Sustainable Stainless Steel Architecture

Pittsburgh Convention Center, Photo Courtesy of Allegheny Technologies

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Introduction

Stainless steel is one of the most environmentally friendly metals commonly used in construction. It is used to help generate energy, save energy, provide clean air, conserve water, avoid hazardous chemicals, and limit metal contamination of the environment and landfill waste. If the correct stainless steel and finish are selected and properly maintained, it will remain attractive over the life of the building even if that spans hundreds of years. Even after many years of neglect, stainless steel can often be restored to its original appearance or reused in other applications. Many of the characteristics that determine whether a metal is "green" are either directly or indirectly related to corrosion resistance. Stainless steel's high scrap values and very low corrosion rates ensure high real recycling rates after a long service life. Coatings that outgas or adversely affect the ability to recycle metal are unnecessary. Stainless steel's long service life maximizes the life of other materials preventing premature failure of systems designed with stone, masonry, or wood. Knowledge and use of stainless steel's many applications and advantages can help to create a greener world.

What Makes A Stainless Steel "Green"?

Interest in "green" construction has grown significantly with emphasis on evaluation of entire buildings as well as individual materials. The LEED™ Green Building Rating System and the various product evaluation systems raise many questions that are directly or indirectly related to metal choice. These include the recycled content, potential for product reuse, impact on energy and water consumption, the likelihood of product or coating emissions, impact on indoor air quality, thermal comfort, durability, maintenance requirements, and impact on indoor light.

Ideally, the designer needs a fully quantified master database providing objective life-cycle environmental impact assessments for all construction materials. Unfortunately, that is not available. The data available for different materials are often not directly comparable, and it is important to ask questions. Figure 1 summarizes common questions and answers about the environmental friendliness of stainless steel, which are discussed in more detail in the following sections.

Figure 1: Stainless Steel Environmental Evaluation

What is the recycled content?	60%*
Is it 100% recyclable?	Yes
Does it provide long life?	Yes (reduces maintenance and disposal frequency)
Is there recycled content?	Yes (both post-consumer and post-industrial)
Is construction waste diverted from landfills?	Yes (high scrap value and product reuse potential)
Can it be salvaged and reused during renovations?	Yes
Is it a low emitting material?	Yes (no coatings = zero emissions)
Can it help to improve indoor air quality?	Yes (no volatile organic compounds (VOCs), bacteria removal, corrosion resistant ductwork)
Does it help avoid the use of toxic materials?	Yes (long lasting termite barriers, minimal roof run-off)
Can it save energy?	Yes (sunscreens, roofing)
Can it help generate clean energy?	Yes (solar panels, power plant scrubbers)
Can it conserve water?	Yes (corrosion and earthquake resistant water lines and tanks)
Can reflective panels add natural light?	Yes
Can it extend the life of other materials?	Yes (stone and masonry anchors, fasteners for wood and long-life metals)

*As reported by the International Stainless Steel Forum in 2002. Rate may have declined somewhat due to reduced scrap availability.

Recycling

Reported recycling rates are based on the percentage of recycled metal that is used in the average “heat” of metal produced. Recycling rate data can be difficult to compare. For example, published recycling rates for aluminum are very high because large quantities of aluminum cans are produced and these cans may be recycled several times in one year. In comparison, stainless steel is typically in use for twenty or thirty years before it is recycled. Although stainless steel scrap has a very high recapture rate due to its value, its long service life and the rapid historic growth in stainless steel production make it impossible for stainless steel “heats” to have a very high recycled content. The stainless steel producers would like to have 100% scrap “heats” but there is not enough scrap available. In 2002, the International Stainless Steel Forum estimated that the typical recycled content was about 60%. [1] Recycled content has probably declined somewhat because excess eastern European scrap inventory has now been recycled. It is important to recognize that stainless steel is 100% recyclable, and there is no down cycling no matter how many times it is recycled.

When evaluating metals, it would be more meaningful to look at the probability that an average piece of metal will be recycled. Large expanses of roofing or wall panels are likely to be recycled, but a smaller item like a corroding threshold, gutter, flashing, or railing might end up in a landfill if the scrap value is not high. If metal is lost due to corrosion, it cannot be recycled. Some coatings limit or prohibit recycling of the base metal. Corrosion resistance, scrap metal value, the type of application, and the presence and type of coatings determine whether an average piece of metal will be recycled. Metal components with significant metal mass loss due to corrosion may have negligible or no scrap value. Stainless steel is used for applications that are designed to last a long time, which limits re-melting frequency, but high scrap values, avoidance of coatings, and negligible corrosion rates ensure that most of the stainless steel that is put into service will eventually be recycled.

Corrosion And The Environment

The US government determines the annual economic cost of metallic corrosion on a regular basis. The most recent study, completed in 2001, determined that the total direct cost of corrosion was $296 billion/year and the indirect cost was $255.4 billion/year for a total of $551.4 billion/year. [3] Of that, $113.6 billion/year was attributed to the direct and indirect cost of construction material corrosion. This analysis does not include either infrastructure or industrial construction. The authors estimate that at least 20 to 25% of construction-related corrosion failures were avoidable and indicated that the number could be higher. This includes obvious failures such as roof or wall panel perforation or a railing that has become structurally unsound. This category would also include replacement of components that have become aesthetically unattractive due to corrosion when restoration is either not possible or not cost effective.

The high economic cost is one indication of the significant environmental cost associated with selecting materials that will not remain attractive and/or functional over the life of the building or structure. In green design, the architect must consider the following questions when selecting architectural metals:

- Will the product have to be replaced during the probable life of the building?
- How recyclable or reusable is the product?
- If a coating is specified, will out-gassing or coating loss to the environment due to wear or spalling be a concern?
- Will any coatings limit or prevent recycling of the base metal?
- How much metal will enter the environment due to corrosion? Is the corrosion product hazardous or is the corroded appearance aesthetically unappealing?
- Considering metal loss due to corrosion, how much will not be recyclable and will have to be replaced by mining new metal?
- How much maintenance will be required and are the cleaning products potentially hazardous?

Comparative atmospheric corrosion data for different metal alloys can be used to predict the service life of a component, maintenance requirements, and metal loss to the environment. These data can be found in previous *Construction Specifier* articles and a Nickel Institute publication written by the author. [3, 4, 5] Generalized corrosion maps have been developed based on this atmospheric corrosion testing, which indicate the relative corrosiveness of different locations and can help guide metal selection decisions. One source of these maps is the website http://corrosion-doctors.org. Generally, areas with particularly acidic rain, high airborne particulate levels, higher levels of sulfur and nitrous oxides and ozone, and coastal or deicing salt exposure are the most corrosive and require more corrosion resistant metals.

When environmental friendliness is a concern, it is critical to select metals, like stainless steel, which do not require coatings, but do provide a high level of corrosion protection. These materials will not need to be replaced over the life of the building, and they will not shorten the life of other building materials through their failure. Stainless steel is more corrosion resistant than other common architectural metals and is not affected by some of the pollutants that will corrode them such as nitric acid, carbonic acid, and ammonia, which can be found in acid rain. Potentially corrosive environments for stainless steels and other metals include sulfuric acid in acid rain, high levels of atmospheric particulate, and/or deicing or coastal salt (chlorides). If the right stainless steel and finish are selected and it is properly fabricated, installed and maintained, there will not be a corrosion problem. Please see the additional information resources section for more information on appropriate stainless steel selection.

Enhancing the Indoor and Outdoor Environment

Stainless steel is ideal for interior applications because no coatings are required and there are no emissions. With proper selection, ductwork made of stainless steel will not perforate due to corrosion and can be thoroughly sanitized. Reflective stainless steel panels can be used to bring natural light into buildings. Specifying an effective, long-lasting stainless steel termite barrier can eliminate termite pesticide treatments and may reduce the cost of insurance coverage. Cleaning stainless steel does not require chemicals that are hazardous to workers or the environment. Furthermore, stainless steel is an important part of industrial and automotive emission reduction systems.

Roof run-off data that were generated in a Swedish study that compared stainless steel, copper and zinc (coatings on galvanized steel and zinc sheet) can be found in Figure 2. [6] These run-off levels are representative of the Stockholm area, a region with relatively low pollution levels. The primary focus of this research was the influence of atmospheric corrosion on roof run-off levels, bioavailability, and eco-toxicity. The run-off rates of nickel and chromium were extremely low and, in many samples, the nickel and chromium levels were below detectable limits and all of the samples were well below typical drinking water concentrations. The tests suggest that nickel and chromium are released from stainless steel roofs at such low rates that they do not cause eco-toxicity. The zinc and copper run-off levels were approximately 10,000 times higher, both were in a bio-available form and eco-toxicity is possible as water concentrates during dry periods. A similar study of lead run-off from roofs in low pollution marine and inland rural sites in Oregon found that concentrations were between 0.7 and 3.7 mg/L compared with the United States EPA lead drinking water standard of 0 mg/L (with an action level of 0.015 mg/L). [7] In environmentally sensitive areas, stainless steel roofing should be considered.

Figure 2: Swedish Metal Roof Run-Off Study [6]

Material	Average Annual Run-off mg/m^2 (mg/yd^2)
Zinc (1)	2,800 – 3,000 (2,340 – 2,508)
Copper	1300 - 2000 (1,087 – 1,672)
Type 304 Stainless (2) Nickel Chromium	 0.3 - 0.4 (0.25 – 0.33) 0.25 - 0.3 (0.21 – 0.25)

(1) In the form of galvanized steel and zinc sheet
(2) In many samples, nickel and chromium levels were below detectable limits. The average concentration per liter was well below typical drinking water levels.

Long Service Life

Materials that continue to provide excellent performance over the life of the building or structure have a much lower life cycle cost and are more environmentally friendly because they do not require replacement or contribute to landfill waste. Stainless steel is a relatively new architectural material with the oldest applications dating from the mid-1920's, which was not long after the invention of stainless steel. One example of an older stainless steel roof is on the Butler County Court house in Pennsylvania, and it has remained trouble free and attractive for about fifty years despite adjoining an industrial plant. (See Figure 3.)

Figure 3: The Type 302 stainless steel roof on the Butler County Court House has provided about 80 years of trouble- and maintenance-free service. Photo credit: Catherine Houska, TMR Consulting

The benefits of long service life are more easily seen in side-by-side comparisons of metals in a corrosive environment. The piers in Progresso Mexico clearly illustrate the differences in performance between carbon steel and stainless steel rebar. (See Figure 4.) The pier that is still in service was completed over sixty years ago using stainless steel rebar. Core tests have shown no stainless steel or concrete deterioration, and it is likely that the pier will provide at least another sixty years of service in this corrosive marine environment. Remnants of a second pier are visible in the image. That pier was constructed about thirty years later using carbon steel rebar. It has not been in service for some time, and, in addition to the significant costs associated with replacement and lost service, all of the original materials must be completely replaced at considerable environmental cost.

Figure 4: The functional Progresso, Mexico pier was constructed with stainless steel rebar between 1939 and 1941, and is still in excellent condition. The failed pier was constructed with carbon steel rebar in 1969.

Conserving Natural Resources

Stainless steel conserves natural resources in many ways. Less mining is required because corrosion rates are very low and real recycling rates are very high, so replacement of existing metal is negligible. In structural applications, material requirements are reduced if designers capitalize on stainless steel's superior high temperature performance and if higher strength stainless steels are used to reduce section size. For example, in roofing applications it is possible to use thinner panels and reduce heat gain and air conditioning costs by specifying stainless steel. Stainless steel sunscreens reduce air-conditioning costs, which saves energy, and stainless steel solar cells help to generate clean energy.

The Phoenix City Hall is an excellent example of the cost and energy savings possible with stainless steel sunscreens. Polished and perforated stainless steel screens were placed over most of the windows during construction. They allow natural light to enter while reducing heat gain. The initial capital cost savings due to reduced air conditioning equipment requirements was $285,000, and it was estimated that an annual cost savings of $200,000 would be achieved. The stainless steel finish will not change over time, so the effectiveness of the reflective surface will not be diminished due to corrosion. (See Figure 5.)

Figure 5: Stainless steel polished and perforated window screens on the Phoenix City Hall dramatically reduced air-conditioning costs and improved worker comfort. Photo courtesy of Allegheny Technologies.

Stainless steel water mains are less likely to leak due to corrosion or to break during earthquakes, even after very long service lives. While stainless steel water lines and tanks are a relatively new application in the United States, they have become commonplace in Western Europe and Japan. Soil can be very corrosive, particularly in coastal areas and where deicing salt is used. In Zurich, the necessity of ensuring high water quality and minimizing water loss led to replacement of all of their drinking water mains, storage and pumping facilities with a stainless steel and concrete system. In Japan, stainless steel water tanks and water lines are popular because they are resistant to damage during earthquakes and prevent leakage due to corrosion.

The corrosive by-products from stone, masonry, Redwood, Cedar, plywood, and other wood products can cause rapid corrosion of other metals. Stainless steel anchors, fasteners, and other components are not corroded by these materials and their service life is maximized.

Restoration

The Chrysler Building and the Empire State Building are both excellent examples of the ability to restore stainless steel to its former glory. Both have been cleaned about every thirty years, and there was considerable surface deposit accumulation between cleanings. They are not the only examples. The former Socony Mobil Building (now 150 East 42nd Street) was constructed in 1954 and adjoins the Chrysler Building. It was cleaned for the first time in 1995 after over forty years of service. The photo in Figure 6 was taken during cleaning and shows the dramatic difference in appearance between the clean and dirty areas. Figure 7 shows both the Socony Mobil and Chrysler Buildings after cleaning.

Figures 6 and 7: In 1995, the cleaning of the Chrysler Building encouraged the owners of the adjacent 150 East 42nd Street Building to remove forty-one years of grime. Both buildings were cleaned with a mild detergent, degreaser and water solution and, where necessary, a fine non-scratching abrasive. Both 150 East 42nd Street and the Chrysler Building were restored to their original sparkling appearance. No hazardous chemicals were required. Photos courtesy of Allegheny Technologies.

All three of these buildings were cleaned with a mild detergent and water solution, which contained a degreaser to remove hydrocarbon deposits. A fine, abrasive solution that did not scratch the finish was used when necessary to remove more adherent surface deposits. No aggressive or environmentally hazardous materials were required, and there was no need to use products whose fumes might be offensive or hazardous to either the cleaners or building tenants. The same cleaning method is used regularly on newer buildings, which receive more frequent cleaning.

Reuse

Salvaging and reusing products is the most environmentally friendly source of materials available to architects. When the Pittsburgh-based architecture firm IKM Inc. was given responsibility for modernizing and brightening the lobby and entrance of 525 William Penn Place, they found stainless steel wall and elevator panels darkened by fifty years of wax, oil and grime and marred by some scratching and denting. (Figure 8.) As a LEED™ Accredited firm committed to green design, they explored the possibility of refinishing and reusing at least some of the stainless steel in the new design. While the new lobby shown in Figure 9 looks quite different, most the stainless steel is fifty years old. It was cleaned, refinished with non-metallic abrasive pads, modified as necessary, and reused. The stainless steel components that could not be reused were recycled. If there is another renovation in fifty years, perhaps the stainless steel will be reused again.

This is not the only example of stainless steel reuse. Exterior stainless steel wall panels were recently cleaned, reshaped, and reused when a New York industrial office building was gutted and redesigned. Stainless steel's durability means that it can remain in service while other building products are sent to landfills.

Figures 8 and 9: The stainless steel panels in the lobby of 525 William Penn Place in Pittsburgh had become dirty and scratched after about fifty years of use. During renovation of the lobby of 525 William Penn Place, the 50-year old stainless steel panels were removed, cleaned, refinished, and reused. (Photo credits: Catherine Houska, TMR Consulting and IKM Inc.)

Conclusions

Products manufactured from stainless steel are an excellent choice for protecting the environment and creating comfortable, attractive structures. Although independent data comparing the life-cycle environmental impact of different materials are not yet available, there is no question that stainless steel will receive high ratings. The environmental and aesthetic performance of stainless steel is dependant on selecting an appropriate stainless steel, finish, and design.

Additional Resources

Additional free information on stainless steel selection and use in architectural applications can be obtained from the:

- Nickel Institute (http://www.stainlessarchitecture.org)
- International Molybdenum Association (IMOA) (http://www.imoa.info).
- The Construction Specifier articles identified in references [4] and [5] contain comparative corrosion data and stainless steel selection guidelines.

Acknowledgements

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