The roof of a structure is a key element of any building design and one of its most important structural aspects. Value-conscious building owners seeking long-term roofing solutions that combine aesthetics and performance are increasingly turning toward metal roofs. According to the National Roofing Contractors Association, metal roofs have surged in popularity over the past decade.

Metal roofs have shown an ability to stand up to the elements, and provide low life-cycle costs and longevity with minimum maintenance. In addition, manufacturers are expanding their metal roofing options in a wide variety of finishes, profiles and colors that enhance building aesthetics. Advances in coatings and finishes have enabled the formulation of “cool” metal roofing that add to the roof’s energy-saving properties and can impact the costs of heating and cooling the building.

In specifying a metal roof numerous questions arise during design development, and with the plethora of metal roofing products on the market, it is important to understand the complexities of the various roofing systems. Only by specifying the proper roofing system, underlayment, substrate and finish will the full potential of a metal roof be realized.

Characteristics of Metal Roofing Systems

There are two basic types of metal roofing systems, which are classified according to the way in which the roof resists water. This is determined by their slope or pitch. The first type, structural roofing, features water-resistant panels and is used on low-slope roofs. Architectural, or non-structural roofing, is designed to shed water quickly, and requires steeper slopes.

Value-conscious building owners seeking long-term roofing solutions that combine aesthetics and performance are increasingly turning toward metal roofs.
CONTINUING EDUCATION

should consider these issues at the panel specification stage. Complicated seaming operations may ultimately prove to be less cost effective. Architects may also want to compromise panel quality. Installation cost is another consideration. Panels requiring fabrication methods. On some projects, practical restrictions as to panel length may necessitate production of panels at the job site. Architects may also want to weigh the advantages of panel systems that have been designed to be roll-formed on site. The trapezoidal profile is most commonly found in metal building-type applications. The trapezoidal profile is a three-piece assembly that is seamed in the field. This panel may be more labor intensive as the cap may be somewhat unwieldy on long panel applications, however, it is a profile that can be used for radius panel applications as well. "Code Considerations," next column.) Structural metal panel roof systems are typically fitted over a roof assembly that includes structural metal framing and parapets. In areas with heavy snowfall, high wind-load areas or when the Owner requires a roof assembly with a high "R" value, panels may be installed over solid substrates, such as metal decking, plywood, oriented-strand board (OSB) or in conjunction with ISO board insulation to achieve the necessary structural load of the panel system along with the required "R" value of this roof assembly. Batt insulation is typically part of the assembly and thermal barriers such as wood blockers may be installed between structural framing and the roof panels. Structural panel profiles. This test procedure is generally not applicable to panels that are installed over solid substrates such as metal decking or plywood. In addition, many specifications require that panels be tested for water infiltration. The ASTM 1680/formerly E331 Standard Test Method for Water Penetration of Exterior Metal Roof Panels by Uniform Static Air Pressure Difference essentially evaluates how resistant the standing-seam panel system is to moderate-to-heavy rains with light winds that are considered “average daily rain events.” Specifications may also require that structural panels meet the requirements of ASTM E1592(formerly E 250), which is the standard test method for rate of air leakage through interior metal roof panels. Although structural metal roofing panels typically involve higher up-front costs than other roofing alternatives, the low maintenance costs and long life expectancy make it a competitive roofing alternative on most projects. There are a few exceptions, however. Structural metal panels may not be appropriate in roof applications with an extraordinary number of penetrations or in a particularly caustic or aggressive environment, though new coating systems greatly broaden the scope of application.
Aesthetic Factors. While structural roofs are commonly used in schools, industrial facilities, shopping centers, prisons, low-slope commercial buildings and warehouses, their utilitarian applications do not mean they are without aesthetic appeal. A new building to house the headquarters of Belton & Menke, Inc., a civil and environmental engineering firm located in Minneapolis, Minnesota, was designed by Paulson Architects, of St. Paul, to create a unique “engineering look.” “We were dealing with a simple shape overall,” says Bryan Paulsen, AIA. “The challenge was how to take a ‘box’ and give it a distinctive identity by adding verticality and visual interest.”

The focal point of the design centered on the main entrance area of the 20,000-square-foot building. Utilizing approximately 3,700 square feet of silver metallic panels and produced a building that “shimmers during the day and tends to glow at night,” according to Paulsen. The entry area roof utilizes 3,700 square feet of silver metallic panels and features a prominent overhang with non-ventilating soffit panels also finished in silver metallic; coordinated silver metallic window frames were used for accent.

The Architectural Roof

A second major grouping of panel profiles are referred to as architectural panels. Like shingled or slate roofs, architectural roofs carry rainwater off the roof. They are said to be hydrokinetic. Such roofs generally have a pitch of at least 3:12, although some architectural profiles have been designed for pitches as low as 2:12. Architectural profiles are suitable for projects in which the roof requires weather resistance and performs as a visible, decorative element in the overall aesthetics of the building. Dramatic visual effects can be created with architectural roofs that are not possible with structural roofs.

Architectural roofs are generally designed to be installed over a solid substrate, the most common of which include plywood, metal decking or OSB, an engineered wood product, common of which include plywood, metal decking or OSB, an engineered wood product, with architectural roofs that are not possible with structural roofs.

The Basics of Underlayments

A key consideration in any design is keeping the building’s contents dry. Since the roof is the primary barrier to water penetration, specifying the proper underlayment is critical in protecting the building from precipitation.

A properly installed underlayment can control water entering a roofing system. In structural roofs, metal panels are installed over intermittent supports, an underlayment typically is not used. If there is a solid substrate, the National Roofing Contractors Association recommends using an underlayment. To minimize leaks, an underlayment of 30# felt or an in-situ water guard membrane underlayment can be installed on top of insulation and along roof edges, valleys, ridges and hips, which are particularly prone to leaking. While such a waterproof membrane won’t assure a totally leak-free roof, it will help prevent water from leaking directly into the building envelope.

As an alternative and as upgrade to traditional roofing felt, a peel-and-stick membrane can be applied as an underlayment. A fast-growing roofing trend, peel and stick products reduce the amount of time, labor and materials needed to install roof membranes and are less unsightly and is often a source of dispute with the building owner. Oil canning results from either: an uneven substrate; bad source material; rolled-in oil-canning caused by poorly-adjusted rolling equipment; membrane fasteners; expansion/contraction; or any combination of the above. Some of these conditions—particularly uneven substrates, membrane fasteners and problems caused by expansion/contraction—can and should be remedied by the installer at the jobsite.

Potential Installation Problem Areas

Architects should be aware of common installation issues and problems that may result from a hasty design or installation process for metal roofing. Note that in the design stage of the structure, the goal is to achieve positive drainage flow of the water off the roof into properly designed rain-carrying equipment, be it patterns, external or internal drains, or similar means or methods to get water off the roof.

Oil caming: Oil caming refers to deformation, bulging or warping of the metal. While some oil caming is to be expected in a metal roof, excessive warping in the panel can be unsightly and is often a source of dispute with the building owner. Oil caming results from either: an uneven substrate; bad source material; rolled-in oil-caming caused by poorly-adjusted rolling equipment; membrane fasteners; expansion/contraction; or any combination of the above. Some of these conditions—particularly uneven substrates, membrane fasteners and problems caused by expansion/contraction—can and should be remedied by the installer at the jobsite.

Underlayment: Underlayment should be installed horizontally and staggered (single tabbed) from eave to ridge.

Fasteners: Typically, a minimum of two fasteners per clip are required per manufacturer’s instructions to provide better load-down strength and prevent the clip from tangling around a single fastener.
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sacrificial properties of zinc. In bare (unpainted) form, it can prove superior to galvanized steel coated with an alloy of aluminum and zinc, which has gained market share in many architectural applications, but developments in alloying technology may make additional cost over other "non-cool" colors. Selection process, particularly since the agency could obtain this "cool color" with no additional cost over other "non-cool" colors.

Clip Spacing: Proper clip spacing per the manufacturer’s details is necessary to ensure proper performance of the complete system.

Metal Substrates
Metal roofs have been used for centuries, and have proven to be durable, with both structural and architectural systems remaining operational for a minimum of 30 years, and often for the life of the structure itself. Typically, metal roofs have long useful lives and favorable sustainability ratings as compared with other roofing materials. Metal roofing substrates include metallic-coated steel, aluminum, copper, zinc, and stainless steel. Each material has distinct characteristics and, in particular, the corrosion resistance of a metal roof can vary depending on which substrate is specified.

Steel. Strength, corrosion resistance, longevity and economic value make steel a popular roofing material. Metal roofs are predominantly steel. To increase longevity and anti-corrosiveness, steel undergoes special surface treatments.

Galvanized steel, which has been used for over 75 years in architectural applications, is rendered corrosion resistant by a zinc coating applied to its surface that bonds metallurgically to the steel’s surface. Without this zinc coating, steel roofs with oxidation from moisture and oxygen in the air. Zinc provides "sacrificial protection," which means that zinc "repairs" itself if the steel surface is harmed by scratches, nail holes or other damage; zinc molecules move to protect exposed steel. Galvanized steel is available in several grades, specified by coating weight—for example, G-30, G-60, G-90— with the “G” rating referring to the amount of zinc per square foot, per side. G-90 is the weight generally accepted for commercial architectural applications. Galvanized steel is sold bare (mill finish) or coated with a paint finish. It accepts many different finishes, and is notable for its low relative expansion and contraction rates. Most common is 24-gauge steel, though panels are available in heavier gauges. ASTM Grade 653 (formerly known as ASTM 446) steel is required for U.S.-rated assemblies.

More than 30,000 square feet of 24-gauge steel G-90 galvanized panels were used in the renovation of the Amicalola Falls Lodge in the Amicalola State Park near Dawsonville, Georgia. The lodge’s color stable roof had begun to leak within a year of its installation in the late 1990s. Given the short life span of the original roof, the Georgia Department of Natural Resources (GA DNR) sought a roof system that would provide longevity as well as energy efficiency. The galvanized steel panels feature a 1-inch leg height and a continuous interlock for improved structural performance and wind resistance—a key consideration in view of the severity of the mountainous storms. Decking was repaired before installation of new standing-seam panels, flashings, vented ridge, gutters, downspouts and vented soffit eave flashing. The proper size of valley flashing is determined by roof pitch, panel length, and expected snow loading and rainfall.

Stainless steel is an increasingly popular corrosion-resistant substrate for architectural roofing. In bare, unfinished form, stainless is used in many flashing applications including through-wall flashing. A typical alloy for architectural application is Type 304/304L, Type 316/316L alloys are generally reserved for more aggressive environments such as coastal areas and chemical plants. Manufacturers now offer stainless steel with a polyvinylidene fluoride (PVDF) finish—a combination that provides one of the most corrosion-resistant, weather-resistant materials available.

Copper. A popular material that has been in architectural use for centuries, copper is noted for its superior corrosion resistance. Its field ages to a rich green patina. Though the patina is known for its superior corrosion resistance, flatness and surface characteristics, lighter weight panels, ease of installation and life cycle advantages. While higher in cost per square foot than steel and subject to volatile pricing, aluminum’s lightweight and workability can offset the difference in labor cost savings on many jobs. Because aluminum expands and contracts at twice the rate of steel, it may require modifications in flashing design on longer panels. Generally, aluminum is not available for structural panel applications, but developments in alloying technology may lead to wider panel availability in the future.

Nonetheless, aluminum is gaining acceptance among architects. Hill Road Middle School/Benjamin Davis Elementary School, Landover, Maryland was topped with 40,000 square feet of 24-gauge aluminum. Its weight, lightness and workability can offset the difference in labor cost savings on many jobs. Because aluminum expands and contracts at twice the rate of steel, it may require modifications in flashing design on longer panels. Generally, aluminum is not available for structural panel applications, but developments in alloying technology may lead to wider panel availability in the future.

Aluminum. Aluminum is known for its superior corrosion resistance, flatness and surface characteristics, lighter weight panels, ease of installation and life cycle advantages. While higher in cost per square foot than steel and subject to volatile pricing, aluminum’s weight, lightness and workability can offset the difference in labor cost savings on many jobs. Because aluminum expands and contracts at twice the rate of steel, it may require modifications in flashing design on longer panels. Generally, aluminum is not available for structural panel applications, but developments in alloying technology may lead to wider panel availability in the future.

Despite its higher cost per square foot than steel and subject to volatile pricing, aluminum’s weight, lightness and workability can offset the difference in labor cost savings on many jobs. Because aluminum expands and contracts at twice the rate of steel, it may require modifications in flashing design on longer panels. Generally, aluminum is not available for structural panel applications, but developments in alloying technology may lead to wider panel availability in the future.

Steel coated with an alloy of aluminum and zinc, which has gained market share in architectural application, combines the corrosion resistance of aluminum with the sacrificial properties of zinc. In bare (unpainted) form, it can prove superior to galvanized steel in many applications in terms of longevity and maintenance. This coating is typically available in AZ-50 or AZ-55 coating thickness. It has less of the sacrificial properties inherent in galvanized steel, which may be a factor if the material is exposed. But the zinc component of the alloy offers good corrosion resistance at cut or slit edges. A twenty-year non-perforation warranty is available from most distributors. Aluminum- and zinc-coated steel accepts a wide variety of finishes. Care should be taken to make sure that bare product does not come into direct contact with lead, copper, graphite, or green, wet, or treated wood as it may be subject to galvanic corrosion.
Typically not used for roofing panels, anodizing has applications in coping, curtainwalls, and cladding. Essentially, the controlled oxidation of aluminum, anodizing is a process that occurs naturally when aluminum is exposed to the atmosphere. The resultant aluminum oxide coating is one of the hardest architectural aluminum finishes.

Life Cycle Cost Comparisons

A metal roof may have higher initial costs than other roofing materials, but it also offers higher durability and longevity. Metal roofs require very minimal maintenance requirements, making them a cost-effective choice. Due to their durability, longevity, and minimal maintenance requirements, metal roofs offer very favorable life cycle costs.

In 2003 and 2004, the Ducker Research Company conducted an in-depth analysis of 36 roofing systems across the United States in order to compare three different types of low-slope roofing systems—metal, asphalt, and single-ply systems—on service life, life-cycle cost, and maintenance. The Ducker study found that metal roofs are expected to last 17 years longer than asphalt and 29 years longer than single-ply. The study further found that the life-cycle cost of a metal roof system is significantly lower than that of an asphalt or single-ply roof, with life-cycle costs of metal roofs reported at 80 cents per square foot per year, asphalt at 37 cents; and single-ply roofs at 57 cents per square foot per year.

Due to their durability, longevity, and minimal maintenance requirements, metal roofs offer very favorable life cycle costs.

Finishes

Roofing system manufacturers offer many organic-base finishes in an increasing range of standard and custom colors to harmonize the roof with the building exterior and the surrounding environment.

Anodizing, typically not used for roofing panels, anodizing has applications in coping, storefront, and curtainwall. Essentially, the controlled oxidation of aluminum, anodizing is a process that occurs naturally when aluminum is exposed to the atmosphere. The resultant aluminum oxide coating is one of the hardest architectural finishes. In the anodizing process, the metal is first cleaned, then chemically treated and etched. A light, medium, or hard etch can be specified. At this point, color can be introduced to the process using one of two methods.

In the hardcoat process, the electrical current is applied to the aluminum in the anodizing bath. The material’s ultimate color depends on a number of variables including alloy composition, the chemical bath, level of electrical current, and the amount of time spent in the tank. As a result, color can be inconsistent, and a sample range should be pre-approved by the architect.

The two-step anodizing process is newer, more cost-effective process that produces better color consistency and a wider color range. The actual color is actually added twice. The first step is undertaken to produce aluminumoxide and the second step is to allow for the deposit of metal salts in the porous surface. Tin, cobalt or copper salts are used in the second step to produce the color. The material is then immersed in a hot water bath to seal the coating. One drawback of this process is that for exterior use, the color palette is still limited to bronze and gold tones or close.

PVDF, Polyvinylidene fluoride (PVDF) resin, is a thermoplastic fluoropolymer that relies on the superior strength of the carbon-fluoride bond, one of the strongest chemical bonds used in building applications. It is used in fluoropolymer resin coatings and paints that have become a popular family of finishes for architectural application and are reserved for metal building applications in abrasive, corrosive environments. PVDF is the premium paint finish for durability and fade resistance. These finishes offer excellent weathering properties, alkali resistance, formability, abrasion resistance and resistance to airborne pollutants. They also have a self-cleaning finish. Because they are blendable, PVDF finishes have a broad range of colors. Newer PVDF formulations have broadened the available bright color palette. Up to four-coat formulations are available, with new product development focusing on low-cost metallics and low-cost bright colors, water-based primers and printed costs such as wood grain finishes.

At a new Creekside Medical Office Building in Douglasville, Georgia, designed by Hill Foley & Associates, Duluth, Georgia, the roof utilizes approximately 12,000 square feet of 24-gauge steel panels covered with an aged copper-colored PVDF finish. The building is highlighted by curved entrances utilizing 1,000 square feet of 24-gauge panels, using a traditional PVDF paint.

Polyester, low-cost coatings, available in a large range of colors, polyester coatings feature good ultraviolet and color fastness. Polyester coatings do perform as well as PVDF coatings in many respects, including fading and chalking, typical applications for polyester coatings include metal buildings, agricultural panels, signs, gas station canopies, and interior applications.
Cool metal roofing refers to sustainable, energy-efficient roofing products comprising unpainted metal, pre-painted metal, and granular-coated metal that are marketed in diverse finishes, colors, textures, and profiles. The term extends to substrates, underlayments, and insulation as well as the exterior roof surfaces.

Basically, a cool roof is one that reflects and emits the sun’s heat back to the sky instead of absorbing it into the building. “Cool” is measured by solar reflectance and thermal emittance in a range of 0 to 1. The higher the value, the “cooler” the roof.

In conclusion, a properly designed and constructed metal roof will last for decades without tearing, puncturing, burning, or shrinking. It will withstand ultraviolet degradation, chemical contaminants, and exposure to fire elements. By their nature, metal roofs are fire- and wind-resistant, have durability and low life-cycle costs, and many are reflective, easily vented, and help reduce heat gain into a building. Roofing systems can also be designed to reduce a building’s heating and cooling costs.

Specifying the right combination of reflectance and emittance based on climate can increase the building’s energy efficiency. In cold climates with high heating bills, a metal roof with high solar reflectance and low thermal emittance will achieve maximum cooling and heating energy efficiency. The most appropriate option: an unpainted cool metal roof product. But for warmer climates with steep air-conditioning costs, a cool metal roof with high solar reflectance and high thermal emittance is better.

Warranties

Most architectural metal specifications call for the issuance of a finish warranty covering resistance to color fade, weathering and finish performance. PVDF finishes are typically warranted for 20 years when applied in coil form, and for five years when applied in spray-coat form, although some 10-year warranties are available. The most important performance characteristic is probably the finish resistance to color fade. Color fade is expressed in “Hunter” units, referring to the Hunter Colorimeter that is used to measure color variation. In terms of color fade, a lower number reading means higher performance. A rating of 5 or better is expected for PVDF over 20 years, while a rating of 8 or better is typical for polyester over 30 years. A rating of 5 or better is barely discernible to the naked eye. Another measure of finish performance is chalking, which is the result of a breakdown in the carbon-bonds in the finish. This is evidenced by the white powder that comes off the paint surface. Chalking is rated on a scale of 1 to 10. In this case, a higher rating correlates higher performance. Twenty-year performance for PVDF is typically at least 6, with 30-year performance for polyester typically 5 or higher. Another parameter is coating thickness, which is critical to the overall finish performance. Standard specifications for PVDF call for a .2 mil primer coat and a .8 mil ± .1 mil PVDF coat. Total dry film thickness should be 1.0 mil ± .1 mil.

Not all warranties offer the same coverage, and should be reviewed carefully to see whether, for example, coverage is prorated. Finish warranties should also reference paint adhesion, abrasion resistance and chemical resistance.

The Cool Metal Roof

Recently, coatings formulated for cool metal roofing panels combine “cool pigment” technology with high solar reflectance and high infrared emittance properties, thereby offering ever greater payoffs in saving energy by reducing a building’s cooling needs. Cool pigment technology strengthens paint and coatings with engineered formulations that reflect wavelengths in the infrared region. These infrared reflective pigments mean darker colors will function more like lighter colors in terms of solar reflectance, enabling architects to specify darker colors such as earth tones that still meet requirements of the federal energy programs.

Cool metal roofing offers sustainable, energy-efficient roofing products comprising unpainted metal, pre-painted metal, and granular-coated metal that are marketed in diverse finishes, colors, textures, and profiles. The term extends to substrates, underlayments, and insulation as well as the exterior roof surfaces.

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The Cool Metal Roofing Coalition and Oak Ridge National Laboratory report reflective metal roofing can save up to 40 percent in summer cooling energy costs, and highly emissive metal roofs can reduce urban air temperatures by as much as 12 degrees. According to the coalition, these cool roofs with specially formulated coatings and construction methods engineered to enhance solar reflectance and infrared emission properties meet the EPA’s Energy Star® Roof Products Program performance criteria for reflectivity and have infrared reflective pigments mean darker colors will function more like lighter colors in terms of solar reflectance, enabling architects to specify darker colors such as earth tones that still meet requirements of the federal energy programs.

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**LEARNING OBJECTIVES**

After reading this article, you should be able to:

- Describe the two major metal roofing systems
- Explain the importance of underlaminates
- Compare the advantages of metal substrates
- Discuss recent trends in high-performance, energy-efficient finishes

**QUESTIONS**

1. Architectural roofs are differentiated from structural roofs as measured by which of the following?
   - a. aesthetics
   - b. slope
   - c. span
   - d. age

2. Architectural roofs are used on:
   - a. steep slopes
   - b. low slopes
   - c. slopes of 1:12
   - d. hydrostatic roofs

3. Structural metal panel systems:
   - a. are designed for a 3:12 slope
   - b. fit over structural metal framing and purlins
   - c. require an air seal
   - d. never require underlayment

4. Peel and stick membranes:
   - a. are not as effective as roofing felt
   - b. are not recommended at valleys and eaves
   - c. are more labor-intensive than roofing felt
   - d. are more effective than roofing felt

5. Oil canning:
   - a. is a finish problem.
   - b. refers to waviness in the panel.
   - c. cannot be remedied on the job site.
   - d. results from improper clip spacing.

6. Substrates steel is rendered corrosion resistant by:
   - a. reflective pigments
   - b. a strong underlayment
   - c. zinc coating
   - d. anodizing

7. Life-cycle costs of a metal roof:
   - a. are higher than single-ply roofs
   - b. are higher than asphalt roofs
   - c. are 57 cents a square foot
   - d. are lower than both asphalt and single-ply roofs

8. The premium paint finish for durability and fade resistance is:
   - a. polyester
   - b. two-step anodizing
   - c. PVD
   - d. hardcoat anodizing

9. The most important finish characteristic is:
   - a. paint adhesion
   - b. chemical resistance
   - c. salt resistance
   - d. fade resistance

10. A cool metal roof:
    - a. reduces a building’s cooling needs
    - b. improves aesthetics
    - c. absorbs infrared waves
    - d. refers to the roofing surface area

**Program title:** "Metal Offers Durable, Energy-efficient Roofing Solutions," (05/07).

**Directions:** Refer to the Learning Objectives for this program. Select one answer for each question in the exam and fill in the box by the appropriate letter. A minimum score of 80% is required to earn credit. To take this test online, go to construction.com/CE/

**AIA/CES Credit:** This article will earn you one AIA/CES LU hour of health, safety, and welfare credit. (Valid for credit through May 2009).

**Petersen Aluminum Corporation** produces a complete line of metal roofing products. Their Cool Colors Palette meets cool roof certification requirements. Visit us at http://www.pac-clad.com or call 1-800-PAC-CLAD.

**Material resources used:**
- PVDF
- Two-step anodizing
- Polyester
- Hardcoat anodizing
- Reflective pigments
- Zinc coating
- Chalking resistance
- Aesthetic improvement
- Hydrostatic roofs
- Hydrokinetic roofs
- Slopes of 1/4:12
- Slopes of 1:12
- Low slopes
- Steep slopes
- 3:12 slope
- A 3:12 slope
- A 3:12-slope
- A 3:12-roof
- A 3:12-sloped roof
- A 3:12 roof

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