Engineering Concerns in Metal Roofing

by Mike Huber, PE

When it comes to designing or specifying commercial metal roofing, knowledge is security. There are ten fundamental areas of concern with metal roofing, and no substitute for understanding the basic design considerations that apply to them. While particulars will vary according to geographical region, system profiles used, and the characteristics of each building, awareness of the principles underlying each of these concerns is a valuable tool for any design professional to have.

The advantages of metal

When determining whether metal is a viable alternative to conventional roofing materials, such as single ply or built-up asphalt roofing, here are the main considerations.

- How important are aesthetic considerations? Many metal systems offer significant aesthetic advantages over conventional roofing. From the richly toned natural surfaces of copper and titanium, to the hundreds of colors currently available for steel roofing, metals offer an exciting spectrum of aesthetic options. High-profile projects, office or retail complexes, hospitals and schools, are some examples of applications for which curb appeal is a primary motivator.
- How unusual is the building geometry? Some architectural designs can only be achieved through the curving properties of metal solutions; for example, the metal domes so popular for sports and entertainment facilities.
- How long does the owner intend to keep the building? Metals such as copper and titanium can be expected to last hundreds of years. Even steel roofs have an anticipated life span of 30 years, which is more than three times longer than that of many other roofing options.
- How committed is the building owner to sustainability? A property owner who wants to meet LEED ® performance criteria will put a premium value on metal solutions. Most metal substrates consist of material that has already been recycled, and all metal substrates are themselves recyclable when the time comes for eventual tear down or replacement. As an example, a recent survey of aluminum producers revealed that the total recycled content in flat-rolled products for the building and construction market was 80 to 85 percent.

It should be noted that despite the common misconception that metal roofs are heavier roofs, the light-gauge metals used for roofing are among the lightest weight roofing materials commonly used today. In fact, only single ply systems are consistently lighter. Metal systems are appropriate not only for new construction, but for retrofitting a new roof over an existing roof, especially where roof deck designs require a lighter-weight roof covering.

© 2010 Garland Industries, Inc.

On the negative side of the equation, there are some application considerations that work against the viability of a metal solution:

- Buildings requiring a lot of penetrations and flashings provide more opportunity for installation error. Since metal systems typically require more complex detailing, they should be avoided in such applications except where the contractor craftsmanship is impeccable and there is independent auditing of the installation process.
- Applications with highly corrosive effluents, such as steel and utility plants, may be better served with non-metal solutions, since metals are innately susceptible to degradation from corrosion.
- Marine environments (within five miles or less of a salt-laden sea) are generally not well-served by traditional steel roofs. However, some alternative metals, such as aluminum, are viable in marine environments.

It should be noted that buildings subjected to extreme wind-uplift pressures may appear to be less suitable to metal roofing solutions. Since metal roofs are non-continuously adhered, they are, by their nature, more susceptible to wind uplift. However, high-performance metal roofs, when properly designed and installed, frequently overcome this apparent disadvantage, outperforming conventional roofs in extreme wind conditions, as evidenced during the recent hurricanes in the southeastern U.S.

Evaluating metal alternatives

Specifiers have never had such a wide array of aesthetic metal options, and aesthetic concerns are the driving factor when choosing one metal substrate over another. The other major factor to consider is longevity. Generally speaking, the longevity of a material increases in proportion to its cost.

- Steel roofs, which are almost always treated with a metallic coating to protect against oxidation and corrosion, generally can be expected to last 30 years or longer with traditional metallic coatings such as galvanized or Galvalume®[1]. Today's metal roofing manufacturers sometimes offer proprietary metallic coatings for steel systems that can further extend their anticipated life span.
- Aluminum roofs are more corrosion-resistant than steel roofs, and can be expected to last from 50 to 100 years, depending on environmental considerations, such as weather and corrosives. Aluminum is also the lightest in weight of the readily available metal substrates, so may offer some advantages in retrofit situations. However, it is generally acknowledged that the weight differences between roof panels of varying metal substrates, with their associated claddings, is negligible.
- Other premium metal substrates, such as copper, stainless steel, zinc, and titanium, can be expected to last hundreds of years.

[1]Galvalume® is a registered trademark of BIEC International, Inc.

Within the wide realm of metal roofing solutions, there are three basic sub-categories:

- Structural systems are the most capable of withstanding wind uplift pressures. They are designed for watertight rooftop performance.
- Architectural systems are the least capable of sustaining wind uplift pressures. Primarily a decorative covering, architectural systems typically require an underlying waterproofing membrane as they are not, in themselves, watertight.
- Hybrid systems share characteristics of structural and architectural systems. Each hybrid offers varying levels of wind uplift resistance, aesthetic versatility, and waterproofing.

Systems are also classified by the way in which they are anchored to the substrate, that is, the roof deck or structural roof framing. Fastening methods generally fall into one of two categories:

- Through-fastened systems use screw fasteners that are drilled through the metal roof panels into the deck. These systems are more economical and fairly strong, but typically considered less aesthetically pleasing and more susceptible to leaks since the fasteners are exposed to the elements.
- Standing seam systems use accessories called clips, which are located within the metal seam and concealed from the exterior surface of the roof. The clips that hold the adjoining roof panels together are then fastened to the roof substrate. Such clips are not exposed to the elements. It is generally considered to be easier to make a standing seam system weathertight, due to the configuration of the panel that places the seam above the surface of the roof and therefore above the path that water takes when flowing off the roof.

Standing seam roof systems are far more common than through-fastened systems in metal roofing applications. Therefore, although this article focuses on engineering concepts that are shared by all metal roofing, greater detail is provided for those principles of most concern to standing seam applications.

If you are choosing among standing seam systems, another important consideration is the height of the seam leg. Generally speaking, the higher the leg height, the stronger the system. To understand this concept, it might be helpful to imagine the seams as I-shaped beams: the taller the I-beam, the stronger the member.

Clip designs for standing seam metal panels also distinguish metal roofing systems from each other. In evaluating clip designs, you need to prioritize the building owner's performance requirements. The material thickness of the clip (gauge) helps determine its inherent strength, which in turn helps to determine the minimum wind-uplift resistance requirements for a particular roof.

Sealants are another primary differentiator between metal systems. Sealant chemistry, and the role that sealants play in ensuring a secure metal installation, warrants an article of its own. For a better understanding of the principles involved, researching the key phrases of "air infiltration" or "water infiltration" with the added word "roofing" is recommended.

1. Building code requirements

Historically, there have been three primary regional building codes used in the United States:

- Building Officials & Code Administrators (BOCA), serving the Northeast
- Standard Building Code Congress International (SBCCI), serving the Southeast

- International Conference of Building Officials (ICBO), serving the West

In recent years, the three regional U.S. building-code bodies consolidated their efforts into a single *International Building Code (IBC),* under the auspices of the International Code Council (ICC). Local jurisdictions are still in the process of replacing previously applicable regional codes with the new unified code, as their de facto standard of reference.

However, in any construction situation, the local code always takes precedence. There are currently more than 40,000 building codes across the U.S. Although the majority of them base their codes on a standard code of reference (previously a regional code, but increasingly the IBC), when local codes deviate from their referenced standard they are *always stricter*. Even after the IBC has been universally adopted, as it is expected to be, architects, engineers, and specifiers will always have to take into consideration any additional mandates prescribed by local jurisdictions.

Although the most current version of the unified code is IBC 2009, as of this writing most jurisdictions have not yet adopted it. To date, IBC 2006 is the norm in most areas, but IBC 2009 will eventually supplant it.

In both the 2006 and 2009 versions of the IBC, the chapters relevant to metal roofing are:
- Chapter 15, "Roof Assemblies and Rooftop Structures," which provides minimum requirements for metal roofs
- Chapter 16, "Structural Design," which provides structural requirements for different aspects of construction, including but not limited to roofing

No article is a substitute for becoming intimately familiar with these two chapters. In particular, don't overlook the critical roof-related information in Chapter 16. Here is a review of the different aspects of the code that relate to metal roofing, and a brief explanation of their relevance:

- **1504.1**, "Performance Requirements: Wind Resistance of Roofs" applies to all types of residential and commercial roofs. In providing the performance requirements for metal roofs, it cross-references Chapter 16 for the all-important standards for identifying wind load, a critical aspect of metal roof design. The performance requirements found in section 1504.1 cannot be properly understood and implemented without the equally critical information found in Chapter 16.

- **1504.3.2**, "Metal Panel Roof Systems" stipulates that metal roofs must be tested in accordance with UL 580 or ASTM E1592. The protocols for these tests include methods for testing wind-uplift resistance.
- The material in **Chapter 16** is frequently overlooked and includes detailed guidelines for identifying the wind load requirements for all aspects of construction, including metal and other roofs. It is in section 1609.1 that you will find clear references to ASCE 7 (see section 3 of this article for more detail), the mandated standard for identifying wind load requirements.

A few areas of the U.S. have developed their own codes, rather than referencing the IBC standard. Most notably:
- The Florida State Building Code, no doubt in response to the extreme weather hazards of the coastal environment, has developed a code which, among other things, mandates more stringent wind-uplift requirements than the IBC standard.
- The California Building Code mandates Class A fire ratings for a broader range of applications, as well as stringent energy efficiency standards, in support of that region's concerns about the extreme dryness that can promote extensive brush fires, and a heightened community awareness of environmental concerns.

2. Wind uplift

As previously explained, the non-continuous attachment of metal roofs makes them particularly susceptible to wind uplift concerns. Wind subjects metal roofing materials, and the quality of their installations, to their most rigorous test.

The major factors relevant to a roof's ability to withstand wind-uplift pressures are:
- Wind speed (the greater the speed, the greater the wind-uplift pressure)
- Building elevation (the higher the building, the greater the wind-uplift pressure)
- Exposure to wind (i.e., whether or not the building is protected from wind by surrounding structures)
- Roof slope (the lower the slope, the greater the wind-uplift pressure, depending on the building dimensions)
- Building geometry/dimensions (not only the size of the roof, but the geometric complexities of its design that might break or facilitate wind flow)

The complexities of analyzing and identifying probable wind-uplift forces make it impossible for building codes to limit the use of metal systems to certain geographies or generic conditions. Rather, they establish a methodology for identifying anticipated wind-uplift pressures, then stipulate that the specified roof must be capable of withstanding such pressures. The methodology used applies a general formula to the particulars of an installation, as described above.

To complicate things further, the amount of wind-uplift pressure varies greatly even across the various expanses of a single roof. Common sense dictates that the perimeter of a roof, which initially breaks the wind flow, must be designed to sustain far greater pressure than the middle of the roof. Similarly, the corners of a roof, which are simultaneously exposed to pressure from different directions, must be designed to sustain even greater wind-uplift pressure.

There is no such thing as a generic roof installation. No two roofs will share identical design parameters, as defined by their elevations, slopes, etc. More importantly, a single roof will require more insulation board fasteners per inch and shorter distances between clips (if standing seam) at its corners and perimeters than across its central field. As an example, depending on the wind uplift calculations for the various zones on a single building, the recommended clip spacing could range from as stringent as one clip per one square foot to one clip per ten square feet.

Essentially, all a building code can do is to provide general guidelines for developing clip spacing distances appropriate to anticipated wind-uplift pressures. But it is up to the design professional to identify the probable wind-uplift pressures for each of the three zones of a roof, based upon its particular parameters.

ASCE 7, *Minimum Design Loads for Buildings and Other Structures* provides guidelines for each of three roofing zones:

- Zone 1 represents the central portion of the roof. Since wind forces are somewhat dissipated by the time they reach the center of a roof surface, having already broken against the building's corners and perimeters, the clip distance requirements for Zone 1 are the least stringent.
- Zone 2 represents the perimeter or outside edges of a roof, where wind forces are more severe since it is the edges of the roof that meet the full force of the wind. The clip distances required for the roof edge to sustain anticipated wind-uplift pressures are always more stringent than the distances required for the central surface area.
- Zone 3 represents the roof corners where wind forces are at their most severe. Again, *severity is a relative measurement and does not relate to any specific minimum or maximum pressure.* Simply stated, any roof corner must be capable of withstanding more wind-uplift pressure than its central field or perimeters since roof corners are simultaneously subjected to wind-uplift pressure from two sides.

The American Society of Civil Engineering (ASCE) has developed a calculation, as part of ASCE 7, *Minimum Design Loads for Buildings and Other Structures,* for determining the wind forces in the three roof zones. The calculation first takes into account all of the design parameters that collectively predict the probable wind-uplift pressures for a particular roof. It then provides a methodology for calculating the relative force exerted on each of the three defined zones when subjected to the anticipated wind-uplift pressure.

Due to the complexity of the ASCE-7 methodology, it is usually a structural engineer who will evaluate the parameters of a roof design, identify probable wind uplift, and provide A/Es and specifiers with appropriate clip spacing distances for each of three zones.

3. Value engineering

In the realm of roof performance, reducing up-front costs for short-term savings inevitably leads to increasing costs and liability down the road. Learning to analyze the bottom-line benefits of rooftop longevity is critical to specifying appropriate metal roofing solutions. The performance-to-cost ratio will vary with every roof specified, and can only be identified through a comprehensive review of several factors, including:

© 2010 Garland Industries, Inc.

- How long will the client own the property? Since metal roof systems can significantly outlast most non-metal alternatives, property owners who intend to hold on to their buildings longer will reap the largest rewards from metal's life-cycle costing advantages.
- How disruptive will eventual restoration and re-roofing be to the building's occupants? The installation of a metal roof is odor-free, cleaner, and more environmentally friendly than hot-applied systems. However, installing metal systems can present logistical concerns, especially for high-rise buildings with limited access. Although freight elevators can typically carry materials needed for non-metal systems, for metal systems, large cranes may be necessary to haul longer panels to the top of the building.
- What is the intrinsic value of the property under the roof? The higher the value of the property occupying a building, the easier it is for building owners to rationalize the higher initial costs of metal systems.
- What is the customer's existing budget? If price were no object, we'd all be living and working under roofs of copper, zinc, or even titanium. Regardless of the desirability of long-term solutions, short-term budget realities sometimes prohibit lasting solutions. When a customer's initial budget will not accommodate the costs of a premium metal, innovative financial products such as leasing may be considered. Equally relevant is how soon additional money will become available. It may make sense to install a low-cost alternative on new construction, when budgets are strained, if seven years down the road money will become available for installing a more lasting metal roof system.
- How important are aesthetic considerations, given the roof's location and the building's function? Aesthetic versatility is probably the single biggest reason that owners opt for metal roofing. When aesthetics are a major concern, metal roofing offers added value.

- How likely is it that the owner will follow through on routine maintenance? Generally speaking, metal roofing requires less maintenance than non-metal systems, which may need more frequent re-coating, fresh graveling, or aggressive restoration to maintain resistance to ultraviolet (UV) radiation and weather.
- How frequently will the roof need to be accessed due to HVAC, rooftop photovoltaic (PV) systems, or other utilities? Although metal systems withstand foot traffic as well or better than non-metal roofs, roofs that require a lot of penetrations for HVAC or other appliances are not ideal candidates for metal roofing, as previously explained (see introductory section of this article on the advantages of metal).

4. Lifecycle cost analysis

Lifecycle cost analysis is a worthwhile exercise when attempting to establish the value of metal systems in comparison with non-metal alternatives. ASTM International E 917, *Standard Practice for Measuring Lifecycle Costs of Buildings and Building Systems,* is a uniform procedure for establishing lifecycle costs for all types of roofing systems, including metal roofing.

The many proprietary software tools currently available for analyzing life-cycle cost benefits are generally based on ASTM E 917. However, some of the more ambitious ones attempt to quantify more illusive cost savings. They take into consideration such factors as initial purchase price, maintenance costs, operating costs, disposal costs, and replacement costs over the life of a roof system. Other financial assumptions that must be taken into account are changing material costs, the inflation rate, and costs related to energy use. All anticipated costs over the working life of a roof are added to the initial material and installation costs, in order to arrive at a realistic total cost.

Generally speaking, the longer-lived the metal solution (see introductory section of this article on the advantages of metal), the greater its life-cycle cost advantages.

5. R-value

Today's energy costs have made R-value a "hot" topic for discussion. Before commencing our discussion, it may be useful to note: *the function of a roof is to protect the insulation and everything else under it from water penetration.* No roof, not even one constructed with the most sophisticated green technologies, will ever provide as much insulation value to a building as does the insulation itself.

Insulation is added to the building envelope in order to maintain a desired temperature within the building at a lower cost. Typically, the more insulation that is present between the interior of a building and its exterior, the greater the temperature difference, regardless of whether the outside temperature is hot or cold. The critical measurement for determining the effectiveness of a roof's insulation is R-value, which measures how well a particular material resists the transfer of heat.

Keep in mind that *wet insulation is typically considered to have an R-value of zero*; once a roof develops leaks that penetrate the insulation, the owner's R-value investment is virtually lost.

The insulation materials used with metal roofing are identical to those used with traditional roofs, and the selection process is much the same. The most common insulation materials used today are polyisocyanurate (commonly referred to as polyiso), perlite, expanded polystyrene, and extruded polystyrene, among others.

Although R-value is the primary consideration, density is also of concern. As a general rule, a minimum density of 1-1/2 pounds of insulation per cubic foot is required for all types of roofing. However, specific R-values are mandated by the applicable building code. Keep in mind that energy-saving is an area in which local jurisdictions may prescribe a more stringent standard than that provided in the unified code.

As a point of reference for commercial buildings more than three stories high, American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE) 90.1, *Energy Standard for Buildings Except Low-Rise Residential Buildings,* provides the means to measure energy costs, with temperature tables based on the climates of particular large cities.

It is interesting to note that insulation is also a critical component in ensuring the waterproofing of a metal roof system, in that its ability to insulate the building against cooling is critical for preventing condensation. If you specify your insulation according to the mandated building code, and install a vapor retarder or appropriate ventilation, condensation will not be any more of a concern for a metal roof than it is for any other type of roofing. (See 8 below for a more detailed discussion of this topic.)

Another common misconception is that the heat-conductive nature of metals will somehow adversely impact the insulation's ability to provide R-value protection. This is untrue. Metal roofs do not require more insulation than any other type of roofing to achieve the same level of effectiveness from a given type and amount of insulation.

Although there are many things that can retroactively contribute to the R-value of an existing roof, nothing contributes more greatly to energy efficiency than insulation. Specifying the highest level of insulation is your client's best protection against the rising costs of energy.

6. Energy payback

For all roofing systems, energy payback is derived almost exclusively from R-value, and R-value, as explained in 5 above, is derived almost exclusively from insulation. That said, there is no denying that a high-performance metal roofing solution is among the best ways to protect that investment. Once a customer understands how much of his R-value investment is lost, once water penetrates the insulation, the added protection provided from a high-performance roof becomes apparent.

Aside from that fact, given the rising costs of energy there are good reasons to encourage customers to take advantage of anything that will even incrementally increase their energy efficiency. Building energy use accounts for 35 percent of total energy usage in the United States. Most localities have established minimum energy-saving guidelines for new and existing construction. Again, ASRAE 90.1 is the relevant standard for commercial buildings more than three stories high.

Emissivity (radiated heat) is related primarily to the roof substrate. As explained in section 8 of this article, metals tend to release heat more rapidly than some other roofing materials, adding to their energy efficiency. However, it is the coatings used on metal roofs that typically provide the greatest energy savings through reflectivity.

Metal roofs come in a wide variety of colors, which offer aesthetic versatility while offering varying degrees of albedo (reflectivity measurement) and emissivity in comparison with conventional blacktop roofing. Bright white coatings provide the greatest levels of reflectivity, delivering ratings as high as virtually any alternative roofing method, and a good deal higher than that delivered by conventional blacktop roofing, as indicated in the accompanying table.

Energy Efficiency Terminology

Albedo represents the amount of solar energy reflected away from a surface (reflectivity); the higher the albedo rating, the greater the reflectivity.

Emissivity represents the amount of heat energy that is radiated from a surface; the higher the emissivity rating, the greater the heat shed.

R-Value measures how well a particular material resists the transference of heat.

Solar Reflective Index represents the combined value of albedo and emissivity.

Useful Albedo Comparisons:

Aluminized Asphalt	0.40
Asphalt	0.09
White Coating/Membrane	0.85

Useful Temperature Comparisons (based on a typical 90-degree Fahrenheit day):

White Coated Roof	110° F
Aluminum Coated Roof	140° F
Black EPDM	190° F

Since building owners currently spend over $40 billion a year on air conditioning, and white roofs reduce energy requirements by as much as 40 percent, the use of white coatings on metal roofs can have a significant positive impact on cooling demand on both a micro and macro level. It's been estimated that white roofs could reduce peak cooling demand by as much as ten or even 15 percent.

7. Fire resistance

For metal roofs, one of the most critical and relevant areas of material testing is fire resistance. Factory Mutual (FM®) and Underwriters Laboratories Inc. (UL®) are the acknowledged leaders in international independent laboratory testing.

Unlike roofing materials derived from asphalt or rubber, metal roof substrates are naturally resistant to fire. For that reason, metal material manufacturers generally have to invest less time and expense in order to achieve appropriate fire ratings. Essentially, it is the insulation and underlayment specified as part of the roofing assembly that create concern for the specifier.

When evaluating metal roofing systems, it is necessary to review fire ratings in three critical areas:

- Roof deck
- Roof insulation
- Roof covering

It can easily be seen that a metal roof installed over a wooden (combustible) deck presents a fire safety hazard, despite the metal's natural resistance to flame, since the high temperatures created by fire could inflame the underlying combustible non-metal deck. Non-flammable insulation board and non-meltable barrier boards are two of the methods commonly used to achieve fire-resistance in metal roof assemblies over combustible decking.

Another advantage of metal systems is that hot metals will not emit noxious gases to create the additional health and safety hazards associated with some non-metal materials.

As a general guideline, specifiers should look for Class A fire ratings when evaluating the fire resistance of metal roof assemblies. The IBC mandates that metal roof systems meet the testing standards of one of two similar protocols:

- ASTM E 108, which is used by FM
- UL 790

Always keep in mind that testing protocols, much like building codes, are typically designed to prevent catastrophic failures rather than to promote best-practice engineering.

8. Condensation

Typically, condensation occurs when humid air contacts a cold surface. In the context of the building envelope, there are several circumstances likely to precipitate potentially damaging condensation. These include, but are not limited to:

- Areas in which large groups of people congregate, e.g., gymnasiums, churches, etc.
- Manufacturing environments with processes that exude humid air, such as food processing
- Areas that include showers, pools, steam rooms, whirlpools, or other moisture-emitting equipment

Despite their natural susceptibility to corrosion, metal roofs are suitable for all of the conditions cited above, provided proper insulation (see section 5 of this article) and ventilation or vapor retarders are installed.

Warm, moist air rises, meaning it is usually the building's roof that transfers humid interior air to the colder exterior. Customers' concerns about condensation with metal roofing generally stem from a basic understanding of metal's tendency to release heat quickly. Although it is true that a metal roof has a greater propensity towards condensation, once measures are taken to prevent the humidity from reaching the dew point, a properly installed metal roof will be condensation free.

 © 2010 Garland Industries, Inc.

The dew point is the temperature at which air vapor condenses into moisture. ASHRAE offers guidelines for analyzing critical building factors in order to identify the probable dew point. The principles involved apply to all types of roofing, and the remedies are the same. The architect or engineer's goal is to keep the warm air in and the cold air out so that water never condenses below the roof.

Once the insulation issue has been addressed, the two methods used to control condensation in metal and non-metal roofs are ventilation and vapor retarders. Ventilation can be installed during new construction or afterward, but vapor retarders must be part of the original roof design.

Ventilation refers to air movement between the metal panel and the roof deck or insulation across the roof. Venting is typically achieved through penetrations in the soffit or ridge. The basic idea is to prevent moisture build-up by keeping the air moving. An HVAC system, appropriately adjusted for coolness, is sometimes sufficient to prevent building air from reaching the dew point. When a dew point analysis reveals that neither the HVAC system nor standard ventilating methods will be sufficient to deter condensation, a vapor retarder may be required.

Vapor retarders (also know as barriers) must be part of the original roof design. The correct location of a vapor retarder is on the warm side of the insulation. In climates with cold winters, this means the vapor retarder should be installed at or near the bottom of the roof assembly. In warm climates, the vapor retarder should be installed on the exterior side of the insulation, transforming the roof panel itself into the vapor retarder. Identifying the exact location of vapor retarders is a science in itself, and should be given priority during the design of a metal roof whenever anticipated building use makes condensation a concern.

Generally speaking, condensation is a frequently overlooked design concern for all roofs. Because of the heat-dissipating nature of metals, it is advisable to make sure that dew point analysis is part of the planning process when specifying a metal roof solution for applications that may be prone to condensation.

Interestingly, although metal roofs are more susceptible to corrosion, this is not really a condensation-related concern. Failure to eliminate condensation will cause water to penetrate the insulation and create leaks long before oxidative corrosion of the metal roof covering can occur.

9. Indoor air quality

Moisture penetration through roofing and walls is a major source of mold-breeding moisture that can infiltrate ceiling tiles, carpets, furniture, and HVAC systems. Increased public awareness of the dangers of airborne mold make leak prevention a critical priority, particularly when specifying roofing for public facilities, such as schools, hospitals, and community centers. Properly installed high-performance metal roof and wall systems equipped with appropriate ventilation and/or vapor retarders can eliminate the water penetration and health hazards associated with airborne mold.

All indoor air quality issues concerning the exterior building envelope are ultimately derived from water penetration or condensation. A high-performance metal roof is less susceptible to water penetration longer than most conventional roofing materials. Although metal roofs are somewhat more conducive to condensation, following the guidelines provided in section 8 of this article will eliminate this concern.

10. Snow/ice retention

Snow and ice build-up affect a significant portion of North American buildings; it is imperative the roof be designed to accommodate the added load of snow and ice build-up, and to safely evacuate them from the roof. Interestingly, snow and ice tend to sit on a sloped roof just as they will on a less-steep surface, until melting commences, when they become a grave danger to people or property below.

Just as with wind uplift, snow- and ice- induced pressures tend to vary according to the region of the roof. More weight can occur in enclosed spaces or areas where a roof surface abuts a wall. It is critical that the structural metal panels be designed to accommodate these varying loads. To calculate snow/ice load on a particular roof slope, use the ASCE 7 guidelines, which take into account the geometry of the building as well as its varying levels of exposure.

In addition, because of their lower coefficient of friction (slipperiness), metal roofs are somewhat more susceptible to avalanching problems, roughly in proportion to their degree of slope. The goal of retention systems for metal and non-metal roofs is to prevent snow and ice from sliding down where they can damage people or property. Despite the fact that serious liability issues are involved, there is no mandated standard for snow/ice retention.

Engineering a roof for snow/ice retention requires the thoughtful analysis of many factors, including:
- Anticipated pounds per square foot of load
- Roof pitch (steeper angles will put greater load on a retention system)
- Drift load (snowfall will drift on roofs, just as it does on the ground)
- Vector force (load in relation to slope)

A structural engineer or your snow-retention system manufacturer can help you design a system appropriate to the particulars of a specific building. The most commonly used methods of retaining snow/ice for metal and non-metal roofs are snow guards, which can be either fastened or adhered, and snow fences, which are fastened or clamped into place.

Conclusion

Today's trend for sustainable designs that reduce environmental impact is helping drive the metal roofing market to new heights. Understanding the engineering concerns fundamental to the proper design of metal roofing will enable specifiers to take advantage of this burgeoning market while serving the long-term interests of their clients, enhancing customer loyalty and reducing liability for all concerned.

© 2010 Garland Industries, Inc.

Mike Huber is Director of Engineering, for The Garland Company, Inc. and has been a professional engineer since 1994. As a member of the Garland Speakers Bureau, he is a popular presenter of an American Institute of Architects (AIA) accredited course on the engineering and design of metal roof systems. He holds a bachelor's degree in engineering physics from Miami University and a bachelor's degree in civil engineering from Purdue University.