using insulation boards with thicknesses greater than 3.8 cm (1.5 inches) also prevents positive bonding on uneven surfaces because of the board's inability to deflect.

Lesson learned No. 3: Insulation, cover boards and membranes installed with spray foam adhesive only can adhere if they touch the adhesive. Rolling the material into the adhesive to assure positive adherence is mandatory. The weighting of the insulation with items such as adhesive cans alone is insufficient.

Bead foam adhesives: Bead foam adhesives have gained enormous popularity during the past few years and when installed correctly can provide excellent adhesion and a nice alternative to hot asphalt and full-coverage spray foam, which have certain drawbacks. The key here is "installed correctly". Proper preparation of the roof deck surfaces is required. I have seen foam beads set on concrete roof decks so full of contaminates that the beads were able to be hand-lifted off without resistance. Spacing and size (diameter), as well as compression of various

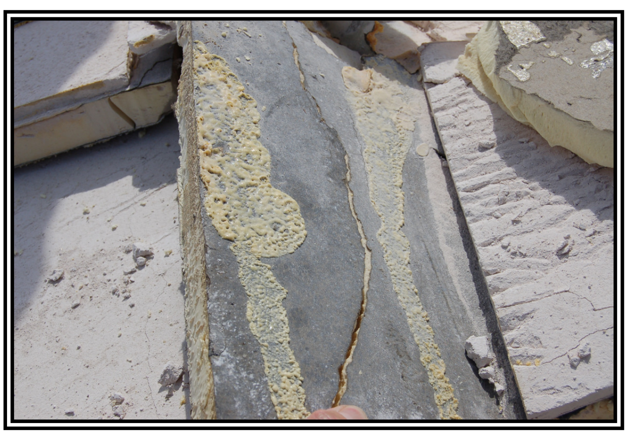


Photo 3: Bead foam adhesives must be applied to clean substrates, and the materials to be adhered must be **compressed through rolling to assure a quality bond and eliminate creation of an air space between foam beads.**

insulation layers, is a concern. Manufacturers typically claim that if the beads are installed at 10.2 cm (4 inches) on center it is comparable to full-coverage spray foam. Human nature and physical tolls often result in spacing that increases as the applicator tires. Additionally, similar to the full-coverage spray foam, the rolling or weighting of insulation/substrate boards into the foam to achieve positive bonding is required, and from my experience, seldom is performed (see Photo 3). Thicker boards make bonding a challenge as well.

Two concerns arise: The adhesive bond is compromised and therefore the wind uplift resistance is reduced, and a void or interstitial space is created when the materials being adhered are not compressed adequately. Stepping insulation and/or substrate boards into place is not adequate and not a method approved by manufacturers. The void created is an excellent avenue for air movement. This air can be a result of infiltration at the roof edge, which helps facilitate lifting the insulation off the roof system, and moist air from the interior, which may manifest itself as condensation within the roof system. Moisture in the insulation facers is a precursor to delamination, possibly resulting in wind uplift and wind damage. Neither condition is desirable.

Lesson learned No. 4*:* Quality assurance regarding surface preparation, bead spacing, and rolling to compress the insulation into bead foam to eliminate air spaces and achieve positive bonding is critical to success.

Concrete roof decks: Common sense assumptions might tell you that a concrete roof deck is an outstanding substrate onto which a roof system can be applied. That may have been the case when little if any insulation was applied and roof systems mostly

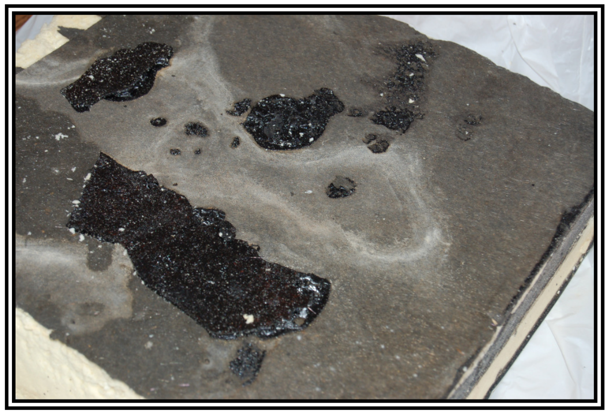


Photo 4: Concrete roof decks can undulate and create depressions where adhesives need to be installed "heavy" and insulation layers need to be thin to conform to the deck profile. Here, the asphalt was not installed heavily enough and the insulation board was too thick to conform. Note the moisture stains, as well.

were bituminous, but current realities tell us concrete roof decks are never a smooth plane surface but rather a quickly screeded surface often filled with depressions, waves and surface laitance. I have seen roof decks with depressions approaching 1.9 cm (3/4 inch) in 2.4 m (8 feet), such that insulation boards actually spanned the depression, making the asphalt adhesive ineffective (see Photo 4). Concrete roof decks must be inspected and string lines or lasers set upon them to determine the surface plane. Insulation needs to be specified in thin layers of 2.5-3.8 cm (1-1.5 inches) so the boards can conform to deck undulations, and adhesive must be installed heavily enough at times to fill large voids, or a layer of surfacing is needed to smooth the substrate. Concrete roof decks must be dry as well. "Curing" is a term used by engineers to describe a time needed for concrete strength; it has no correlation to concrete's dryness. Drying is a function of substrate, temperature, climate, and concrete thickness and mix, and can take months. Rewetting concrete after installation can result in further wetting and extended required dry times.

Lessons learned No. 5: Concrete roof decks must be approached with some pragmatism and understanding of conditions that may affect roof system performance. Design some contingencies; thin, multiple layers of insulation and adhesives that can be installed in heavy thickness without loss of integrity. Remember and learn the difference between cure time and dry time.

How dry is dry?: When is a new concrete roof deck ready to receive the specified roof system? Not when the general contractor says you have to install it. The first concept to understand is the difference between concrete curing and concrete drying. Concrete curing relates to attaining structural integrity; concrete drying relates to the release of moisture resulting from the hydrating process. Drying to allow for a roof system's successful application—one which will achieve long-term service life—may take months depending on the slab thickness, supporting structure and repeated wetting (e.g. rain events). In fact, it takes longer for concrete wetted after installation to dry than it does for new concrete. So when the general contractor tells you to install the roof system, how can you be sure it will perform? The author suggests testing the concrete for moisture content. Designers should specify a test and the allowable moisture content. Simple tests such as a "plate" test, in which an 18" x 18" piece of visqueen is laid over the concrete and the edges are taped and inspected after 24 hours, quickly can give you an idea of the moisture emanating and what can be expected to move into your roof system; if formality is needed, this should be performed with ASTM D4263, "Standard Test Method for Indicating Moisture in Concrete by the Plastic Sheet Method." Quantitative tests include gravimetric and moisture vapor emission rates testing. Testing for dryness should be the responsibility of the roofing contractor (as the installer of the roof system) and the results documented and forwarded to the designer/architect.

Adhesion tests are surface only tests and cannot confirm the moisture content within the concrete, which will migrate upward over time.

Lessons learned No. 6: Testing indicates when concrete is dry. Do not be bullied into installing a roof system that will have future troubles. You do not want to be in a situation where you say, “We should not have been instructed to install the roof system when the deck still had moisture within,” the general contractor can respond, “You should have told us it would be a problem!”

Treated wood: Why are we still specifying preservative treated wood!? You would think with all the discussion of concerns related to treated wood and fastener corrosion—that designers would learn to steer clear. Having observed hundreds of thousands of feet of roof edge wood blocking (using non-treated wood) with little of it deteriorated, the fact that architects, designers, and roof consultants continue their lemming-like attitudes and do not revise their specifications is dumbfounding. Treated wood that is cut to fit on site creates sawdust that, by the letter of the law, should be handled as ‘hazardous waste’, is a health risk to installers and uses fasteners that may fail when you need them most. Designers are forewarned to stay away from treated wood; most likely you will not specify the necessary stainless anchors for the wood, nor the stainless steel nails for the sheet metal anchorage anyway, so go with good ole untreated Douglas Fir—you’ll be glad you did.

Lessons learned No. 7: Designers—treated wood will “eat you” (corrode anchorage) into court. Specify the better choice of wood – Douglas Fir. Contractors—if treated wood is specified, a red light should go off, and you should ask for extra money for stainless anchors and nails if they aren't already specified.

Photo 5: There is no universal contest regarding who can create the smallest opening in single plies at roof drains. Open it up to its maximum size.

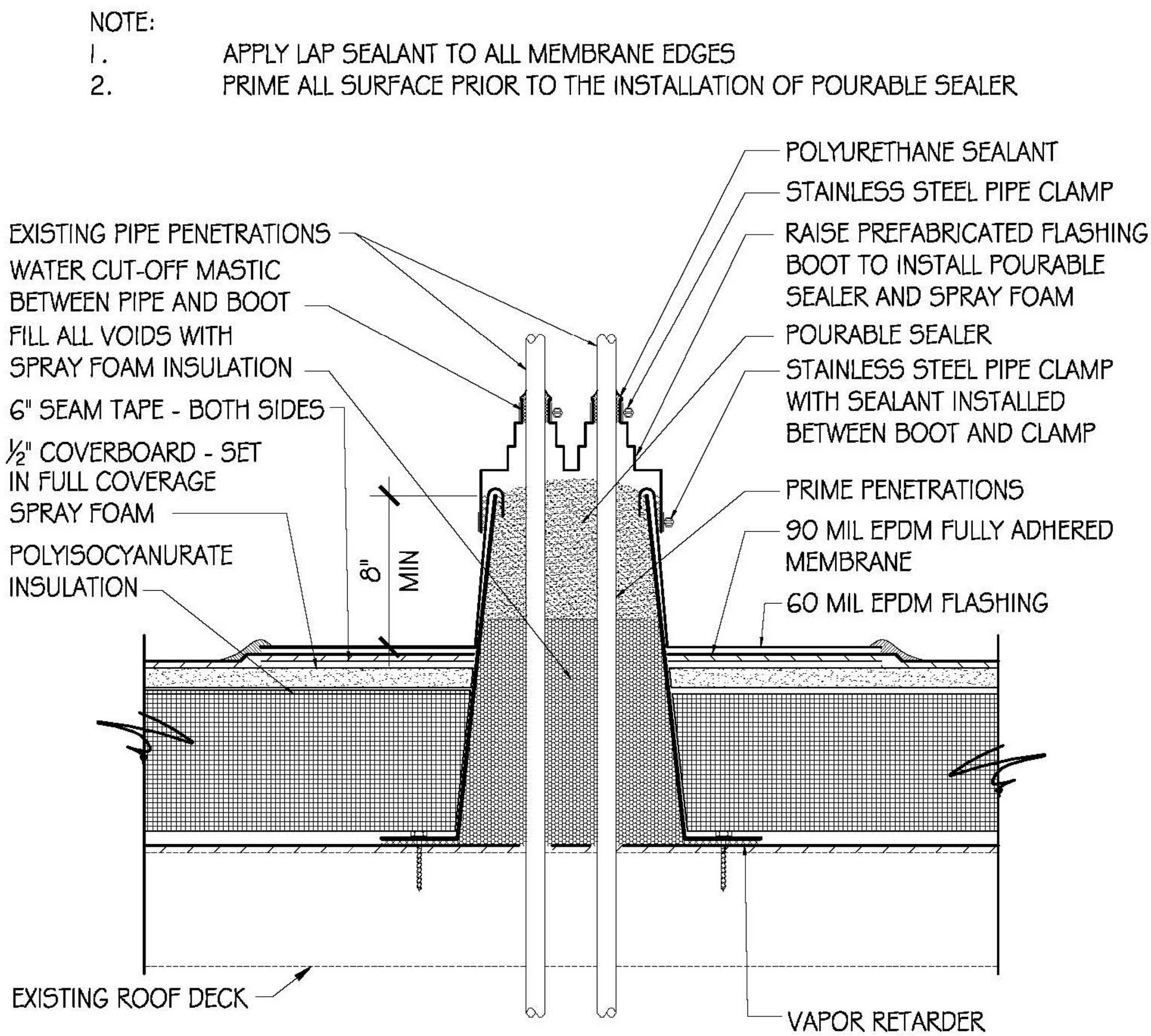
Membrane cutouts at roof drain: It never ceases to amaze me that with roof drain bowl diameters approaching 40.6 cm (16 inches) that contractors continue to cut in the smallest of drain holes; it's not a contest to see who can do the smallest cutout (see Photo 5). Roof drain bowl design is based on Bernoulli's principle, and successful water removal requires that most of the bowl is to be exposed to water flow. When you reduce the membrane's opening diameter, you not only reduce the flow of water into the drain but you minimize the "draft" generated by the cyclonic effect created by the drain bowl. This reduction during periods of heavy rain (often associated with high winds) results in temporary ponding on the roof. The effect of ponding is increased load, which with high winds can induce destabilization and cause a roof's structural collapse. Who's at fault is decided after hundreds of thousands of dollars in legal fees has been spent.

Lessons learned No. 8*:* Keep the roof drain as open as possible. Cut back the single plies to within 2.5 cm (1/2 inch) of the drain bowl's vertical face. A cloverleaf shape is most effective. Do this at the time of installation. It is amazing the number of contractors who will cut small holes at the time of initial membrane installation and say, "Oh, we'll cut it bigger later," as if an architect will know to place that on the punch list. Designers—you need to detail this as well.

Photo 6: One of several concerns with portal type flashings is they are not sealed, allowing air movement from the interior to the EPDM cover where condensation occurs.

Pipe penetrations: One of my personal pet peeves is the use, predominately in new construction, of spun aluminum tall cones with nippled EPDM covers for multiple pipe penetrations. It is a great idea but is often poorly designed into the roof system, and never coordinated between roofing and HVAC contractors; so the final installation often lacks airtight integrity. First, warm interior air flow into the unit is created, and when conditions are correct, condensation occurs; in northern climates, this creates frost within the interior (see Photo 6). Clients often do not fully appreciate the advent of mysterious moisture magically dropping from a roof deck. The spun aluminum tall cone, after pipes are installed, should be insulated with spray foam insulation to prevent air movement. Second, you now have an HVAC mechanic sealing the EPDM around the pipes and aluminum tall cone on a roof. When leaks occur, we all know they call the HVAC contractor! The sealing of the tall cone and penetrating pipes and the EPDM cover to the spun aluminum tall cones must be improved. After installing the spray foam seal, the designer should specify that the tall cone be sealed with pourable sealer. The EPDM cover to spun aluminum tall cone juncture should be sealed with water block and clamped in place with a stainless-steel draw band. The pipe penetrations should be sealed in a similar fashion, with the addition of polyurethane sealant at the top of the nipple. Designers must coordinate this detailing between the architectural drawings and mechanical drawings. I suggest that the same detail be placed on both sheets with the level of responsibility noted (see Detail 1).

Lesson learned No. 9: HVAC components need to be designed into the roof system and coordinated within the contract documents. If you enjoy callbacks and the social nature of them, proceed as usual.



Detail 1: Multiple Penetration Detail - Proper detailing of commodity roof system components can mean the difference between a long-term water tight solution and one that is a continuous concern.

Single ply membranes: Thinner is not better, and loose laying them in adhesive is not good either. The continued specification of the thinnest membrane possible continues to baffle me, and I have reviewed drawings on billion-dollar buildings where 45-mil-thick membranes with a 10-year warranty were specified. Talk about unsustainable. Of course, though a roof membrane's cost is minor, cost still plays into this. Designers—why not try to specify 60-, 75-, 80-, or 90-mil-thick membrane and go for the long term. Another issue is the increasing poor installation of fully adhered systems, especially fleeceback. The membrane's weight is not great enough to set the membrane into the adhesive. Most manufacturers require that the membrane, after setting, be rolled into place to assure positive bonding. This is a quality assurance item that should be followed up on by the designer and contractor. (There is a litany of concerns with adhesives: application, application rates, cold weather storage, etc., that also must be considered and are beyond the scope of this paper.)

Lesson learned No. 10: Proper and detailed specifications, including membrane selection, can offer the added protection needed to achieve long-term service lives and should always be considered for sustainability. Proper application of single-ply membrane, as fully adhered systems is imperative to prevent opening the design team and roofing contractor to protracted legal involvement if a roof failure were to occur.

Conclusion

In the current economic climate, the seeking of legal remedies in response to roof and moisture intrusion concerns is increasing. The cause of the concerns often can be traced to poor or minimal design effort and quality, and/or poor attention to small details in roof system design and installation. It is these relatively small issues that have little cost implication during installation that are reducing service life and costing designers, consultants and contractors hundreds of thousands of dollars in legal settlements and making attorneys wealthy. The “standard of care” of architects and consultants and the customs and practices of contractors must be improved. Sustainability is all about long-term service life (30 years or more). It is a tragedy when any roof system experiences a premature end to its service life. It is even more troubling when the cause of the demise is the lack of care.