Proving its long-term mettle

Longevity, whole-building LCAs, and stainless steel

Whether the project is a new building or major renovation, sustainability is an increasingly important factor in decision-making. Whole-building lifecycle assessment (LCA) makes it possible to look at all phases of a building, from material extraction through construction to decommissioning and, when possible, recycling into a 'new' useful material. When it comes to comparing materials, increasingly available data, an ASTM standard procedure, and LCA analysis software are helping design professionals make better choices to reduce the building's carbon footprint.

By Catherine Houska

Service life prediction is necessary for LCA; it makes corrosion-resistant, long-life, high-recycled-content materials like stainless steel an obvious choice, particularly for corrosive exterior applications. This article explains the fundamentals of whole-building LCA, along with the importance of site assessment and using available corrosion data. It provides examples of the stainless steel's long-term performance in demanding environments.[1]

Whole-building LCA

Sustainable design focuses on environmentally responsible and resource-efficient construction throughout the project's life. Historically, however, the primary focus has been on the post-construction aspects, including energy and water reduction, maintenance, healthy work environments, renovation, and demolition. While specifiers have long understood materials' environmental impacts can be significantly different, and that premature replacement affects the building's carbon footprint, resources have only recently been available to do a thorough LCA.

The environmental impacts associated with material choices are significant – from extraction (e.g., harvesting, mining) through production, use, and finally, its end-of-life. Those impacts include not only energy and emissions, but also water consumption, pollution, and waste. The *International Green Construction Code (IgCC)* and the most recent versions of the most widely used voluntary rating systems – Leadership in Energy and Environmental Design (LEED), Green Star, and Building Research Establishment Environmental Assessment Method (BREEAM) – include whole-building LCA as an option, while organizations like American Institute of Architects (AIA) and large owners like the U.S. General Services Administration (GSA) encourage it.

Once the tallest building in the world, New York City's Chrysler Building retains its elegant, glittering, stainless steel Art Deco styling more than 85 years after it was built.

The availability of the product-specific lifecycle inventory (LCI) data necessary for LCA has grown rapidly. Europe, Australia, and the United States have created databases, and additional international resources exist.[2] If a product comes from a part of the world that does not have an LCI database, the producer may have Environmental Product Declarations (EPDs) containing the necessary information. Stainless steel is in these databases and many producers have EPDs. LCI data for a specific product varies with different regions of the world because of differences in energy sources and emission levels (among other factors, like recycled scrap availability), so producer- or country-specific data must be used.

LCA requires not only initial LCI data for a material, but also a determination of whether there will be replacements during the expected service life. The LCI of a product must be multiplied by the number of expected replacements during the desired service to determine the total environmental impact of a material choice. A material with lower initial LCI values may actually have a far greater negative impact on a building's total carbon footprint if it is unsuitable for the specific service environment and needs multiple replacements.

There are two International Organization for Standardization (ISO) standards defining LCA principles:

- ISO 14040:2006, *Environmental Management: Life Cycle Assessment – Principles and Framework; and*
- ISO 14044:2006, *Environmental Management: Life Cycle Assessment – Requirements and Guidelines.*

ASTM E2921, *Standard Practice for Minimum Criteria for Comparing Whole Building Life Cycle Assessments for Use with Building Codes, Standards, and Rating Systems*, is compliant with these standards. It was developed specifically to provide the minimum criteria for LCAs of buildings and to support codes and rating systems like LEED and *IgCC*. Unless otherwise specified by the applicable code or rating system, ASTM E2921 requires a building service life of no less than 75 years, which is the average lifespan of a U.S. building.

Avoiding material replacement

Corrosion or deterioration can lead to aesthetic or structural failure necessitating premature replacement. The first step in determining an appropriate material involves assessing the site environment to determine whether it would be corrosive. The specific environmental conditions that cause deterioration vary with the material, but include temperature, humidity, coastal or deicing salt exposure, and pollution. This author developed the International Molybdenum Association (IMOA) stainless steel site evaluation, which is used globally.

One should also look at nearby buildings and structures to see how materials are performing, and ask questions about maintenance and replacement history. A material may look good because it is cleaned quarterly, but, if this level of maintenance is unlikely on your project, the product may fail. Applying the

The electrochemically colored shingles on Tokyo's Reiyukai Shakeden Temple have not faded since they were installed in 1975. Photo courtesy of JSSA (building) and Catherine Houska (detail)

understanding of the environment, it is also important to determine whether material suppliers, industry associations, or consultants specializing in that product have long-term atmospheric corrosion testing data for a similar environment, since known corrosion rates are the best way to predict failure.

This author has written articles providing specific guidance on comparative metal selection in coastal and deicing salt, soil, and swimming pool environments.[3] Further, industry association website resources provide significant additional stainless steel selection resources.[4]

The stainless steels most commonly used in architecture are:

- Types 304/304L (UNS S30400/S30403, EN 1.4301/1.4307, SUS 304); and
- 316/316L (UNS S31600/S31603, EN 1.4401/1.4404, SUS 316).

Duplex stainless steels are growing in popularity for structural applications. They include lean duplexes and UNS S32205 (which provides substantially more corrosion resistance than Type 316). There are a growing number of aesthetic finishes available for 2205 sheet.[5]

With 60 percent of the world's population living in coastal zones, increased use of deicing salts, and high pollution levels in developing countries, the corrosion resistance of Type 316/316L or comparable stainless steels is typically necessary unless there will be regular maintenance cleaning. In more-corrosive environments like the Middle East, high deicing salt exposures, coastal splash zones, and near volcanic areas, UNS S32205 and other higher-alloyed stainless steels should be considered.

Long-term performance

Stainless steel provides documented long-term performance with minimal or no maintenance in a wide range of service environments. The first known architectural applications for stainless steel date from the mid-1920s – they were relatively small or low-profile projects such as entrances and industrial roofs.

Many of these early installations are still in service today, including the entrance canopy of London's Savoy hotel (1929).[6] This illustrates the durability and longevity of stainless steel. When properly specified and maintained, it can last the life of the project. When demolition finally occurs, an average of 92 percent of the stainless steel used in construction is recycled back into new metal – an indefinitely recyclable resource – without deterioration of properties.

Early skyscrapers

People have always built large structures as a means of expressing power and wealth, frequently pushing the limits of technology. Fittingly, the first large architectural applications for stainless steel were in the tallest buildings in the world: New York City's Chrysler (1930) and Empire State (1931) buildings. Although the former was only the tallest building in the world for a few months, its elegant, glittering stainless steel art deco styling has made it an enduring, internationally recognized example of elegant skyscraper design. Both buildings have been awarded LEED Existing Buildings (EB) Gold status by the U.S. Green Building Council (USGBC). The two structures' minimal stainless steel replacement has been the result of modifications, hurricane damage, and other issues unrelated to the material's performance.

The introduction of metal and glass curtain wall design in the early 1950s revolutionized tall building design. Stainless steel was used for many of the early prominent building designs including the Socony Mobil Building (1954) and Chicago's Inland Steel Building (1958). By the 1960s, stainless steel was regularly being used for high-profile architectural applications around the world, so there are many project examples with longer than 50 years of service.

Japanese temple

The first coloring methods for stainless steel were introduced in the 1970s, and were developed for durability.

Located in the Parisian museum known as the City of Science and Industry, La Géode is an Omnimax theatre, covered by a geodesic dome with almost 6500 mirror-finished Type 316 panels. Photo courtesy of ParisSharing

Type 316 stainless steel was chosen for Via – a triangular 709-unit New York City tower facing the Hudson, which has been shortlisted for the World Architecture Festival Awards – Completed Buildings – Housing award. Photo © Nic Lehoux

For example, the electrochemically colored shingles on Reiyukai Shakeden Temple (Tokyo) have had no change in appearance since they were installed in 1975.

French museum

La Géode, which opened in 1985, is a geodesic dome with an exterior covered in 6433 mirror-finished Type 316 panels that holds an Omnimax theatre in Parc de la Villette at the Cité des Sciences et de l'Industrie in Paris, France. The largest science museum in Europe, it was designed by architect Adrien Fainsilber and engineer Gérard Chamayou. It is 36 m (118 ft) in diameter and reflects the sky.

Singapore racetrack

The grandstand for the Singapore Racecourse in Kranji boasts a standing seam roof comprising undulating curves achieved with Type 316 stainless steel. Photo courtesy of Ewing Cole. Photographer: Erhard Pfeiffer

The Singapore Racecourse in Kranji was completed in August 1999. The design architect, Philadelphia-based Ewing Cole, wanted the curved, 400 m (1312 ft) long grandstand roof to remind visitors of the graceful movement of a powerful racehorse in motion. Its undulating curves were achieved with a standing seam roof made of Type 316 (UNS S31600, EN 1.4401, SUS 316) stainless steel. Heavy year-round rainfalls are common in Singapore. The owners wanted a durable, long-lasting roof that would remain attractive with minimal maintenance.

"We did not think twice about using stainless steel, because it is a corrosive, tropical island environment," explained the design firm's John Chase. "Stainless steel roofing is widely used in Singapore for that reason."

The architect of record was Indeco, a Singapore firm.

Recent towers

The world's leading architects have continued to use stainless steel for relatively traditional curtain wall, sunscreens, elegant store interiors and transit buildings around the world. Type 316/316L is the preferred exterior stainless steel because of the corrosiveness of the typical service environment, with 1990's One Canada Square in London, England (Cambric finish), being an excellent example of durability.

Some have had regular maintenance and others had none, but they l ook unchanged in appearance. All illustrate the exceptional performance and cost-effectiveness of stainless steel as an architectural design material and its appeal for sustainable designs where long-term performance is expected.

Home to more LEED-rated buildings than any other city, New York is in the midst of a construction boom. Sustainable residential buildings of all sizes are using Type 316L stainless steel on their exteriors, including 245 10th Ave, HL23, Beekman Tower, 50 West Street, 56 Leonard, American Copper Buildings, and Central Park Tower.

One example, Via (625 West 57th St) is the first building designed by the Danish Architecture firm BIG (Bjarke Ingels Group) in North America. Nearing completion, the 709-unit building faces the Hudson River. The Durst Organization carefully vetted the materials and all aspects of construction with consideration of their impact on the environment. Type 316L was selected for both the façade and the custom structural sections supporting the cleaning system because of the building's deicing salt exposure adjoining the Joe DiMaggio Highway.

At 541 meters, One World Trade Center is the tallest building in the western hemisphere. Type 316L supports the podium's glass fins, accents the glass tower's façade corners and forms the 6-ton spire.

There are also many interesting new Type 316L-clad office towers in New York, including the LEED Gold-rated 7 Bryant Park and International Gem Tower, but the largest concentration of stainless steel façades is around the World Trade Center, where Type 316L visually connects the buildings' diverse design styles while making them more sustainable and resilient.

Although it is the smallest building in the complex, the National September 11 Memorial Museum Entry Pavilion needed a very special finish for the Type 316L rainscreen.

"We created a subtle rhythm by alternating #4, #3, #4 with glass bead, #3 with glass bead and a custom Main Steel satin finish," said Bill Zahner (of the eponymous architectural metal and glass engineering firm, Zahner). "Gloss readings were taken of each and we worked with Snøhetta (architect) to arrive at the combinations that are now on the building."

The LEED Gold-rated One World Trade Center opened in 2014. Its 541 m (1776 ft) height coincides with the year the *Declaration of Independence* was signed, making it the tallest building in the western hemisphere. Type 316L supports the podium's glass fins, accents the glass tower's façade corners (a proprietary 'laser' finish), and forms the 6-ton spire (6.35 mm [1/4"] plate).

Rogers Stirk Harbour + Partners' Three World Trade Center will be completed in 2018. The 80 story, 329 m (1079 ft) building will be clad with Type 316L in a proprietary 'linen' finish, and has been pre-certified to LEED Gold.

Restoration and reuse

New York City's Chrysler and Empire State Buildings are both excellent examples of the ability to restore stainless steel to its former glory. Both structures have been cleaned approximately every 30 years, with considerable surface accumulation of dirt and grime between restorations. A similar case is New York City's Socony Mobil Building (150 East 42nd Street), constructed in 1954 and adjoining the Chrysler Building. It was cleaned for the first time in 1995 after over 40 years of service.

All three buildings were cleaned with a mild detergent/water solution containing a degreaser to remove hydrocarbon deposits and a fine abrasive where necessary to remove more adherent surface deposits. No aggressive or environmentally hazardous materials were required, nor any products emitting hazardous fumes. Similar solutions are used on buildings with more frequent cleaning regimes. These buildings exteriors have corrosion resistance equivalent to Type 304. With increased deicing salt use, New York has become more corrosive and the lower levels of these buildings must be cleaned regularly or coated. Today, Type 316 or an equivalent stainless is being used in new projects in New York for added corrosion resistance.

Conclusion

Whole-building lifecycle analysis tools and databases finally make it possible to fully assess building performance and achieve more sustainable designs. To minimize the building footprint, the materials should be capable of lasting the life of the project with minimal maintenance. This can make stainless steel a suitable candidate.

Type 316/316L – used here on One Canada Square in London, England – is the preferred exterior stainless steel because of the corrosiveness of the typical service environment. Photo courtesy of Outokumpu

With many examples of stainless steel projects exemplifying long service life, Type 316/316L is the primary alloy being selected for long service life applications in the corrosive exterior environments that exist in much of the world, though more corrosion-resistant stainless steels like 2205 are also available.

Notes

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1 The author would like to acknowledge the support of the Nickel Institute and International Molybdenum Association (IMOA) in the preparation of this article.

2 To use the databases for these three regions, see "European Platform on Life Cycle Assessment" (http://eplca.jrc.ec.europa.eu), "Australian Life Cycle Inventory Database (www.alcas.asn.au) and "National Renewable Energy Laboratory Life Cycle Inventory Database" (www.nrel.gov/lci).

3 Previous articles by this author for *The Construction Specifier include* "Designing on the Waterfront" (November 2007), "Stainless Steel for Severe Coastal Environments" (September 2011), "Architectural Metal Corrosion: The De-icing Salt Threat" (December 2006), "Preventing Corrosion in Soil" (April 2006), and (co-authored with James Fritz), "Swimmingly Stainless Pool Design" (December 2005).

4 Visit www.imoa.info or www.nickelinstitute.org.

5 See this author's May 2015 *The Construction Specifier* article, "Duplex Stainless Steel Revolutionizes Structural Design."

6 See this author's co-written (with P.G. Stone, and D. J. Cochrane) Nickel Development Institute reference book, *Timeless Stainless Architecture*, from October 2001.

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