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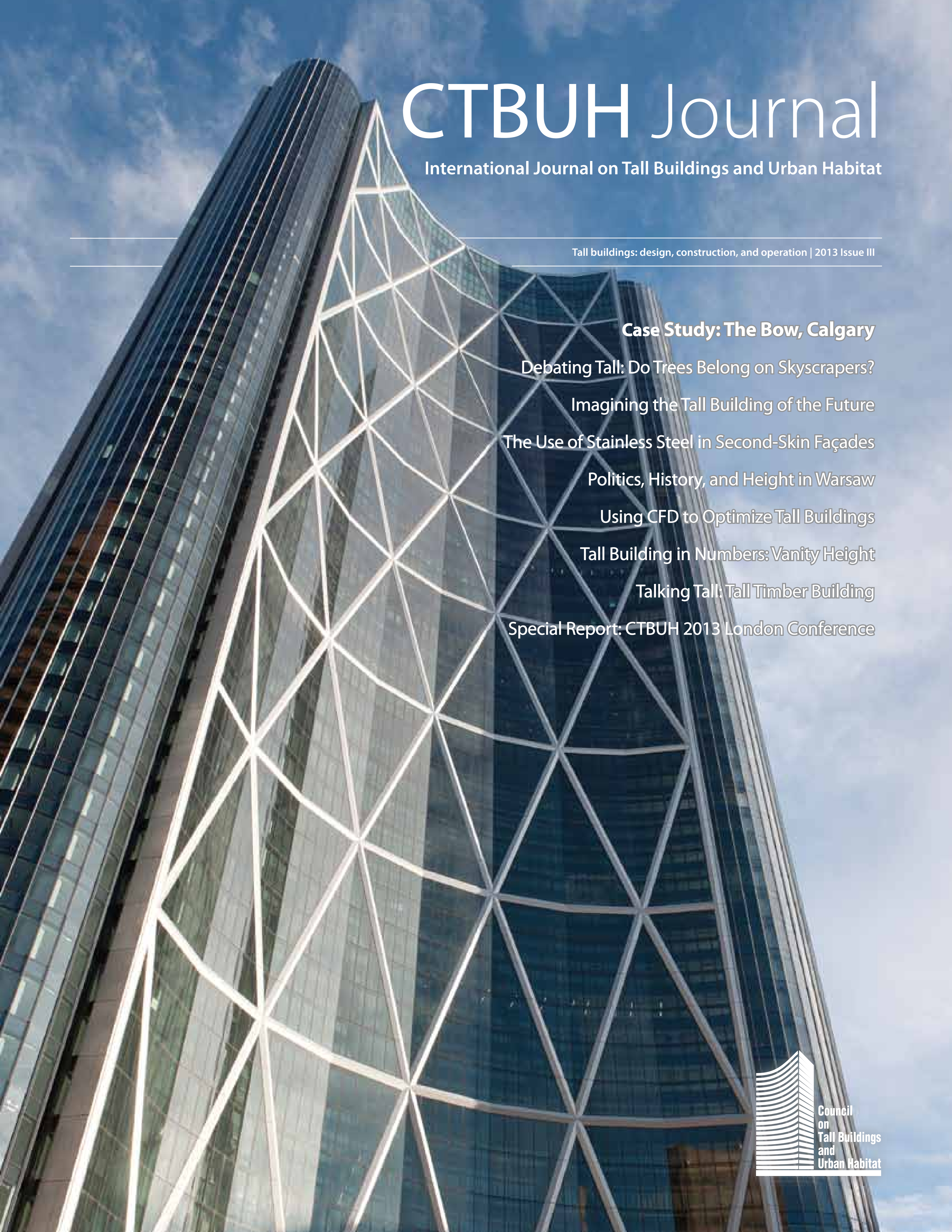

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“We have a ‘wood first’ policy in British Columbia, where public buildings have to consider the use of wood first and effectively prove why they can't use wood in the building design in order to proceed.”

Michael Green, page 46

The Use of Stainless Steel in Second-Skin Façades

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Exterior walls are being transformed from relatively simple climate-defensive mechanisms to more active membranes that screen weather to reduce energy requirements. Innovative designs are being used on award-winning projects around the world, and these concepts could be applied to a much broader range of buildings. Bioclimatic architecture refers to designing buildings to improve thermal and visual comfort. These designs incorporate systems that provide protection from summer sun, reduce winter heat loss, and make use of the environment for heating, cooling, and lighting buildings.

Long before central heat or air-conditioning, mankind modified building designs to suit the climate and achieve natural cooling or improved heat retention. The practice of screening exterior façades from sun or winter storms is an old concept that has regained popularity with growing international interest in bioclimatic design concepts that better harmonize buildings with their environments. These concepts can be important tools in achieving energy-consumption reduction goals, while transforming exterior walls from relatively simple "climate-defensive" mechanisms into more active membranes. These screens are increasingly being used on larger structures.

Bioclimatic façade systems can consist of traditional overhangs and setbacks, but increasingly a layer of screens is being placed outside of the primary environmental barrier. These screens serve as a double envelope or second skin to achieve the building's energy reduction goals. European and US research has improved the ability to model the screens' potential benefits. This article will discuss new modeling developments and illustrate how several types of exterior stainless-steel weather screens are being used on award-winning and innovative hybrid bioclimatic façade projects around the world and explores the potential for application of bioclimatic façades in high-rise buildings.

The emergence of whole-building life cycle assessments (LCAs) as a sustainable design tool is increasing awareness of the high environmental impact of repeated material replacement and encourages specification of durable products that will remain in place over the project's service life. Stainless steel is a logical material for corrosive environments with industrial pollution or salt exposure, particularly when there would be minimal to

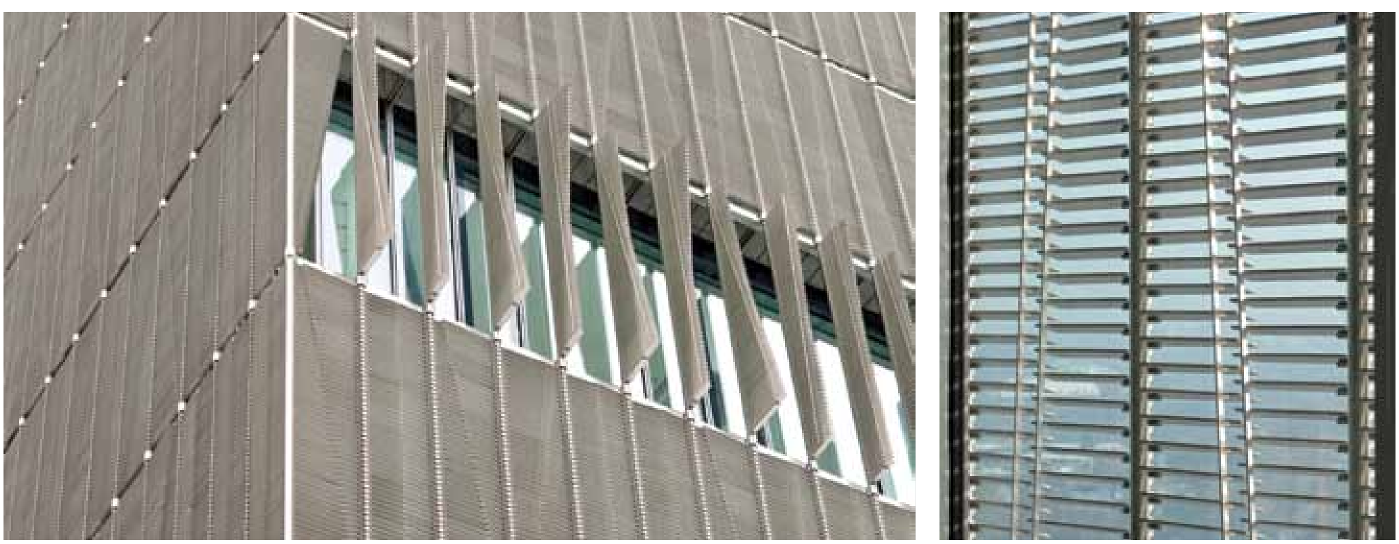

Figure 1. Type 316 stainless steel exterior sunscreens in varying styles were used on the ThyssenKrupp corporate campus to actively adjust to seasonal and weather conditions to reduce energy requirements. © ThyssenKrupp AG

no maintenance and there is an expectation of at least 50 years of service.

Bioclimatic Second-Skin Façades

Bioclimatic second-skin façades are typically between 0.2 and 4.5 meters away from the environmental barrier. The intermediate space can be used to moderate heat, light, wind, noise, pollution, and other environmental stresses. This space can provide shading, light and air redirection, thermal load balancing, and resistance to heat loss and gain.

The building inhabitants' connections with their surroundings are improved by these designs. The inner environmental barrier wall frequently has operable windows or provides other provisions for ventilation. The second skin at least partially shades the inner wall, reducing summer cooling requirements while still allowing daylight to enter the building. During the winter, these outer second skins can shelter the inner wall from winter storms, while allowing the sunlight to enter and warm up the building, lowering heating loads.

Bioclimatic second-skin weather screens can either be active, computer-controlled systems that constantly adjust to the environment or low-tech, fixed passive systems. Here, we focus on four screen types and provide both active and passive screen examples:

- fixed and operable louvers;
- woven mesh;
- perforated panels; and
- green (i.e., vegetated) façade screens.

Tension-supported systems, such green screens and louvers, parallel the inner wall, while lightweight framing can be used to vary the distance between the inner insulated skin and second skin, making seamless curving, geometric, and other shapes possible by using woven mesh or perforated panels.

These second weather-screening skins can cost-effectively reduce energy consumption while improving the building's appearance, at a much lower cost than is possible through modifying load-bearing walls (Murray 2009 & 2011). These façades can also enhance building security and safety by providing visual barriers.

In fixed, woven meshes, perforated panels, or louvers, several factors influence the solar shading benefit and natural interior lighting levels, the opening size, solar reflectance and transmittance influence the solar shading benefit and natural interior lighting levels. Therefore, seasonal daylight modeling is necessary for design optimization. In climates where the sun angle significantly changes with each season, fixed louvers may allow sunlight to enter in the winter, while reducing heat gain in the summer.

Active Second-Skin Façades

There are many variations on active second-skin façades, but they are typically operable metal louvers, wooden slats, or perforated panels supported by stainless-steel tension systems or frames. All have integrated computer-controlled mechanical systems that work with the building's heating and cooling systems to respond dynamically to varying conditions (Gonchar 2007, RMI 2008).

Sections of the shading system open or close with changes in the sun's trajectory or the weather. This allows active second-skin façade systems to maximize the benefits of solar radiation or lighting, minimize heat gain, or shield the inner wall during winter storms, reducing heat loss. Natural ventilation is maximized to improve occupant health and control building temperature levels.

Energy is necessary to operate these systems, and maintenance of the mechanical and sensing systems is required. Active second-skin façades have been particularly popular in Europe, Asia, and Australia, although some of the earliest examples are in North America (e.g., Occidental Chemical Center, Niagara Falls, New York, completed in 1980).

> “Bioclimatic second-skin façades are typically between 0.2 and 4.5 meters away from the environmental barrier. The intermediate space can be used to moderate heat, light, wind, noise, pollution, and other environmental stresses.”

ThyssenKrupp Campus

The TKQ architect consortium, consisting of JSWD Architekten and Chaix & Morel, designed a seven-building corporate campus in Essen, Germany for ThyssenKrupp, which was awarded a Gold-level German Certificate for Sustainable Buildings. Energy requirements are expected to be 20 to 30% below statutory requirements. The integrated computer-controlled environmental systems adjust the natural ventilation and sun-shading levels to respond to changing weather conditions. When used with geothermal heating and cooling, the need for air-conditioning was eliminated, and winter heating requirements were greatly reduced (see Figure 1).

All the buildings are simple, glazed shapes made more interesting by their Type 316 sunshade systems. Building Q2, the corporate conference and training center, has custom, perforated, passive sunscreens. Active motorized horizontal slat sunshades were used on Building Q1. Motorized triangular, square, and trapezoidal fins were employed on Buildings Q5 and Q7. A dull abrasive blasted finish was applied to the outside, while a highly polished finish was applied to the inside of the slats and fins. Adjustment of the slats' angles determines interior light and temperature levels.

Figure 2. Type 316 perforated screens on the San Francisco Federal Building helped eliminate air-conditioning in 70% of the building's occupied spaces. © Iwan Baan Studio

Figure 3. Perforated Type 304 screens give 41 Cooper Square a sculptural appearance while reducing the building's energy consumption. © Iwan Baan Studio

Figure 4. Woven stainless steel sweeps down from the 19th floor of Abu Dhabi's Capital Gate Tower, reducing energy requirements. © Jeff Schofield

San Francisco Federal Building

The USGBC LEED Silver San Francisco Federal Building is a narrow, 56,205-square meter 18-story tower connected to a four-story annex and adjoining a public plaza. Built in 2007, it was the first office tower in the United States to give preference to natural ventilation (see Figure 2). The computer-controlled ventilating inner skin adjusts to daily and seasonal climate fluctuations, providing natural temperature control, about 70% of the work area is naturally ventilated rather than air-conditioned. Approximately 90% of the workstations have natural lighting.

The southeast façade has computer-controlled, perforated 1.5-millimeters Type 316 stainless steel sunscreens (with a dull finish that simulates abrasive blasting) covering full-height glass window walls, shielding them from heat gain and inclement weather. The building surpasses the U.S. General Services Administration's (GSA's) energy performance criteria by 50% and sets new standards for passive climate control, for a projected annual energy cost savings of US$500,000 (Gonchar 2007).

41 Cooper Square

Built in 2009, 41 Cooper Square is an engineering building at The Cooper Union, a Manhattan design college. It was the first LEED-certified educational building in New York City (see Figure 3). At 41 Cooper Square, semi-transparent Type 304 stainless steel perforated panels are offset from the window wall. The perforation holes are 3.2 millimeters in diameter and cover between 50 and 90% of the panels, maintaining views whether they are open or closed. The building's computer-controlled environmental system adjusts the panels to reduce heat radiation in the summer, shelter and insulate the inner wall in winter, and allow natural light to enter. While the core building is traditional in shape, this second skin gives it a dramatic sculptural presence with areas of light and shadow.

The sculptured sunscreen, natural ventilation, vegetated roof, and radiant heating and cooling ceiling panels reduced the building's energy requirements by 40% relative to a standard building of its type. About 75% of the building's interior spaces are lit with natural light. The use of Type 304 at a site with both coastal and de-icing salt exposure is expected to increase cleaning requirements relative to the more commonly specified Type 316, which is more corrosion-resistant.

Passive Second-Skin Façades

Passive systems are simple second-skin façades with fixed, semi-permeable membranes. They can consist of woven mesh, perforated sheets, fixed louvers, or vegetated screens. These assemblies can be ideal when minimal maintenance is expected or electricity is less reliable, as they are not mechanically tied to the internal climate management systems (Gonchar 2007, RMI 2008).

Like active screens, passive systems provide shelter from harsh weather by reducing the impact of rain, direct sunshine, and winter storms. Abu Dhabi's Capital Gate Building is a striking example of partial shading, with stainless-steel woven mesh sweeping down its south side, eliminating more than 30% of the sun's heat (see Figure 4).

ASU Walter Cronkite School

Los Angeles-based Ehrlich Architects designed the LEED Silver Walter Cronkite

Figure 5. Type 316 sunscreens shield windows on the Cronkite building at Arizona State University (ASU). © GKD

provides teaching, performance, and exhibition space for primary and secondary school arts-education courses. Designed by Steffian Bradley Architects, this 42,735-square meter concrete and glass building has dramatic seamless exterior compound curves, made possible by a Type 316 stainless-steel mesh sunscreen system.

School of Journalism and Mass Communication at Arizona State University (ASU) to be aesthetically impressive and environmentally responsible. Its Type 316 fabric sunshades mitigate solar heating and allow natural light to enter, while making it easier to view flat-screen TVs and computers; while adding aesthetic texture to the glass wall.

The continuous wall of 64 windows on the building's west side is covered by 223 square meters of stainless-steel fabric sunshades. Its transparency gives occupants a view of downtown Phoenix. Stainless steel was selected because it is durable and maintenance-free (see Figure 5.

Guangzhou Second Children's Activity Center

Completed in 2006, Guangzhou Second Children's Activity Center (see Figure 6)

The building is elevated to retain open circulation at street level. The building orientation relative to the prevailing wind direction and the open ground and upper floors allow for natural ventilation, eliminating the need for air-conditioning in common spaces. The luminous sunscreen curves outward and shelters the linear inner wall, while maximizing natural light exposure, creating a distinctive identity and minimizing energy requirements in a hot climate.

Stockholm Congress Centre

The new Stockholm Waterfront Congress Centre, located on the city's harbor, is a layered structure designed for significant energy reduction. A second façade of softly reflective stainless steel angles outward from the glass wall. The façade employs 3,500 Z-shaped duplex 2205 stainless steel sections (with a semi-reflective finish simulating glass-bead blasting), 3 to 16 meters in length.

Stockholm is not a severe coastal environment, but sections of the screens are sheltered from rain, and regular maintenance cleaning is not planned. Corrosion-resistant and high-strength duplex stainless steel 2205 (see Figure 7) was specified to meet durability requirements. Completed in early 2011, it received Swedish green-building certification.

Vegetated Passive Façades

Vegetated screens present a low-technology option that passively adjusts to the seasons, shielding windows from summer sun and, after the leaves fall, allowing winter light to warm buildings. European and Australian research has shown the potential for significant energy reduction through this method. When fully vegetated, these assemblies also: reduce noise and electromagnetic pollution, increase green spaces, improve air quality and occupant health, offset carbon taxes (for countries that have them), and can be used for food production.

Success depends on appropriate vine selection, maintenance pruning, and fertilizing. The supporting structure cannot

Figure 6. Guangzhou, China's Second Children's Activity Center was wrapped in stainless steel mesh to reduce energy requirements and create a seamless sculptural shape. © Steffian Bradley Architects

Figure 7. Stockholm Congress Centre used duplex 2205 sunscreens for better corrosion performance. © Outokumpu

> “Successful sustainable bioclimatic design requires material selections that can last the structure or project’s life, taking into account exposure to pollution, corrosive salts, and the likelihood of manual or rain cleaning.”

rely on coatings for corrosion resistance, since they cannot be reapplied (RMI 2008, Helzel & Taylor 2012, Hopkins 2012).

The support structure should not release biocides such as zinc, and strength should not deteriorate over time with UV exposure, as will occur with plastics. A high level of strength is necessary to withstand higher wind loads when fully vegetated. Exposure to corrosive coastal or de-icing salts, pollutants, and even natural fertilizers must be considered. For these reasons, stainless steel is the most suitable choice for long-term installations.

Council House 2

Completed in 2006, Melbourne, Australia’s 10-story Council House No. 2 (CH2) is the first commercial building to achieve Green Building Council of Australia’s (GBCA’s) Green Star “6” rating. Relative to the city’s Council House No. 1, it uses 85% less electricity, 87% less gas, and 72% less potable water. The CO_2 emissions associated with building operation were reduced by about 60% (Tan 2007 & Morris-Nunn 2007).

Architect Design Inc. used passive sunscreens, natural ventilation, and conductive ceiling cooling to reduce energy requirements. On the building’s north side (which receives the most sun), one-meter balcony projections shield windows from high-angle sun, and vegetated screens along their sides minimize low-angle sun, filter glare, and connect occupants with their environment while providing privacy (see Figure 8).

The plants are supported by a Type 316 mesh and tension cable system with planters on each floor. The screen extends over the roof terrace, providing an arbor-like sunshade that grows into a shelter that achieves energy-consumption reduction levels equivalent to those supported by a vegetated roof.

Stainless Steel Selection

The term “stainless steel” refers to a family of alloys that provide varying levels of corrosion resistance, strength, and formability. While the most commonly specified stainless steels are Types 304/304L, 316/316L, and, to a lesser extent, 2205, 904L and 317LMN, many other grades have been used. Stainless steels provide much higher corrosion resistance than other common architectural metals, particularly when there is pollution and chloride salt exposure (i.e., de-icing or coastal salt).

Second skins are at least partly sheltered from rain-washing, particularly on the inner side facing the environmental barrier. This area is visible to building occupants. Corrosion research shows that sheltered surfaces typically accumulate much higher levels of corrosive pollutants, salts, and particulate. Most climates have high enough temperatures and enough moisture present (e.g., condensation, humidity, fog) to initiate corrosion and, when combined with higher corrosive deposit levels, more corrosive conditions are created. Surfaces that are fully exposed to heavy rain are naturally cleaned, reducing deposit accumulations and the severity of the environment.

Climates with minimal rain and very high levels of particulate and chloride salt deposition rates, as occurs in arid coastal areas like the Middle East, are a documented exception. These areas have higher deposit accumulation and corrosion rates on fully exposed surfaces.

Care should be taken in specifying tightly woven and cable products, since chloride crevice corrosion can occur unless a more corrosion-resistant stainless steel is specified. On highly loaded structural components, chloride stress corrosion cracking must also be considered. Additionally, stainless steel structural components should be used to support stainless steel screens – carbon steel or aluminum structural components can cause galvanic corrosion.

Type 304/304L is generally appropriate for mild outdoor applications with low levels of urban pollution. Type 316/316L is suggested for exposure to low to moderately corrosive coastal and de-icing salts, moderate industrial and higher urban pollution levels.

Unless there will be regular cleaning, type 316/316L does not provide sufficient corrosion resistance for applications with higher surface chloride salt or pollution accumulations, as might occur in some sheltered or more severe environments.

When a service environment is expected to be more corrosive or sheltered, duplex 2205 is generally the most cost-effective non-proprietary option. Cable and woven products that might be susceptible to chloride salt crevice corrosion can be obtained in 904L and 317LMN, which have equivalent corrosion resistance to 2205. When an environment appears severe, the advice of a stainless steel corrosion specialist should be obtained. There are many different stainless steels with varying levels of corrosion resistance and strength.

Sustainable Design Benefits

On average, international stainless steel production contains about 60% recycled scrap content. In North America and Europe, which have a high historical use of stainless steel, the recycled content may be as much as

90% for Types 304/304L and 316/316L. Further, more than 92% of the stainless steel used in architecture, building, and construction is recaptured and recycled at the end of service into new metal.

Numerous studies around the world have examined runoff from various materials. The primary purpose has been to determine whether the runoff is potentially toxic to humans, plants, or wildlife. Stainless steel has extremely low runoff levels (often below detectable limits), and it is not a biocide or otherwise toxic to the environment. When properly specified, stainless steel can last the life of a project even if it will span hundreds of years. There has been extensive structural research and it is included in EuroCode, ASCE/SEI 8, and the new AISC Design Guide Stainless Steel.

Tall Building Potential

The application of bioclimatic design principles to tall building design is not new, and there have been many notable contributions. Olgyay proposed the Vitruvian model and a method for achieving environmental control by working with climate in the 1960s (Olgyay 1963). Ken Yeang's more recent work successfully applies low-energy bioclimatic design methodology to modern skyscrapers and has popularized the concept (Yeang & Richards 1994, Yeang 1996).

Weather-screening design concepts discussed in this article have been applied to increasingly taller buildings in recent years, and improvements in predictive software make their potential benefits easier to determine. The use of a dramatically curving woven stainless-steel mesh screen up to the 19th floor of Capital Gate Tower (160 meters) illustrates the aesthetic and practical potential for shading on tall buildings (Schofield 2012).

On traditional tall building shapes, high and shifting winds, particularly at corners, must be considered during design; wind modeling is needed to determine the impact on building structural loading of any design element projecting from the surface. It may be necessary to move sunscreens away from corners, limit their outward projection, and make similar adjustments, such as limiting plant screens to lower floors.

Figure 8. Plant screens were used along the balconies on the north side of Council House No. 2 and over the roof deck to shelter them from sun. © Ronstan Tensile Architecture

However, a significant evolution in tall-building design concepts is occurring. The innovative design of Kingdom Tower, Jeddah creates areas that are so sheltered from wind that open-air balconies are feasible on very high floors. Rethinking tall buildings by creating aerodynamic shapes that reduce structural loading will make it possible to use screening systems at much greater heights, including once-thought-futuristic gardens, supported by plant screens climbing toward the sky.

Conclusion

Successful sustainable bioclimatic design requires material selections that can last the structure or project's life, taking into account exposure to pollution, corrosive salts, and the likelihood of manual or rain cleaning. Stainless steel is the most corrosion-resistant of the readily available architectural metal options and is capable of providing the structural strength required for weather screens. When an appropriate stainless steel alloy and finish are specified, they provide attractive performance over the building's life. ■

This article was revised from "Designing Sunshades into the Façades: Stainless Steel Selections," Catherine Houska, ***The Construction Specifier,*** *June 2012.*

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