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Copper in a Sustainable Context

by Anne L. Schade, CSI, CDT

Copper has been used for roofing, flashings, and other exterior building components for centuries. In Europe, there are examples of architectural copper installations tracing back to the Roman Empire. Also, portions of the copper roof on the cathedral in Hildesheim, Germany, date from the 1200s.

Long before there was an environmental movement, the building community recognized correctly designed and specified copper installations were durable, recyclable, and virtually maintenance-free. Indeed, copper was very close to meeting the needs of the present without compromising the ability of future generations to meet their own needs—a often used definition of sustainability.

Despite (or perhaps due to) widespread use of copper in everyday life, from water distribution tubing to cookware, the early 1960s brought apprehension about the metal's effects on the environment. Rather than the material's use as a building product, these concerns tended to focus on copper's extraction processes (*i.e.* mining) and industrial discharges to waterways.

All images courtesy Revere Copper Products

The copper industry responded by enacting land reclamation projects at historic and then-current mining operations, while also building or upgrading wastewater treatment facilities and establishing air emission controls. By the mid-1980s, manufacturing practices and discharges from most facilities not only met state and federal requirements, but often exceeded them. However, the perception of copper from a green perspective would be marred decades later.

In 2000, the City of Palo Alto, California, commissioned the environmental source assessment study, "Architectural Uses of Copper: An Evaluation of Stormwater Pollution Loads and BMPs [Best Management Practices]."[1] While many believe the final report had numerous flaws, the effect on the design/construction community was substantial. Many architects and engineers were given an overly negative—and largely unfounded—view of the metal's effect on the environment.

Previous features in *The Construction Specifier* have focused on the technical aspects of designing for copper and its unique aesthetics.[2] In an attempt to raise awareness of the material's true impacts, this article instead looks at the specification of copper from within a sustainable context.

The Palo Alto study

The Palo Alto report consisted of information that seemed to rely on existing literature and did not involve new field measurements or tests. Nevertheless, among the conclusions drawn from the report was "a copper roof on a new [232.6-m^2] 2500-sf home is estimated to initially corrode at the rate of 1 kg (2.5 lb) annually."[3]

An immediate consequence of this report was the city passed an ordinance to "prohibit the installation of copper metal roofing and gutters, and even copper-granule-containing asphalt shingles on new and existing buildings."[4] Further, the study was embraced in many quarters beyond California, often without question or in-depth peer review. To some, architectural copper became a pariah—a material to be avoided at all costs.

Years earlier, similar concerns had been raised in Europe. As a result, beginning in 2000, the European Copper Institute (an affiliate of the International Copper Association [ICA])—undertook a risk assessment of all copper products in the European Union to categorize the sources of the element to the environment, as well as its effects.

That study, now nearing final acceptance by the European Commission, showed the actual copper available to the environment from external building applications was 1.2 percent of the total inventory of copper emissions. As shown in Figure 1, the amount of copper from exterior architectural applications was similar to the level from fireworks (1.1 percent).

European regulators were particularly surprised by one finding of this inventory: almost all the copper emitted in the EU was from intentionally dispersive applications (*e.g.* agricultural pesticides, fertilizers, and livestock feeds), rather than from the lifecycles of durable products.[5]

As discussed later in this article, other concerns lay with the Palo Alto study. To make an informed decision on the best ways to use copper, various questions need to be answered. Architectural copper and its embodied energy must be understood, but so too must the true effect of copper runoff.

Where copper comes from (and where it goes)

In the United States, architectural copper is made primarily from scrap (or recycled copper). While the percentage and the source varies, a 2006 Copper Development Association (CDA) market study—conducted for a 10-year timeframe—suggests at least 70 percent of the material used domestically in architectural copper is recycled.

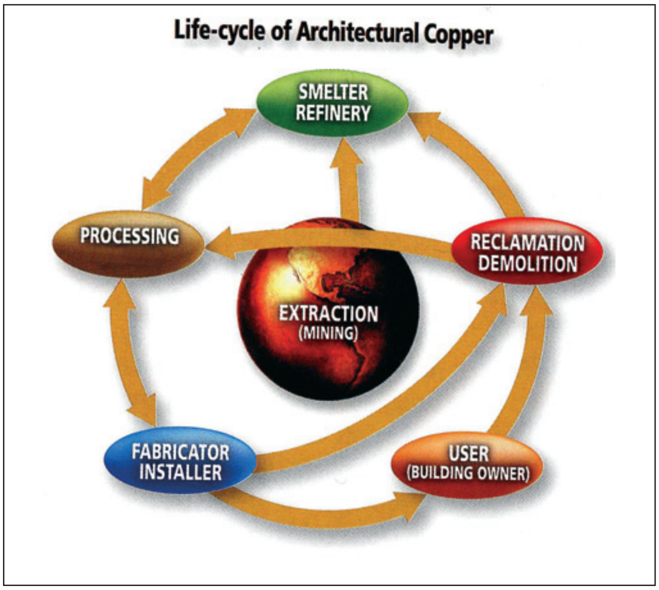
In the value chains for its durable products, copper is recyclable in all forms and states. Copper cuttings, filings, and similar 'excess' metal produced during fabrication, as well as the copper in discarded, finished products can be reclaimed and recycled. Recycling salvaged copper is not a new, fashionable idea—it is an ancient and continuing practice. It is believed the Colossus of Rhodes (one of the seven wonders of the ancient world) was made of copper alloy. The reason not a trace of it remains is likely due to the fact it was recycled and used in other building projects. Likewise, many implements and ornaments created by ancient artisans from copper were melted and refashioned repeatedly.

Architectural copper is similarly a 'cradle-to-cradle' product. When a copper roof or wall cladding has served its useful life, it can be recycled simply by re-melting—smelting and refining are usually unnecessary.

Although the recycled content of architectural copper varies by producer, most will certify the percentage in their products; some provide documentation showing products made from 90 to 95 percent recycled material.

Embodied energy consumption

With all the discussion of lifecycle assessment (LCA), the design/construction community's attention has recently been turned to embodied energy—the energy used throughout a commodity's 'life' for manufacturing, transporting, and disposal. Deutsches Kupferinstitut (DKI) has determined the embodied energy for architectural copper made from primary



The lifecycle of architectural copper is longer than many other materials. Its reuse allows it to assume a 'cradle-to-cradle' role.

and secondary cathodes, along with clean scrap, is anywhere between 15 and 30 MJ/kg (6.5 to 13 MBtu/lb).[6]

However, DKI goes on to note the importance of considering a material's life span when it comes to embodied energy comparisons. For example, when selecting a roof for a building with an expected life of 100 years, the designer has several options. A roof made of a petroleum-derived product (single-ply or built-up) may last 25 years, while the service life of a copper roof could likely exceed that of the building. Therefore, a valid comparison of embodied energy in a case like this should be copper versus four times the embodied energy of the petroleum product.

Runoff research

While the source assessment study performed for the City of Palo Alto assumed copper corrosion and the runoff from roofs are the same, this is not the case. Copper is subject to atmospheric corrosion (this is how the metal's green patina is formed) and, indeed, runoff from roofs, gutters, and other architectural applications will contain copper. However, the amount or form often changes as the runoff travels from the installation to the environment.

After several years of work, scientists sponsored by the European Copper Institute recently completed a model to estimate the amount of copper in roof runoff, depending on local precipitation and air quality conditions.[7] The copper runoff predictions of the model for the San Francisco Bay area are much lower than the Palo Alto estimates; annually, they are about 1 g Cu/m^2.[8]

Further, not all forms or compounds of the metal—or many other chemicals—are harmful. In the environment (*e.g.* water and soil), copper usually binds readily to natural inorganic and organic chemicals, greatly reducing the bioavailability of the copper (*i.e.* the degree to which a chemical or element can be absorbed by an organism), and thus its potential toxicity. In May 2007, the U.S. Environmental Protection Agency (EPA) revised how water quality criteria for copper is set; EPA now recommends a method to estimate copper criteria based on its local bioavailability.

In the Palo Alto report, it was assumed all runoff entered the San Francisco Bay in a fully bioavailable and toxic form. Later research projects demonstrated this was not true.[9]

When acidic rain falls on copper, it releases ionic copper (Cu^{2+}), the form of the metal that may adversely affect sensitive aquatic organisms. Ionic copper may be sufficiently concentrated to be acutely toxic to the most sensitive of aquatic species at the roof downspout and drain at the street. However, this level of ionic copper may not be observed in the balance of the watershed.[10]

By simply allowing the stormwater to flow through the drainage system, the ionic copper binds to a variety of natural materials (*e.g.* decaying leaves), so the remaining bioavailable concentration is often lowered to the level where environmental harm is no longer observed.[11]

In other words, before the runoff reaches a receiving stream, much of the copper in it has been converted to a form that has little to no bioavailability. The 2000 Palo Alto study overlooked this important fact. Therefore, in most situations, it is safe, prudent, and desirable to specify copper for roofing, flashing, and rainwater goods. Standards dealing with this and other aspects of architectural copper are available through www.copper.org.

Notes

1 The November 2000 text of the report is no longer available on the City of Palo Alto Web site (www.city.palo-alto.ca.us). However, the revised report—dated 2006—can be downloaded for reader review.

2 See this author's "Specifying and Designing Copper Roofs" in the December 2004 issue of *The Construction Specifier,* for example.

3 See note 1.

4 Visit www.city.palo-alto.ca.us for more information on Sewer Ordinance 16.09.160(b).

5 Copper is an essential micronutrient for all life, and is an essential agricultural additive. Copper-deficient soil is a major problem in worldwide production of food and raising of livestock. In many areas of Europe, as well as parts of the United States, livestock feeds must be supplemented with copper to correct the deficiency that would otherwise occur

Specifying Architectural Copper

Architectural copper is rolled copper sheet and strip (in flat lengths or coils) in ounce-weight thickness for roofing, flashing, wall cladding, rainwater goods, and general sheet metal work. In the United States, it is produced to ASTM International B 370, *Standard Specification for Copper Sheet and Strip for Building Construction*.

By this specification, the building material can be any copper with a minimum copper content (including silver) of 99.5 percent. Although architectural copper often contains a greater percentage of copper and may meet the requirements of other copper materials, it does not have to be C11000.

Copper designated as C11000 (and certain others) is produced to ASTM B 152B, *Standard Specification for Copper Sheet, Strip, Plate, and Rolled Bar*. Note 3 of ASTM B 152 states:

> This specification is not intended to cover material rolled to ounce-weight thickness. Such material is covered by Specification B 370.

The specifier may do his or her client a disservice, economically speaking, by calling for a specific copper alloy, rather than identifying the ounce-weight required and the application for which it will be used. This leads to the question of how copper thickness can be designated.

Ounce-weight is the weight of copper sheet or strip expressed in ounces per square foot. The reason for this measurement's use may be lost to history, but it is safe to assume copper always had a certain intrinsic value. Minor deviations in thickness would have resulted in a consumer being overcharged for the material received. Therefore, before the widespread use of micrometers, there needed to be a way for consumers to be certain about the thickness of their purchase.

Since the density (*i.e.* g/cm^3 [lb/ci]) of metals is essentially constant, all it takes to determine the thickness of a sheet is a way of measuring area (*e.g.* a ruler) and weight (*e.g.* a scale or balance). Thus, armed with these rudimentary measuring devices, a customer could determine if he or she was getting that for which was paid.

As illustrated below, the current edition of ASTM B 370 lists nine ounce-weight thicknesses for architectural copper. Of these, certain types should only be used for specific applications:

- 6-, 8-, and 10-ounce: solely for concealed flashings, as it is too light to withstand potential physical damage and may not have enough columnar strength to transfer movement;*
- 12-ounce: used for some exposed flashings and certain roofing applications, but has insufficient columnar rigidity for some types of roofing, flashings, and rainwater goods;
- 16- and 20-ounce: has enough columnar rigidity for roofing, wall cladding, rainwater goods, and flashing in most architectural applications; and
- 24-, 32-, and 48-ounce: suitable for built-in gutters (where greater columnar rigidity is necessary) and wall panels (where extreme flatness is desired).

* When subjected to temperature changes, sheet metal shapes expand and contract. This movement results in stress (*i.e.* load). The ability of the metal shape to resist this load and transfer expansion movement is referred to as columnar rigidity.

ASTM International B 370 and Copper Thickness

Ounce-weight/sf	Theoretical thickness; mm (in.)	Minimum thickness at any point; mm (in.)	Lot-weight tolerances (± percent)
6	0.206 (0.0081)	0.180 (0.0071)	10
8	0.274 (0.0108)	0.246 (0.0097)	8
10	0.343 (0.0135)	0.315 (0.0124)	6
12	0.411 (0.0162)	0.381 (0.0150)	5
16	0.549 (0.0216)	0.518 (0.0204)	4
20	0.686 (0.0270)	0.655 (0.0258)	3.5
24	0.820 (0.0323)	0.782 (0.0308)	3.5
32	1.09 (0.0431)	1.04 (0.0411)	3
48	1.64 (0.0646)	1.58 (0.0621)	2

When used appropriately, copper roofs offer both aesthetic and functional benefits for buildings.

if only locally grown grains and feeds were consumed.

[6] For more information on the work done by the Deutsches Kupferinstitut, visit their Web site at www.copper-life-cycle.org.

[7] See "In Vitro Studies of Copper Release From Powder Particles in Synthetic Biological Media," by Inger Odnevall-Wallinder et al. This article appeared in the January 2007 edition of *Environmental Pollution* (vol. 145, no. 1).

[8] See "Probability-based Estimates of Site-specific Copper Water Quality Criteria for the Chesapeake Bay, USA," by W. Ray Arnold and William J Warren-Hicks from the January 2007 edition of *Integrated Environmental Assessment and Management* (vol. 3, no. 1).

[9] See B. Boulanger and N.P. Nikolaidis's "Mobility and Aquatic Toxicity of Copper in an Urban Watershed," in the 2003 edition of the *Journal of American Water Resources Association* (vol. 39, no. 2).

[10] This information comes from Harold T. Michels' article, "Research Projects: Copper Roof Stormwater Runoff." Visit www.copper.org/environment/NACE02122/nace02122d.html

[11] See W.R. Arnold et al's "Effects of PVC, Cast Iron, and Concrete Conduit on Concentrations of Copper in Stormwater," from the September 2005 issue of *Urban Water Journal* (vol. 2, no. 3).

Additional Information

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Abstract

For centuries, copper has been employed as a building material, but a relatively recent study suggested its use for architectural applications could have adverse environmental impact. The copper industry responded through research conducted in conjunction with universities, governmental bodies, and various other organizations. This article examines some of the findings, discussing copper's potential in sustainable design.