STAINLESS STEEL'S SUSTAINABLE ADVANTAGE IN ARCHITECTURE

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Abstract

In the US alone, construction is about a $1.2 trillion market and the segments most familiar to the stainless steel industry are small relative to the total market: power (4.2%), water supply/sewage treatment (3.4%) and roadway/bridge (6.6%).[1] Public, private and government buildings are the bulk of the market and architectural metal use has been growing substantially.

The increased use of architectural metals in this huge market for raw materials presents a significant opportunity for stainless steel, particularly with the growth in "green" construction. Appropriate specification and use of architectural metals are important aspects of sustainable design. Lifecycle assessments (LCA) for individual metal families are available but are often not specific to architectural applications; do not consider differences in environmental conditions, service life, and other project-specific variables; and may have no relevance to the "green" building evaluation systems. Given these issues, it is necessary to assess the relative sustainability of stainless steel products using architects' decision-making tools.

The dominant international approach for evaluating the environmental friendliness of buildings was developed by the World Green Building Council's (WGBC) member countries. While specific elements of "green" building scoring systems can vary, the underlying concepts are similar and they are increasingly driving materials selection decisions.

Competitive products have worked aggressively to influence the scoring systems and decision makers in addition to developing product variations to meet emerging market needs. Stainless steel has tremendous potential in the growing market for "green" structures, but industry involvement has been far more limited. The stainless steel industry needs to understand the fundamentals of the scoring systems and the advantages on which they can capitalize, and then work to influence further system evolution. This paper will review existing opportunities, data requirements and the applications where further industry involvement is needed to capitalize on this long-term market opportunity.

Why Build Green?

Concern about the environment and global climate change have stimulated tremendous interest and demand for "green" construction, but shorter term economic factors also contribute to the stronge corporate and government support for this movement. Industry statistics can be helpful in understanding the potential benefits of "green" construction. In the US, buildings account for about 65% of electricity consumption, 36% of energy use, 30% of greenhouse gas emissions, 12% of potable water consumption, 30% of all raw material production and 30% of waste output. [2] This represents a measureable improvement in US statistics. In the developed world, building construction is believed to be responsible for 40% or more of greenhouse gas emissions and other measurements of environmental impact are also believed to be higher. [3]

The potential for significant reductions in imported energy reliance and building operating cost, improved worker health and productivity, and the market opportunities associated with introducing or promoting “environmentally friendly” products are significant short-term financial and strategic motivators. These inducements, along with a high level of public concern about climate change and public demand for greener structues, have encouraged both corporations and federal governments to fund research and take active roles in the development of green building councils.

Building Evaluation Systems

The United Kingdom’s Building Research Environmental Assessment Method (BREEAM) was the world’s first “green” building rating system (1990) closely followed by the US Green Building Council’s (USGBC) Leadership in Environmental and Engineering Design (LEED). Green Building Councils were subsequently formed in other countries and the World Green Building Council (WGBC) was formed in 2002. Australia, India, Canada and Japan have building scoring systems based on this model.

WGBC currently has eleven active member countries, which represent over 50% of global construction activity. In these countries, federal and local governments support “green” construction through civic building and zoning requirements and incentives. For example, there are 12 federal agencies, 27 states, and 72 cities in the US, which require or encourage “green” construction. China, which is forming a GBC, recently adopted green construction policies and standards and has 11 “green” cities and 140 “green” buildings under construction. An additional fifteen countries are at various stages of establishing GBCs. (See Table 1) “Green” buildings are regularly being built in many other countries that have not formally begun this process.

Table 1. World Green Building Council (GBC) Members and Emerging GBCs

Members	Australia, Brazil, Canada, India, Japan, Mexico, New Zealand, Tiawan, United Arab Emirates, United Kingdom, United States
Emerging GBCs	Argentina, Chile, China, Eygpt, Germany, Greece, Guatamela, Hong Kong, Isreal, Korea, Nigeria, Panama, Philippines, Switzerland, Turkey, Vietnam

While there are scoring system-to-system differences, it can be assumed that at least 85% of the score content will be identical. The US LEED scoring system is the most widely used internationally and Table 2 summarizes the elements of that are relevant to stainless steel. [4] There are 69 available points and there are different “green” building classification levels: certified, 26-32 points; silver, 33-38 points; gold, 39-51 points, and platinum, 52-69 points.

Construction material suppliers have actively influenced the system and extra points can be gained by using “certified” wood; low-VOC adhesives, wood, carpet and coating systems; rapidly renewable materials (i.e. wood); and painted metal roofing. Logically, materials with no VOC emissions, like stainless steel, should yield more points, but the system only awards points for using low VOC products. Furthermore, unless a building is being renovated and materials reused, there is no point advantage associated with material longevity. It is possible to achieve a higher “green” rating with a painted carbon steel roof than with a bare stainless steel roof with a much longer service life.

“Green” architects often understand the inherent problems. Stainless steel is most frequently used when a minimum building design life is required or when a design firm makes a policy decision to take a more environmentally practical approach to design and material specification. In either case, they still have to provide clients with “green” buildings using the existing system. To achieve this balance, they need stainless steel industry support to understand stainless steel’s benefits, help justify specification and influence system change.

The most significant impact of efforts to incorporate life cycle assessments (LCA) into the scoring system has been to require that material surface solar reflectance indexes (SRI) be determined. Starting in mid-2007, the US LEED system began requiring that any new construction project earn at least 2 points for energy reduction (14% decrease) to be considered for certification. Smaller office buildings must earn a minimum of 4 points (21% reduction). The Australian scoring system has also adopted stringent requirements. Eleven of the 69 points in the US LEED systems are associated with optimizing building energy performance.

Table 2. Summary of the US LEED scoring system categories relevant to stainless steel products

Category	Points	Opportunity
Sustainable Sites		
Storm water design: quality control	1	Reduce pollutant loadings in roof run-off
Heat island effect: roof	1	May reduce roof temperature (A)
Energy & atmosphere		
Optimize energy performance	1 - 10	May help to reduce building energy requirements (A)
Materials & resources		
Building reuse: maintain 75% surface area walls, floors, roof	1	May be reused during major renovations
Building reuse: maintain 95% surface area walls, floors, roof	1	May be reused during major renovations
Building reuse: maintain 50% interior non-structural	1	Interior surfaces may be reused
Construction waste management: divert 50% from disposal	1	High recapture rate & reuse is possible
Construction waste management: divert 75% from disposal	1	High recapture rate & reuse is possible
Construction waste management: 5% salvaged materials	1	Product reuse is possible
Construction waste management: use 10% salvaged materials	1	High recapture rate & reuse is possible
Recycled content: 10%	1	Provide industry data
Indoor Environmental Quality		
Indoor chemical & pollutant control	1	Grills/grates limit occupant-borne contaminants from entering building
Total possible points	12-21	

(A) SRI values have to be calculated per ASTM 1980. Steep-sloped roofs must have a minimum SRI of 29 and low-sloped roofs must have a minimum SRI of 78.

Energy Reduction

The current scoring systems place a very high emphasis on building energy reduction which means that roofs and, at a secondary level, wall panels can have a significant influence on the score. Two parts of the scoring system address this issue: heat island effect and optimizing energy reduction. The term "heat island" refers to urban air and surface temperatures that are higher than those of nearby rural areas. Cities and suburbs have air temperatures that are up to 5.6°C (10°F) warmer than the surrounding countryside. Cool roof systems with high reflectance and emittance stay up to 39°C (70°F) cooler than traditional materials during peak summer weather and air conditioning costs can be reduced by 20 to 70%. Air pollution (electricity generation) and smog are also reduced. When air temperatures are above 21 C (70 F), smog increases by 3% for every 0.5 C degree temperature increase.

The US government has funded cool roof material research at several national laboratories since the mid-1990’s, and private and public groups have done additional work. The two most important surface properties are high solar reflectance and thermal emittance. Solar reflectance is the percentage of energy reflected away by a surface. Thermal emittance is the percentage of energy a material radiates away after it is absorbed. The Solar Reflectance Index (SRI) is a formula defined by ASTM E 1980 incorporating both solar reflectance and emittance values which compares surface performance to standardized black and white surfaces. The resultant value is expressed as a fraction (0.0 to 1.0) or percentage.

Conventional roof surfaces have low reflectance (0.05 to 0.25) and high thermal emittance (over 80%) and typically attain temperatures of 66 to 88°C (150 to 190°F) at midday during the summer. Bare metal or roofs with metallic surfaces have high solar reflectance (0.5 or higher), emittance levels that range from 20 to 60% (dependant on surface finish) and typically reach temperatures of 60 to 77°C (140 to 170°F). (The reflectance and emittance of bare metals are very sensitive to surface texture and the presence of surface oxides, oil film, etc.) Cool roofs with high reflectance and high emittance only reach 38 to 49°C (100 to 120°F) in the summer sun.

Table 3 provides data from Lawrence Berkeley National Laboratory's Cool Roofing Database. [5] To obtain credit for heat island reduction, roofs must meet minimum SRI values: steep-sloped roofs, 29; and low-sloped roofs, 78. A minimum SRI of 29 is targeted for wall panels. Both wall panels and roofing play an important role in building energy reduction.

Table 3. Solar Reflectance and Thermal Performance of Roofing

Product	Solar Reflectance	Infrared Emittance	Temperature Rise, C (F)	Solar Reflectance Index (SRI) %
Galvanized steel, new bare	0.61	0.04	30 (55F)	46
Aluminum, new bare	0.61	0.25	27 (48F)	56
Metal, proprietary white coating	0.85	0.91	9 (16F)	107
Clay tile, red	0.33	0.9	32 (58F)	36
Concrete tile, red	0.18	0.91	39 (71F)	17
Concrete tile, white	0.73	0.9	12 (21F)	90
Asphalt, generic white	0.25	0.91	36 (64F)	26
Asphalt, generic black	0.05	0.91	46 (82F)	1
Wood shingle, brown stain	0.22	0.90	37 (67F)	22
Wood shingle, proprietary white coating	0.84	0.89	6 (10F)	106

"Cool" roof coatings contain transparent polymeric materials and a white pigment, such as titanium dioxide or zinc oxide, to make them opaque and able to reflect 70 to 80% of the sun's energy. New coatings are able to achieve high SRI ratings without limiting the roof color to white. The highest values are achieved when coatings are applied to a smooth substrate, such as metal, because they mask its low emittance. Coatings may last 20 or more years but some manufacturers suggest reapplication every 10 years to maintain SRI performance. The scoring system does not consider the negative environmental impact of repeated coating application, substrate service life or system replacement frequency.

Stainless steel finishes are not included in public databases or the US Environmental Protection Agency's roofing comparison calculator software. The US and Australian scoring systems make SRI testing necessary for certified "green" buildings and other systems are expected to adopt this requirement. While testing is starting to occur on a project-by-project basis, suppliers and the industry would benefit if stainless steel SRI data were widely available. Finish modifications that produce improved SRI values should be considered. Participation in the industry and government sponsored Cool Roofing Rating Council (CRRC) could be beneficial, because the organization actively promotes "cool" materials. SRI values deteriorate with time and the CRRC is promoting installed finish testing. Surface accumulations are a recognized cause of deterioration while the role of corrosion has been fully explored. Stainless steel may have a long-term advantage.

Other Score Elements

Stainless steel provides several other potential advantages relative to other construction materials that may improve a building's score. This includes low metal roof runoff rates, a long service life that can permit product reuse, and high recycled content and recapture rates. Points are awarded for the quality of roof run-off and the use of captured water for internal applications where non-potable water can be used (e.g. toilets, showers and laundry) and irrigation. There is concern about runoff from copper, zinc and galvanized roofs and non-metallic roofs like asphalt, and water filtration is one option for obtaining a storm water quality control point. Stainless steel's low runoff levels may make filtration unnecessary.

The aluminum and carbon steel industries have carefully crafted marketing messages using industry-wide data to give the impression that these construction materials have consistently high-recycled contents. Decision makers are generally unaware that the aluminum sheet used in construction contains no recycled content and assume very high recycled content levels. This gives stainless steel an advantage, but, without more data, it may be minimized by a shift toward end-of-life recapture rates. End-of-life recapture rates only consider recycling of the metal left at the end of building life or material replacement. While stainless steel still has an advantage, metal loss to corrosion, which could be a particularly significant factor in more corrosive environments, is not considered. (See Table 4 for a comparison of metal products. [6])

Table 4. Recycled Content Versus End Of Life Recapture Rates

Metal	Recycled Content	End Of Life Recapture Rates
Carbon Steel		
Ingetrated mills	25 - 35	70
Mini mills	≥ 95	97
Stainless Steel	60	> 80
Zinc	23	33
Copper		
Electrical wire	0	> 90
Other products	70 - 95	> 90
Aluminum []		
Sheet	0	70
Extrusions	varies	70
Castings	≤ 100	70

Note: Data was obtained from the industry association websites or telephone conversations except as noted.

Building renovation and material reuse in new projects are the only aspects of the scoring system that currently provides credit for long-term material performance. For example, if an existing building is renovated and a high percentage of existing wall or roof panels, structural steel, and concrete floor decks are reused, the building can earn extra points. The surface area of the material that is reused is used to evaluate point eligibility. Reuse of interior surfaces also earns point credit. There are examples of stainless steel interior and exterior panel reuse that can be used to promote the materials' long-term environmental friendliness and encourage specification in new projects by architects who are aware of the current system limitations. The most effective long-term solution for increasing market potential is to lobby for system changes, possibly with enlightened architectures and other industries with long-lasting products.

Project Examples

The David L. Lawrence Convention Center in Pittsburgh, Pennsylvania, USA was designed by Rafael Vonoly Architects to the highest green design standards. When it was completed in 2003, it was the world's first green convention center and the world's largest green building. The building received a Gold US LEED certification. The architects minimized energy requirements for this 139,350 m^2 (1.5 million ft^2) building by using a sweeping Type 304 stainless steel roof, a natural ventilation system, and skylights to reduce lighting requirements. The building has exceeded energy reduction expectations. On average, the design eliminated the need to use artificial heating or cooling in the exhibit hall during 33% of event days. A low reflectivity roof was required to avoid blinding pilots or reflecting light into nearby buildings. Because there are occasional tornadoes in the area, the stainless steel roof was also designed to withstand hurricane-force winds. (See Table 4.)

The architecture firm IKM Inc. was given the task of renovating the lobby and entrance of a 50-year old stainless steel building in Pittsburgh, Pennsylvania USA. The original stainless steel panels were dirty and scratched. The firm had the panels removed, cleaned, refinished, reshaped and reinstalled in the new lobby design. Any panel that could not be reused was recycled. This high level of interior surface reuse made it a very “green” renovation. (See Figure 2.)

Figures 1 and 2: David L. Lawrence Convention Center’s roof helped to reduce building energy requirements. (photo credit: Allegheny Technologies) In this Mellon Bank office building, 50 year old stainless steel was cleaned, refinished and reused in the new design. (photo credit: IKM Inc.)

Conclusions

There are many areas where stainless steel provides initial and long-term benefits relative to other materials. Market education efforts by the Nickel Institute and other organizations are increasing architects awareness of stainless steel’s inherent practical advantages, but a broader industry effort is needed to capitalize on this significant international market opportunity. The industry must provide the SRI data required by “green” construction scoring systems, but long-term SRI performance and surface finish research should also be considered. By working within the system and partnering with other interested parties, practical environmentally responsible scoring system changes can be made that capitalize on stainless steel’s advantages.

References

[1] U.S. Census Bureau, Manufacturing, Mining, and Construction Statistics
[2] US Green Building Council website. Data summarized from various U.S. government agencies including the U.S. Department of Energy and U.S. Geological Service
[3] World Green Building Council website
[4] Version 2.2 LEED for New Construction and Major Renovations, US Green Building Council website
[5] Lawrence Berkeley National Laboratory, Environmental Technologies Division, Cool Roofing Database
[6] C. Houska and S.B. Young, “Comparing the Sustainability of Architectural Metals”, The Construction Specifier Magazine, July 2006, pp. 80 - 90.