Novel Materials, Tried and True

The exterior of the University of Alaska Museum of the North is clad with 1,674 interlocking metal panels installed in stair-stepped pattern. The panels have three coats of a custom finish white with mica flakes.

PHOTO: ALCOA

Learning Objectives

After reading this article, you should be able to:

- ✔ Discuss the benefits and applications of various architectural metals.
- ✔ List the comparative benefits of specific types of metals, in terms of weatherability, structural characteristics, and compatibility with other metals.
- ✔ Explain how to specify metal to avoid galvanic corrosion and other effects that shorten the materials' useful service lifetimes.
- ✔ Understand the alloys and combinations of metal as well as the names and special characteristics of some common metal alloys.

By C.C. Sullivan and Barbara Horwitz-Bennett

England's Houses of Parliament and Westminster Abbey, Madrid's Royal Palace, and Paris' Notre Dame Cathedral all share a couple of interesting traits. They are still standing today. And they are made of metal.

"Metal has a rich history and track record stretching back almost 3,000 years and has been used on some of the oldest and most prestigious structures in the world," notes Rob Haddock, president of the Metal Roof Advisory Group (MRAG), Colorado Springs, Colo.

Metal remains popular as a building material for many reasons. "Metals offer durability, strength, and versatility that when matched with aesthetic possibilities are unmatched by any other material known to man," says L. William Zahner, AIA, president and CEO of the metal engineering and fabrication specialist A. Zahner Company, Kansas City, Mo.

Metal is "unsurpassed as roofing, wall cladding, curtain wall, guardrail, handrail, flashing, and trim material," notes Richard S. Koziol, AIA, NCARB,

a principal in the Northbrook, Ill., office of Wiss, Janney, Elstner Associates. "It is very durable, can be formed and shaped relatively easily, offers a variety of surfaces and textures, is very strong yet lightweight, and is sustainable and recyclable. Sheet metal can be produced in a large variety of surfaces and finishes, offering aesthetic and structural options that are only limited by one's imagination."

Moreover, in terms of strength-to-weight ratio and, depending on market conditions, affordability, metal can often beat out other long-lasting materials such as stone, precast concrete, and masonry.

But metal's greatest attribute—albeit one that is often overlooked and undersold—is its durability, says Haddock, who has been installing and detailing low- and steep-slope metal roof systems for 35 years. "All of the popular metals used in the industry have service lives well in excess of 40 years in most environments," he says. "In 'friendly' environments, the service life of coated steel can be as much as 60 years, and for other materials like zinc and copper, it can be well over 100."

METAL EXTERIORS: LASTING PROTECTION

One of the most common uses of metal is to protect the building exterior. Metal roofing is just such a use. While other low-slope commercial roofing choices—built-up asphalt, thermoplastic, synthetic rubber, or modified asphalt membranes—may have lower first costs, these alternatives typically offer service lives of 18 years or less, according to the MRAG's Haddock.

In fact, Zahner, an industry-recognized architectural metals expert who has written several technical reference books and designed a number of high-profile metal façade projects, says, "When properly detailed and installed, one can expect metal roofs to provide a lifetime of protection."

In addition, metal usually wins out when it comes to life cycle costs. In an oft-referenced study by Ducker Research, Troy, Mich., on low-slope roofing, survey respondents estimated the life cycle cost of a metal roof to be 30 cents a square foot per year, compared to 37 cents/sf for built-up roofing and 57 cents/sf for single-ply membranes.

Additional advantages of metal roofs: lighter weight, reduced structural support needs, and strong performance during adverse conditions. "Metal roofing is also wind-tested to the most demanding protocols of the roofing industry," says Haddock, referring to such standards as FM4471, ASTM E-1592, and UL580. "By altering material, gauge, seam spacing, frequency of attachment, and seam reinforcement, metal can be engineered and tested to meet the highest wind speeds that any hurricane can produce. Further, the mechanical properties of metal do not change with time and exposure as they do with many alternative materials—so its wind resistance doesn't change with age."

Comparative Costs for Cladding Materials

(per square foot, 2008 costs)

Metal siding panels	$7.66
Stucco	$12.28
Tilt-up concrete	$13.00
EIFS (synthetic stucco)	$15.86
Solid brick (single wythe)	$22.61

Source: RSMeans

Metal is also known to perform well in hail storms, and its noncombustible nature makes it resistant to fire damage, according to Scott Kriner, AIA, LEEP AP, president, Green Metal Consulting, Macungie, Pa.

Cladding. Another area where metal is appealing when it comes to installed cost is siding. In a recent survey released by RSMeans, the Reed Construction Data provider of construction cost information based in Kingston, Mass., found the cost of metal siding panels to be $7.66 per square foot in 2008. Competitive materials, including stucco, tilt-up concrete, brick, and exterior insulation and finish systems (EIFS), were found to be at least 60% more expensive. (See chart, "Comparative Hardness of Various Metal Alloys.")

Wall panels. Whether using a conventional, insulated, or preformed product, metal panels are also a common choice for commercial wall systems.

"Metal wall panels can be fabricated with a highly insulative foam core sandwiched between two metal skins. This insulated metal panel material has one of the highest R-values per inch of any wall building material," says Kriner, founding chairman of the Cool Metal Roofing Coalition and technical director for the Glenview, Ill.-based Metal Construction Association.

Ideal for cold storage facilities, manufacturing plants, hospitals, airports, arenas, schools, and office structures, the panels are easier and less expensive to install than tilt-up, precast, or concrete block, according to The Metal Initiative (TMI), a Glenview, Ill.-based coalition of manufacturers and associations. Cost-effective *preformed panels* are most commonly manufactured with sheet steel, although aluminum, copper, and zinc are used as well. Both preformed panels and *insulating metal panels*, or IMPs, are offered in an extensive variety of sizes, textures, colors, and profiles. According to TMI, the more popular profiles include batten, integral batten, corrugated, and stepped designs, all of which help create distinctive reveals, shadow lines, and other distinctive architectural effects.

STEEL—STRENGTH AND PERFORMANCE

A large variety of architectural metals are available to Building Teams in the North American market. The most common, at least by tonnage, is steel, which is used extensively in wall cladding, roofing, trim, flashing, handrails, and guardrails, according to Wiss, Janney's Koziol, a building envelope consultant who serves as president of the Chicago area chapter of the Institute of Roofing Waterproofing & Building Envelope Professionals.

"Steel's high strength-to-weight ratio makes it the number one choice for constructing the skeletal components of buildings from small to very large," says Mike McLane, AIA, principal of the architectural and planning firm, Taylor, Newport Beach, Calif. "Iron, one of the primary elements of steel, is also one of the most readily available elements in the world," he adds, explaining why economics also contribute to the material's historic prevalence.

Of course, various forms of iron and steel have been used for centuries as a structural and decorative material for gates, balconies, railings, storefronts, window lintels, and sills. The mid-nineteenth century saw builders gradually transitioning to structural steel due to its superior strength. Steel has also been used historically as a decorative material for window and door frames, grilles, staircases, and elevator doors, according to *Metals in America's Historic Buildings*, by the late preservationist Margot Gayle and Columbia University's David W. Look, AIA.

In today's context, "Stainless steel, iron, and steel are excellent choices as construction materials due to their unlimited design flexibility, quality, high level of performance, and inherent sustainable qualities," says Dean J. Vlahos, AIA, LEED AP, a partner with WWCOT, an architectural and planning firm based in Santa Monica, Calif. Vlahos points out that 100% of stainless steel is recyclable and more than 50% of new stainless steel comes from reclaimed scrap. At the same time, these attributes are not entirely unique to steel, as the majority of metals are highly recyclable, and thus are considered an environmentally friendly material when it comes to sustainability and cradle-to-cradle life cycle assessment.

"Metals in general have high recycled content and are 100% recyclable at the end of their useful life," says the Metal Construction Associations' Kriner. They are durable products that reduce the need for frequent replacement, which lowers the building's carbon footprint and reduces the solid waste stream of replacement materials.

According to Ted Miller, president of the metal-composite material fabricator The Miller-Clapperton Partnership, Austell, Ga., "Even after metals' primary use has ended, they can be recycled into new forms and functions. While other materials like wood and plastics can be used for a lot of building components, their life expectancy is usually far surpassed by their metal counterparts."

Spotlight: Stainless Steel at the Taubman Museum

In order to execute the geometrically radical design created by Randall Stout Architects, Los Angeles, for the 81,000-square-foot Taubman Museum of Art in Roanoke, Va., prefabricated panels fabricated by metals subcontractor A. Zahner Company were custom-designed and custom-fit on site to conform to the undulating and fragmenting structure.

Once the panels were shipped and installed to establish the form of the building, the building skin—made of stainless steel and shingled, patinated zinc—was applied. Through a joint effort between A. Zahner and the architects, a custom complex mineral form of zinc oxide was created specifically for the museum in order to emulate the color tones of the surrounding Blue Ridge and Appalachian Mountains.

Steel framing is featured as an architectural element in the atrium lobby, and the roof is made of stainless steel as well.

Shingled, patinated zinc panels and stainless steel cover the undulating structure housing the Taubman Museum of Art in Roanoke, Va., designed by Randall Stout Architects, Los Angeles, and fabricated by A. Zahner Company, Kansas City, Mo.

Of course, the Achilles heel of many metals is that they corrode when exposed to moisture, salts, and certain other building materials. In addition, steel is highly susceptible to *galvanic corrosion*, which occurs when steel comes into extended contact with more noble metals. (The more noble a metal is, the more resistant it is to corrosion and oxidation.) Zahner delineates three conditions that can lead to galvanic corrosion:

1. Oxygen is present and available to the metal surface.
2. In the presence of moisture, an electrolyte develops. The electrolyte contains ions, which are charged particles that can move from one metal surface to another, creating a polarity between two or more elements.

3. The electron flow from one metal to another occurs either by way of water—electrolytically—or via direct contact.

"By preventing any one of these, the potential for galvanic corrosion is reduced," says Zahner.

A useful reference on galvanic corrosion is *ASTM's Standard and Guide for Development and Use Galvanic Series for Predicting Galvanic Corrosion Performance*. The ASTM guide's "Galvanic Series in Seawater" chart ranks metals from the negative, active end—those that are more prone to galvanic corrosion—to the noble, passive end—those that are the least prone. Thus, a partial list (from "negative, active" to "noble, passive" would be: zinc, galvanized steel, aluminum, steel, iron, active stainless steel, lead, tin, active nickel, brass, copper, bronze, passive nickel, monel, passive stainless steel, silver, gold, and platinum.

The metals industry is well informed about the performance of metals under different conditions; consequently, "appropriate protective techniques are in place and operationally effective," according to Miller. Protective coatings can be applied to prevent everyday corrosion; noncorrosive stainless steel or Cor-Ten weathering steel can be used as an alternative. Zahner often uses weathering steel in pre-oxidized colors, which he says many Building Teams appreciate for their leather-like surface appearance. His shop also can treat carbon steel to create exciting colors ranging from shimmering deep blues to marbled black and grays.

ALUMINUM—LIGHTWEIGHT AND SHAPELY

Compared to steel and many other architectural metals, aluminum is generally more lightweight, more resistant to corrosion, and better able to conform to a wide variety of shapes. "Aluminum is one metal that is extruded into shapes due to its very high strength-to-weight ratio. It can be easily finished and worked because of its relative softness in comparison to a metal like steel," explains Joseph A. Castner, AIA, RIBA, LEED AP, a principal with design firm KlingStubbins, Cambridge, Mass.

In fact, curtain wall framing is a common application for aluminum due to relative ease at which various shapes of the metal can be extruded. "Aluminum can be welded, extruded, or cast, and can be finished in a variety of ways," notes Wiss Janney's Koziol. "These qualities make aluminum an ideal material for use in wall cladding, curtain walls, roofing, flashing, exterior, and interior trim."

For much the same reason, Zahner often uses aluminum to fabricate engineered, profiled panel systems—the kinds of custom-designed panels that can be molded into unique shapes such as irregular curves and bends.

Although aluminum was discovered in 1855, it took a few more decades until a method was discovered to extract pure aluminum from naturally occurring compounds in large quantities at a reasonable cost, according to the authors Gayle and Look. Aluminum's first extensive use in North America was for the Empire State Building, completed in 1931, and its first major curtain-wall applications occurred in the 1950s as part of New York City's United Nations Building and Pittsburgh's Alcoa Building.

More recently, aluminum composite materials (ACM) have become popular, says Miller, who chairs the Metal Composite Material Fabricators Council and serves on MCA's board of directors. ACMs, he explains, are composed of thin sheets of coated aluminum over a polyethylene core. "They come in a variety of sheet sizes that can be bent, folded, or rolled, making them ideal for exterior use as a building skin or decorative elements. Generally, ACMs are coated with fluoropolymers, but newer, more exotic coatings allow its color to change dramatically under varying light conditions and make it a way to add pizzazz to buildings."

In terms of weighing aluminum up against steel, profes-

Spotlight: Aluminum Composite Panels at Miller Children's Hospital

Combining the qualities of aluminum and metal composite panels, a new project in Long Beach, California, will bring a splashy new look to the area when the Miller Children's Hospital Pediatric Inpatient Addition opens its doors in early 2010.

Designed by the architecture firm Taylor, based in Newport Beach, Calif., the exterior wall panels are treated with a special coating which enables their color to change from blue to green based upon the changing angles of the sun and changing views as one moves around the facility.

Other noted metal elements include aluminum curtain walls, metal siding panels, and laminate panels at the hospital's entry area.

Designed by architecture firm TAYLOR, Newport Beach, Calif., special metal coating will produce an eye-catching palette of colors on the Miller Children's Hospital Pediatric Inpatient Addition façade in Long Beach, Calif.

sional engineers J. Randolph Kissell and Robert L. Ferry, in *Aluminum Structures: A Guide to Their Specifications and Design*, debunk the myth that aluminum is not sufficiently strong to serve as a structural metal by noting that the most common aluminum structural alloy, 6061-T6, has a minimum yield strength which is almost equal to that of A36 steel.

In addition, Kissell and Ferry, founders of the Hillsborough, N.C.-based TGB Partnership, a consulting firm specializing in aluminum structural design, state that comparing the two metals based on cost per unit weight or unit volume is misleading, based on different strengths, densities, and other properties.

So while carbon steel is less expensive than aluminum, it also requires corrosion-resistant coatings and higher ongoing operation and maintenance costs. In addition, the low material cost of steel is sometimes offset by higher fabrication costs

But while aluminum does exhibit high resistance to corrosion, experts recommend treating the metal if you're looking for long-term durability in exterior applications. Historic preservation authority John G. Waite, FAIA, principal of John G. Waite Associates, New York City, writes in *Deterioration and Methods of Preserving Architectural Metals* that aluminum can be damaged as a result of regular contact with damp, porous brickwork or stonework, or even by contact with runoff from damp, unseasoned lumber which releases certain acids. Second only to copper in terms of its very high thermal coefficient, aluminum may also suffer fatigue from thermal expansion and contraction. Last, due to the metal's softness, it can also be prone to abrasion.

On the other hand, aluminum is a highly recyclable material. In fact, an Arlington, Va.-based Aluminum Association survey of aluminum producers last year discovered that the total recycled content of domestically produced flat-rolled products for the building and construction market was approximately 85%. In addition, the association claims that aluminum building components can be repeatedly recycled back into similar products with no loss of quality.

In sum, "Aluminum is considered a low-maintenance material with design flexibility and ease of reuse for curtain walls, windows, wall panels, and roofs for new and remodeled projects," notes Dean Vlahos, a veteran of three decades of experience in architectural forensic and director of WWCOT's Architectural Forensics division.

COPPER—PATINATION AND DURABILITY

Just like aluminum, copper is "infinitely recyclable." Executives at the British Copper Development Association remark, only partly tongue in cheek, that the copper on the penny in one's pocket "may be as old as the pharaohs."

Or take the Statue of Liberty: Through a century of sun, wind, and rain, Lady Liberty's beautiful copper skin had only oxidized 0.005 inches, making it one of the few major elements of this National Landmark that didn't need to be refurbished or replaced when the statue was renovated for its centennial.

"Copper is a very durable metal, and its aesthetic is valued because it provides corrosion resistance and durability naturally, without any human-made treatments or coatings," says Wiss, Janney's Koziol. The patina formed on the surface of copper as it oxidizes creates a barrier that makes the metal highly resistant to corrosion, which is why copper works well for roofing, flashing, trim, and cladding applications, he adds.

In fact, the New York–based Copper Development Association points out that copper flashing offers such longevity—around 80 years—that it usually outlasts the roof. So although copper flashing tends to be more expensive than other materials, it may offer a better life cycle cost value.

As for the patina that develops on copper over time, designers must decide if a verdant hue is aesthetically desirable. "I find copper to be one of the most interesting of all metals," says Zahner. "Other than gold, it is the only metal with a natural color other than gray. Copper says 'elegance' and we are constantly working with various copper alloys to push new and unique color tones and textures."

If, however, you want to retain copper's original color for as long as possible, the Copper Development Association recommends the use of overhangs and sloping copper surfaces away from other materials, gutters, and drip edges. That way the weathering process which occurs when copper salts mix with rainwater can be significantly slowed. In addition, a clear coating can be applied to copper panels to provide short-term protection to weathering.

Because copper is one of the most noble metals, care must be taken to prevent it from causing galvanic corrosion when in contact with less noble metals. One strategy, says the Copper Development Association, is painting adjacent surfaces with bituminous or zinc chromate primers or paints. Taping or gasketing with non-absorptive materials also can help.

As for fastening copper with other metals, CDA's architecture regional manager Wayne Seale recommends that the fasteners be made of copper, copper alloys, or stainless steel. Designers should also seek ways to prevent rainwater from running off the copper to other metals, particularly aluminum or galvanized-steel gutters and downspouts.

COPPER ALLOYS—AESTHETICS AND DURABILITY

Copper alloys—brass, bronze, and nickel-silver—are known for their striking aesthetics and durability. In fact, KlingStubbins' Castner identifies copper alloys as being associated with high-end buildings. "Because of the expense involved, these alloys were associated with projects that were high quality, where cost was less of an issue," he says.

For example, bronze—which was historically an alloy of

copper, and today, copper and brass—was traditionally used for custom-designed doors and decorative features on historic public buildings, according to preservationists Gayle and Look. Even today, brass (copper plus zinc) is used to add elegance to doors, windows, elevators, and escalators. As for nickel-silver, it's actually an alloy of copper and nickel, despite its name. "It offers a beautiful light golden tone, and although it's one of the more expensive of the copper alloys, nickel-silver, when used correctly, offers extremely elegant color tones," says Zahner. Historically, nickel-silver was used to contrast other metals and became quite popular in the 1920s and 1930s; it is still in use as a striking decorative material today.

Another application is nickel electroplating, which serves the dual function of a decorative finish and corrosion resistance. In fact, two-thirds of all nickel annually manufactured goes into the production of stainless steel, specifically for this purpose.

Although copper alloys are known for their weatherability, one type of corrosion is unique to brass and bronze alloys with more than 15% zinc. Called dezincification, according to preservationist Waite, the copper-zinc alloy can be dissolved when exposed to acidic or strongly conducting solutions. The effect is pronounced, leaving the metal pitted, porous, and often weakened. Appropriate preventive measures should be taken to avoid exposing copper-zinc to these solutions.

ZINC—LONGEVITY, LOW MAINTENANCE

Zinc is known for its long-lasting, low-maintenance, and corrosion-resistant traits. As with copper, says Koziol, zinc resists corrosion by forming an oxide film when exposed to the atmosphere. Zinc is typically alloyed with copper or titanium (or both) for use in architectural applications for improved strength and to reduce brittleness, he adds.

Laurent Heindryckx, technical manager of the commercial zinc roof and wall system fabricator Umicore Building Products USA, Raleigh, N.C., explains how this process works: "Zinc forms a protective layer of hydroxycarbonate when exposed to water and carbon dioxide. This natural patina protects zinc and naturally reforms when accidentally scratched. This self-healing characteristic makes zinc very attractive to building owners." Because of these properties, zinc is also used to protect other materials, such as galvanized steel, from corroding.

Historically, zinc was used exclusively to manufacture brass, but by the late-16th century, it was recognized as its own metal in Europe, according to the Washington, D.C.-based American Zinc Association. Although zinc has been used in Europe for the past 200 years—about 85% of the metal roofs in Paris are made of zinc—it was not adopted in the U.S. until 1850.

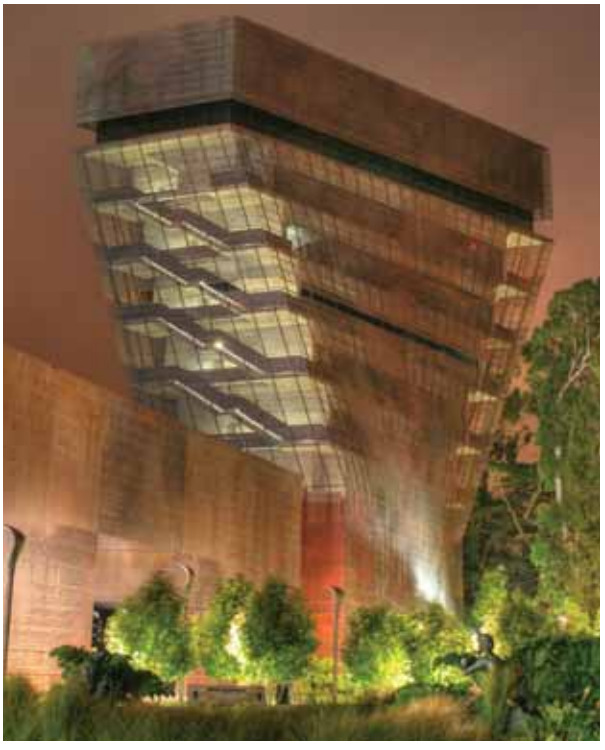
One of the reasons why zinc is such a popular roofing and cladding choice is its longevity. Zinc roofs can last 100 years, and zinc wall applications can last as much as 150 years. The material was historically thought of primarily as a roofing material,

Spotlight: Copper Skin at the de Young

What has been dubbed "one of the most unique metal surfaces used on any building," San Francisco's de Young Museum of Art—designed by Swiss architectural firm Herzog & de Meuron—presents visitors with a dynamically evolving, eye-catching building skin using one million pounds of commercially pure copper.

Aiming for a surface that would emulate light passing through a canopy of trees, the architects partnered with the fabricator A. Zahner Company to create the novel skin. After creating "digital maps" from images of light passing through an actual canopy of trees, the digital information was then coded to machine processes that pushed dies to varying levels across the sheet. All in all, more than six million impressions were applied to the surface or punched through the copper plates.

The museum's roof is also made of copper. The system is a very-low-slope copper roof where water is evacuated via concealed stainless-steel gutters within the roof system.



More than six million impressions on one million pounds of commercially pure copper emulate the look of light passing through a canopy of trees on the façade of San Francisco's M. H. de Young Museum of Art, designed by Swiss architects Jacques Herzog and Pierre de Meuron and metal fabricator A. Zahner Company, Kansas City, Mo.

but recently zinc has come into favor as a cladding material because of the aesthetic appeal of its patina. KlingStubbins architect Joseph Castner points to zinc's "excellent longevity" and softness, which allows it to be worked in the field with hand tools.

At the same time, zinc falls into the price range of higher-end building materials such as slate, stainless steel, and copper. Umicore's Laurent Heindryckx says there are two reasons why the initial installation cost of zinc roofs is higher than roofs made of painted steel and aluminum: "First, the cost of the raw material is higher per square foot. Second, the quality of the workmanship required to install long lasting products is higher, and therefore more expensive. However, the cost per square foot per year is relatively low when the service life of the metal is considered."

In terms of environmental considerations, zinc's long life span means that it seldom needs replacement. Although it is 100% recyclable, it only has a recycled content of about 17%, according to Heindryckx. At the same time, he notes, "less energy is used for refining and recycling zinc because of its low melting point, whereas copper and stainless steel need twice [as much] energy, and aluminum even four times more."

While zinc is resistant to corrosion on its top side—which is why close to half the zinc produced every year is used for galvanizing steel—it is vulnerable to corrosion on its underside when exposed to moisture for a prolonged time, says Koziol. Consequently, "Venting the underside of zinc sheeting is required to prevent corrosion from the underside." As for galvanic corrosion, zinc is not compatible with copper or iron, so zinc is usually installed with a minimum slope in order to drain water.

Aesthetically, zinc comes in matte grey, black, pigmented blue-grey, red-grey, and green-grey. "Zinc offers an interesting gray surface, but can also be enhanced to produce oxides of color tones that rival the natural minerals found in decorative stone," says Zahner.

TITANIUM—COMPATIBLE WITH GLASS AND CONCRETE

Also lending an attractive grey appearance is titanium, a nickel alloy. "Titanium, when detailed and constructed correctly, is a beautiful, extremely thin and soft grey metal. It can also receive interference coloring to enhance its soft natural color," says Zahner.

Due to its strength, durability, corrosion resistance, and low thermal coefficient, titanium is actually become a roofing option for commercial and institutional building owners, according to Haddock.

In fact, titanium's coefficient of thermal expansion is half that of stainless steel and copper, and one-third that of aluminium, making it almost equal to glass and concrete in that regard. As a result, the thermal stress on titanium is very low and it is highly compatible with glass and concrete, according to *The A to Z of Materials*, Warriewood, NSW, an Australia-based online resource for the design and engineering community supported by a team of global materials scientists.

Designed by Rees Architects, Rees Plaza in Oklahoma City features a standing seam copper wall cladding system. Naturally weathering copper was chosen to help blend the building with its verdant park setting.

Zahner adds that titanium's low expansion and contraction characteristics allow for tight-fitting surfaces. "Like stainless steel, titanium resists oxidation in natural environments and maintains an even appearance indefinitely," he says.

In addition, titanium has very low thermal conductivity—one-tenth that of aluminum—making it an excellent insulator. It is also relatively lightweight, enabling easier fabrication and installation and requiring less structural support, according to AZoM.

At the same time, titanium is somewhat harder to work with, says Zahner, and one of the more expensive of the architectural metals. For those reasons, it offers more potential as a surfacing material.

Monel. Another "exotic metal" with properties similar to titanium's is monel. Although it is quite expensive, its strength and corrosion resistance make it a great application for harsh environments such as coastal areas, explains Castner.

Monel is an alloy of approximately two-thirds nickel and one-third copper. Discovered in 1905, it was more commonly in the first half of the 20th century for applications such as roofing, until it was replaced by more economic metals like stainless steel and aluminum, according to Gayle and Look.

GALVANIZED STEEL—ECONOMICAL, BEAUTIFUL

Galvanized steel and Cor-Ten steel are also viable metal options available to designers. "Galvanizing steel is an ideal way to extend steel's life by improving its resistance to the elements," explains McLane. "Galvanized flashing, siding, and roofing are relatively inexpensive, long-lasting products. If they are also coated or painted, their life expectancy is increased even further."

Typically a pure zinc coating is used for galvanizing; in addition to increasing steel's longevity, the zinc becomes part of the steel recycling circuit.

"When used correctly, hot-dipped galvanized steel is an economical choice and can provide beautiful irregular reflective

surfaces," says Zahner. "We create our own hot-dipped galvanized panels and forms that can be spectacular in appearance."

Cor-Ten. According to Castner, Cor-Ten is a steel alloy that forms a patina on the surface to slow the rate of corrosion, such that it requires no other finish to protect the metal. "It is particularly well-suited to the drier climates where it achieves that patina finish early and then stops corroding because the environment is dry."

In addition, it is becoming a more attractive choice for cool roof systems. However, Vlahos warns against other applications. "Cor-Ten should not be used for siding or roofing. It is more susceptible to the risk of corrosion due to improper design, fabrication, erection, and maintenance. Cor-Ten does not perform well for roofing panels or wall panels because it is susceptible to weathering and corrosion. The material will reform, resulting in perforations in the surface over time."

METAL COMPOSITE MATERIALS

Metal composite materials, or MCMs, are defined as two metal skins sandwiching an engineered plastic core. When they were first used in construction in the early 1980s, the metal of choice was aluminum. But more recently, zinc, copper, stainless steel, and titanium are being manufactured into panels as well.

Ted Miller, of the Miller-Clapperton Partnership, says MCMs (as outlined by Section 1407 of the International Building Code) offer superior flatness over many other building materials, which can have surface imperfections that show in the finished product. "MCMs are easily formable with both computer-controlled machining centers or simple hand tools, and they can be utilized to 'trim out' the intersection of other major materials to form a seamless transition," says Miller.

Metal used in composite materials offers very high strength, rigidity, flatness, and durability, says Kriner. Applications include interior and exterior wall systems, curtain walls, facades, signage, and replacing full-thickness aluminum or steel wall products.

Metal composite materials are easily workable into a wide range of geometric configurations, and due to their light weight, they require less structural support than some other architectural metals.

NOVEL FINISHES—CREATING 'UNLIMITED DESIGNS'

Although metals can be galvanized, anodized, and painted in countless number of colors, a number of novel finishes can greatly enhance the decorative qualities of metal.

For example, prints of "unlimited designs" can be prepainted onto metal sheet products, according to Kriner. Wall cladding can have stucco-facsimile textures or concrete appearances. And metal roofing is available in a wide variety of colors and granular coatings to simulate wood shake, clay tile, asphalt shingle, and slate.

Similarly, there are faux metal finishes to emulate wood grains or stone looks, according to Miller: "Many of the color finishes offer interesting metallic and prismatic looks as well as a textured." Zahner adds colored zinc and colored and custom-textured stainless steel, as well as "angel hair" stainless steel.

In addition, copper in colors other than green and pre-weathered weathering steel are also "beautiful surfacing materials," says Zahner.

An unusual approach to metal finishes comes from Josh Shelton, principal of el dorado inc., Kansas City, Mo. "I like to think of light as an interesting finish for different metal surfaces," he says. "Being aware of what type of light an exterior wall panel will receive from dawn to dusk can really animate the profile of a selected metal siding. Also, integrating lighting systems into metal wall systems can achieve the same effect at night."

MORE THAN A FEW CHOICES

Although there are many building materials to choose from and each has its time and place, metals, in Castner's opinion, "in general are well suited as a building material because of their weight-to-strength ratios, durability, workability, and cost. In essence, great value."

Most architectural metals also have an impressive recy-

Spotlight: Zinc Roofing at UNC Greensboro

When it came time to choose a roofing material for the Science Building and Hall for Humanities & Research Administration Building at the University of North Carolina in Greensboro, longevity and durability were high on the priority list. Consequently, the university chose zinc panels with a pre-weathered quartz-zinc surface.

Though the product had a higher first cost than other materials, Fred Patrick, the university's director of Facilities Design and Construction, was able to justify the expense to the university's board of trustees. "'Utilizing better materials that will meet our long-term goals will save money for us in the long run,'" Patrick recalls telling the trustees. As a result, he says, "The university was willing to pay a little more up front for quality materials that will meet our standards. Once they saw how products like zinc actually save us money in the long run, we got the green light."

Designed by Calloway Johnston Moore & West, Winston Salem, N.C., the building called for zinc panels that were specified with a backside coating to ensure the prevention of corrosion on the underside of the panels. The designers also chose to go with a sloped roof, as opposed to a flat roof, in the interest of longevity.

In terms of blending aesthetics and durability, CJMW project manager Andy Sykes says, "Zinc is a very natural material with a self-healing characteristic that protects it from scratches and mars."

cling track record, as Zahner explains. “Scrap from fabrication processes, damaged material, and obsolete metal structures are readily recycled and put back to use in new metal constructs,” he says. “Can you name another material that comes close to this?” BD+C

Glossary of Metal Deterioration

In addition to the well-known causes of metal deterioration—corrosion and galvanic corrosion—a number of other chemical and mechanical elements can cause the breakdown and eventual failure of metal.

Historic preservation expert John G. Waite, FAIA, principal of John G. Waite Associates, New York, defines the many terms associated with metal corrosion in his book *Deterioration and Methods of Preserving Architectural Metals*. Here is a partial glossary:

Abrasion. The erosion of the metal caused by dirt, dust, sand, rain, sleet, or hail, or by rubbing against another architectural element, or through human contact.

Connection failure. Bolted or welded connections of metal elements may fail through overloading, fatiguing, or corrosion of the connectors.

Creep. Deformation of soft metals under sustained stressing, sometimes under relatively high temperatures.

Erosion. Can occur when protective oxide, films, or layers are removed by abrasion and the metal is exposed to corrosive agents.

Fatigue. Metal failure due to repeated cyclic stresses below the elastic limit.

Fire damage. Unprotected iron and steel framing members can fail rapidly when exposed to prolonged fire.

Overloading. Stressing the metal beyond its yield point, causing deformation, fracturing, or failure.

Stress corrosion cracking. Can occur when stresses are induced into the metal during the metalworking process and the metal is subsequently exposed to corrosion.