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Climate Considerations for Facades

Ajla Aksamija, *University of Massachusetts - Amherst*

CLIMATE CONSIDERATIONS FOR Façades

BY AJLA AKSAMIJA, PH.D.

Façades are one of the most significant contributors to the energy budget and the comfort parameters of any building, and their designs and performance are essential factors for sustainable, energy-efficient, high performance buildings. Different design strategies are required for different climatic zones.

Basic methods for designing high performance building façades include: orienting and developing geometry and massing of the building to respond to solar position; providing solar shading to control cooling loads and improve thermal comfort; using natural ventilation to reduce cooling loads and enhance air quality in climates that allow this; and minimizing energy used for artificial lighting and mechanical cooling and heating by optimizing exterior wall insulation and the use of daylighting.

In choosing specific design strategies, consideration should be given to the conditions of the climate zone to minimize environmental impacts and reduce energy consumption. Heating-dominated climates (Climate Zones 5–8) benefit from collection of solar radiation, passive heating, heat storage, improved insulation to reduce heating demand, and the use of daylighting to reduce lighting demand.

In cooling-dominated climates (Climate Zones 1–3), protection from sun and direct solar radiation becomes more important. In mixed climates (Climate Zone 4), combined strategies that balance solar exposure and access to daylight should be implemented.

An important metric for façades is the window-to-wall ratio, which is the proportion of glazed to opaque façade area. This ratio is a significant contributor to a façade's solar heat gain and energy consumption.

In most cases, higher window-to-wall ratios result in greater energy consumption, since the thermal resistance of even a well-insulated glazed façade is typically lower than that of an opaque façade. Minimizing the window-to-wall ratio (energy code recommendations state that the window-to-wall ratio should not be larger than 40%) and specifically addressing each building orientation (for example, minimizing the window-to-wall ratio on east and west façades, and maximizing along the north orientation) should be implemented as design strategies for high performing façades.

For hot and warm climates, increased window-to-wall ratios cause cooling loads to increase due to increased solar heat gain. For mixed and colder climates, higher window-to-wall ratios increase heating loads, especially for buildings located in cold and very cold climates. An important strategy that improves the energy efficiency in any type of climate is to reduce the window-to-wall ratio by increasing the amount of opaque façade relative to glazing.

The following examples illustrate design strategies for two types of climates: mixed and hot.

HIGH PERFORMANCE SUSTAINABLE FAÇADES

High performance sustainable façades can be defined as exterior enclosures that use the least possible amount of energy to maintain a comfortable interior environment, which promotes the health and productivity of the building's occupants. This means that sustainable façades are not simply barriers between interior and exterior; rather, they are building systems that create comfortable spaces by actively responding to the building's external environment, and significantly reduce a building's energy consumption.

What are the properties of energy-efficient building façades? They include allowing daylight into a building; preventing unwanted solar heat from entering the building; storing heat within the mass of the wall; preventing heat transfer through improved insulation; preventing air or moisture from passing through the façade; and allowing natural ventilation to cool the building's interior. These properties are highly dependent on climate, as well as a building's function, occupancy patterns, orientation, and equipment loads.

CASE STUDY CENTER FOR URBAN WATERS

Design Strategies for Mixed Climate

The Center for Urban Waters is a laboratory building dedicated to hydrologic research, located in Tacoma, Wash. Tacoma is located in a region with a mixed marine climate (Zone 4C). *Figure 1* shows average daily temperatures, thermal comfort zone and available solar radiation for each month.

This temperate climate zone allows cooling by natural ventilation, and the relatively mild winters and low solar radiation suggest that a moderate amount of glazing on the south and west orientations will not negatively affect a building's energy performance. Most buildings in this climate type are heating dominated. However, because of the type of research performed and the equipment used in this facility, the Center for Urban Waters is a cooling-dominated building.

The facility is primarily used for studying and analyzing water samples from the waterways of Tacoma and surrounding areas. It is also used for educational activities. The program includes laboratories,

BUILDING AT A GLANCE

Name Center for Urban Waters

Location Tacoma, Wash.

Owner City of Tacoma

Primary Tenant City of Tacoma, Environmental Services Division

Principal Use Research laboratory

Occupants 150

Window-to-Wall Ratio 32%

Square Footage 51,000

Distinctions/Awards
LEED Platinum-NC, 2012

Commercial Real Estate Development Association (NAIOP) Public Project of the Year, 2010

Green Roof for Healthy Cities Award, Extensive Institutional category, 2012

Cost $22 million

Completion April 2010

Courtesy of Benjamin Benschneider/OTTO

This view of the Center for Urban Waters west façade and south façades shows different façade treatment for different building orientations. The west façade consists of an aluminum cladded rainscreen system, combination of operable and non-operable windows, and exterior blinds. The south façade consists of a curtain wall with external horizontal shading elements and fritted glass.

offices, conference rooms, an exhibit center, a cafeteria, and related building services.

The Center for Urban Waters is located on a long and narrow site along the industrial waterfront. The geometry of the site led to a narrow building design, oriented roughly north and south. This design maximizes the daylighting of the interior spaces and uses natural ventilation to reduce the building's energy loads.

The building design incorporates passive sustainable design strategies, which are strongly influenced by the site's orientation. The major programmatic elements are grouped into two zones: a laboratory zone facing inland and an office zone along the waterway.

Because of the programmatic requirements of the research activities, the laboratories require mechanical ventilation. Locating them adjacent to the industrial neighborhood, with its reduced opportunities for fresh air, was a practical response to the site.

On the other hand, natural ventilation for the office spaces was considered highly desirable. The offices benefit from natural ventilation and face the waterway. The office spaces on the north end of the building,

Courtesy of Benjamin Benschneider/OTTO

This interior view of the breakout space, located within the south part of the Center for Urban Waters, shows the curtain wall with horizontal shading elements and operable windows. Part of the curtain wall also uses fritted glazing.

BUILDING TEAM

Architectural Firm Perkins+Will

Client NDC Housing and Economic Development Corporation

Primary Tenant City of Tacoma, Environmental Services Division

Developer Lorig Associates, LLC

Structural and Civil Engineer AHBL, Inc.

MEP Engineer WSP Flack+Kurtz

Landscape Architect Swift and Company

Commissioning Rushing Company

General Contractor
Turner Construction Company

ENERGY, WATER AT A GLANCE

Predicted Water Use Reduction
46% less than building code requirements (system includes two 36,000 gallon aboveground cisterns that collect rainwater from the green roof and rejected water from reverse osmosis procedures conducted in the labs. Collected water is used for irrigation and toilet flushing.)

Annual Water Use 476,626 gallons

Energy Use Intensity (EUI) (Site)
86 kBtu/ft^2

Annual Energy Cost Index (ECI) \$0.83/ft^2

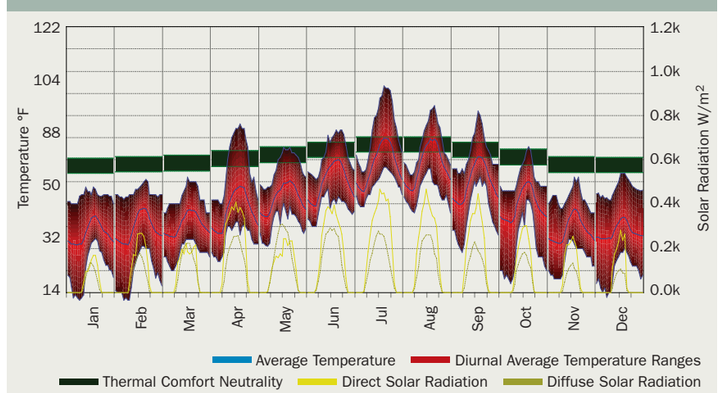
Energy Savings vs. Standard 90.1-2004 Design Building 36%

Heating Degree Days 2,607 (base 65°F)

Cooling Degree Days 74 (base 65°F)

Average Operating Hours per Week 80

FIGURE 1 **CENTER FOR URBAN WATERS: ANNUAL CLIMATE DATA**



Annual climate data (typical year) for Tacoma, Wash., location of the Center for Urban Waters. Cool temperatures are predominant during winter months, while generally mild temperatures prevail for the rest of the year.

with the laboratories to the east, use single-sided natural ventilation. At the south end of the building, where the offices have west and east exposures, natural cross-ventilation is provided. Operable windows on the west and south façades allow occupants to control the amount of natural ventilation.

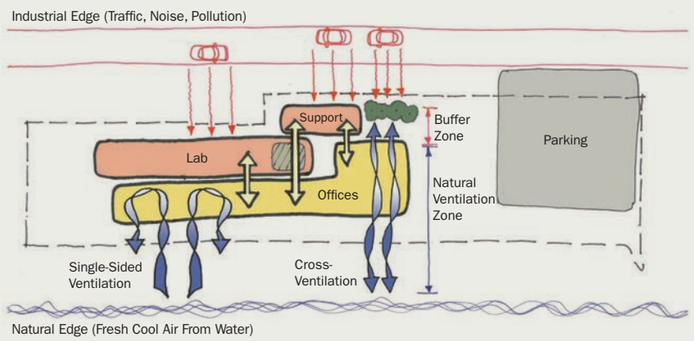
Landscaping is used to create a buffer zone to the east of the offices, keeping out air and noise produced by the neighboring industrial activities. *Figure 2* shows natural ventilation and shading strategies.

Solar orientation was also a factor in the design of the west and south façades. The glazed curtain wall on the south façade uses horizontal shading elements to block midday sun, while providing unobstructed views to the water.

The western orientation of the building receives the greatest solar heat gain. Early designs for this façade included a glass curtain wall protected by vertical sunshades—a reasonable and sustainable approach, but one that proved too costly. Instead, an aluminum rain screen

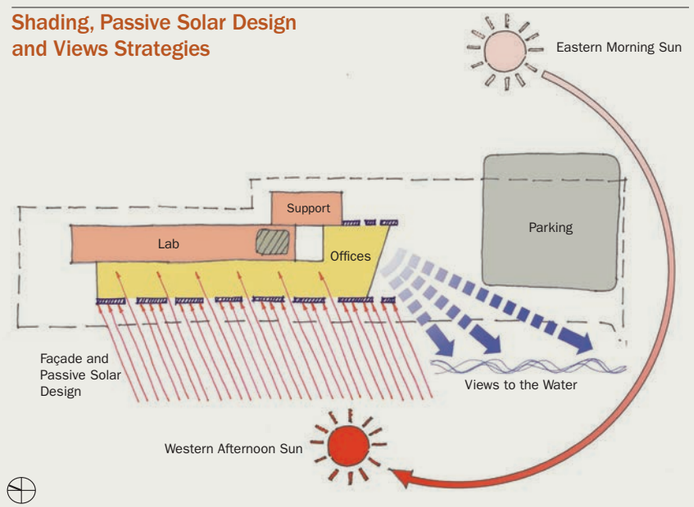
FIGURE 2 **CENTER FOR URBAN WATERS: ORIENTATION AND PASSIVE DESIGNS**

Natural Ventilation Strategies



Designers located building program elements according to their potential use of fresh air and natural ventilation. The waterway side of the building provides access to fresh, water-cooled air, making it ideal for natural ventilation. Designers placed offices, served by operable windows, largely on the waterway side. The side of the building facing the road and industrial area provides reduced opportunities for fresh air. Designers placed the laboratories on this side, since these spaces require mechanical ventilation.

Shading, Passive Solar Design and Views Strategies



The orientation of the sun was considered during the design of this building, and passive shading strategies are used based on the façade orientation. The west façade has a low window-to-wall ratio, and includes external shading elements (blinds that respond to solar radiation and temperature) to mitigate solar heat gain and glare from low afternoon sun. The south façade consists of a curtain wall with a series of horizontal shading elements. For the south façade, the curtain wall is used to preserve views to the outside, while horizontal shading elements block unwanted solar heat gain.

The north façade primarily consists of opaque building elements and minimal amounts of glazing. This strategy improves thermal resistance for this orientation, limiting heat transfer between the exterior and interior environment.

Courtesy of Benjamin Benschneider/OTTO

Courtesy of Benjamin Benschneider/OTTO

Courtesy of Benjamin Benschneider/OTTO

Above This view of the office space shows operable windows, clerestory windows and a lightshelf that constitute the west-oriented building envelope.

Left The south curtain wall includes horizontal shading elements and fritted glass to reduce direct solar exposure.

façade with punched high performance windows was developed.

The designers studied two materials for the opaque parts of the façade: composite panels, in which a resin core is sandwiched between layers of light-gauge aluminum; and formed heavy-gauge aluminum panels. Both materials would perform well, but a life-cycle analysis showed that the composite panels would be more difficult to recycle at the end of the building's useful life.

To compensate for the exclusion of the vertical sunshades, the designers integrated a system of automated exterior blinds into the west façade. Similar to Venetian blinds typically used for interiors, the closed blinds prevent solar heat gain within the building during the afternoon. When open, the blinds also allow passive solar heating.

When the sun is shining on the west façade, the blinds are in the down position, with the blades either open or closed. When the sun is not on the west side, or when the wind is unusually strong, the blinds are in the up position, housed in a pocket behind the rain screen façade.

In some rooms, such as conference rooms, floor-to-ceiling windows with exterior blinds are used to provide expansive views. Elsewhere, such as at the typical open offices, windows are limited to narrow glazed slots to optimize energy performance. The west façade also has high clerestory windows above the vision windows. There are no exterior blinds at these clerestory windows; instead, interior translucent-resin lightshelves at the sills of the windows block direct sunlight and bounce daylight deep into the rooms.

The south façade is the only orientation that uses a curtain wall. Fixed exterior horizontal sunshades, made of 16 in. deep perforated aluminum plates, are supported by tapered aluminum outriggers. Vertical spacing of the sunshades is 12 in. The curtain wall projects outward along the second and third levels at the southeast corner, forming a canopy that protects the main entrance.

This portion of the south façade does not have external shading elements; however, a ceramic frit applied to the glass reduces direct solar exposure. Even with the fritted glass, the spaces behind this part of the curtain wall experience a wider temperature range and have more glare potential than spaces with the horizontal sunshades. Spaces with lower criteria for thermal comfort and glare, such as breakout rooms, were planned for these locations.

On the east façade, a rain screen made of horizontal corrugated metal panels faces the industrial side of the site. Covering the upper half of the second- and third-level slot windows are perforated corrugated metal

screens. These screens help control early morning sun and reduce potential glare, while maintaining views and maximizing daylighting.

The north façade continues the east façade's corrugated metal rain screen. This façade is designed to provide high thermal resistance, so the windows were kept small. Sun shading elements were not needed for this orientation.

The overall window-to-wall ratio for all four façades is low, around 32%. Glass selection was based on the orientation of the windows and the functional requirements of the interior spaces.

The vision areas for all façades consist of double-glazed, air-insulated glazing units, with a low-e coating applied to the exterior surface of the interior glass layer. Curtain wall spandrels consist of insulated glazing units made of green-tinted float glass, sandblasted to a white-line finish on the inner surface of the exterior glass layer, with a colored frit pattern on the inner surface of the interior glass layer. The opaque areas of the façades are designed for an average thermal resistance of R-19.

The east side consists of a rain screen façade with metal cladding, and has a minimal window-to-wall ratio. Perforated corrugated metal screens shade the interior from the early morning sun and control glare.

Courtesy of Benjamin Benschneider/OTTO

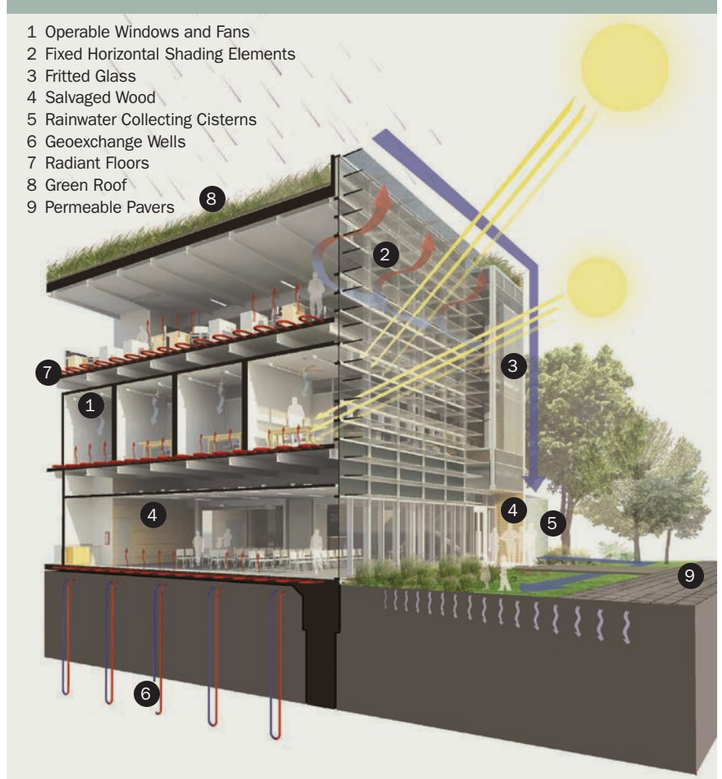
Courtesy of Benjamin Benschneider/OTTO

This view of the Center for Urban Waters from the waterway shows the relationship between the building and its surrounding industrial context. Designers maximized views and opportunities for natural ventilation on the waterway side of the building and limited exposure to the side that faces the road and industrial area.

Besides the high performance façade design, the Center for Urban Waters incorporates other energy-efficiency and sustainability strategies, including vegetated roofs, storm water collection, water reuse, use of recycled and reclaimed materials, geo-exchange wells, radiant heating and cooling, and a heat-recovery system in the laboratories and office spaces (*Figure 3*).

Measurement and verification systems installed in the building track actual building performance and inform users of the real-time energy use.

FIGURE 3 **CENTER FOR URBAN WATERS: SUSTAINABLE DESIGN STRATEGIES**



Design Strategies for Hot Climates

The University of Texas at Dallas (UTD) Student Services Building is located in a hot climate (Zone 2B). *Figure 4* shows annual average daily temperatures in relation to thermal comfort zone for this location and the available solar radiation. Summers are generally hot and sunny, while the other seasons are relatively mild, so summer conditions were the primary concern for the façade design.

The building site was determined by the campus master plan. The UTD Student Services Building is located along the main pedestrian corridor, and its overall form is rectangular, with its longer sides facing north and south orientations.

The program includes spaces for student enrollment, health services, counseling, financial aid, student registration services and a career center. All four sides of the building are enclosed by a curtain wall. The east, west and south façades (and part of the north façade) are wrapped by an exterior assembly of shading devices supported by the curtain wall. The shading system consists of horizontal terra-cotta louvers and vertical stainless steel rods (*Figure 5*).

Three internal atriums provide daylight to interior spaces (*Figure 6*). This design strategy is essential for hot climates, since it is necessary to reduce solar heat gain associated with exterior envelope, while at the same time provide natural daylight for the interior spaces. The combination of shading elements along the façade and internal atriums is an ideal strategy. Almost all of the normally occupied spaces in the UTD Student Services Building have views to the outside.

The building also incorporates other sustainable design strategies. Roof-mounted solar hot water collection panels provide all of the building's hot water needs. Reductions in water demand and the use of rainwater harvesting significantly reduce the building's use of potable water.

Recycled and low-emitting materials were used throughout the

BUILDING AT A GLANCE

Name University of Texas at Dallas Student Services Building

Location Richardson, Texas

Owner University of Texas at Dallas

Principal Use Higher education building

Program Student services, general enrollment services, health services, counseling, career center, financial aid, bursar and registrar

Occupants 350

Window-to-Wall Ratio 80% overall

Square Footage 78,000

Distinctions and Awards
LEED Platinum-NC, 2011

Innovation in Green Building Design Award, Association for Advancement of Sustainability in Higher Education/U.S, Green Building Council, 2011

Cost $20 million

Completion August 2010

The south and east façades consist of a curtain wall and a series of terra-cotta horizontal shading elements. These shading elements are used to create an irregular pattern along different building façades, and to provide shading that is necessary for reducing solar heat gain in a hot climate.

Courtesy of Charles Smith

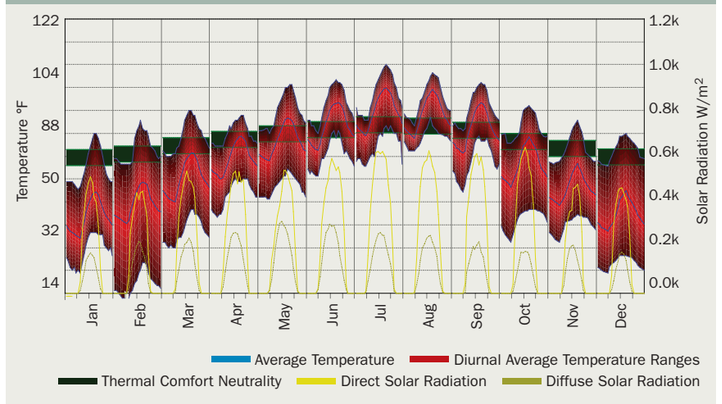
Courtesy of Charles Smith

Courtesy of Charles Smith

Below **The lobby is located on the east side of the building within one of the building's three atriums, which provide natural lighting while limiting heat gain.**

Below right **Terra-cotta shading elements control solar heat gain and are a prominent design feature of the building envelope.**

FIGURE 4 **UNIVERSITY OF TEXAS AT DALLAS STUDENT SERVICES BUILDING: ANNUAL CLIMATE DATA**



Annual climate data (typical year) for Dallas, location of University of Texas at Dallas (UTD) Student Services Building. Summers are generally hot and sunny, while the other seasons are relatively mild.

ENERGY, WATER AT A GLANCE

Predicted Water Use Reduction
86% reduction in domestic water demand (two 20,000 gallon cisterns are used to collect rainwater, which is used for irrigation)

Energy Use Intensity 82 kBtu/ft^2

Savings vs. Standard 90.1-2004 Design Building 41%

Percentage of Power Represented by Renewable Energy Certificates 70%
- **Number of Years Contracted to Purchase RECs** first two years of building operation

Heating Degree Days 1,265 (Base 65°F)

Cooling Degree Days 1,533 (Base 65°F)

Average Operating Hours per Week 112

BUILDING TEAM

Architectural Firm Perkins+Will

Client University of Texas at Dallas

Structural Engineer Jaster Quintanilla

Civil Engineer URS

MEP Engineer Infrastructure Associates

Landscape Architect
Kendal + Landscape Architecture

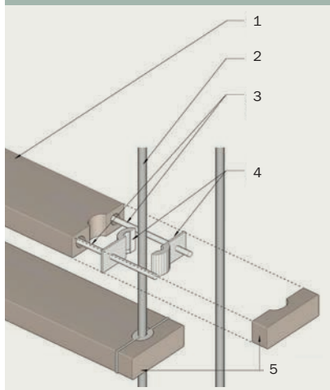
Commissioning Sebesta Blomberg

General Contractor Hill & Wilkinson

building. Indoor air quality and carbon dioxide levels are monitored by the building management and control system, which improves interior comfort conditions.

The building was constructed approximately 10% under budget. Its operating energy costs were reduced by 63% compared to the average of the other campus buildings.

FIGURE 5 **UNIVERSITY OF TEXAS AT DALLAS STUDENT SERVICES BUILDING: TERRA-COTTA SHADE DIAGRAM**



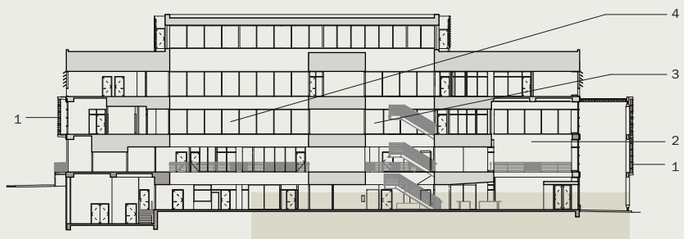
1 Terra-Cotta Blade
2 Vertical Stainless Steel Rod
3 Horizontal Stainless Steel Threaded Rod
4 Extruded Aluminum End Plate
5 Terra-Cotta End Cap

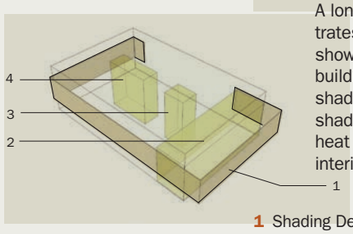
The east, west and south façades (and part of the north façade) are wrapped by an exterior assembly of shading devices. Horizontal terra-cotta blades are supported by pairs of vertical stainless steel rods spaced every 5 ft along the façades. These vertical rods are attached to horizontal outriggers projecting from the building face at the floor levels.

Since terra-cotta has little tensile strength and cannot span between the vertical rods on its own, each blade is reinforced along its entire length with two horizontal stainless steel rods in hollow cylindrical cores. The benefits for selecting terra-cotta are its very low thermal conductivity, as well as natural sourcing of the material.

Extruded aluminum plates at each end secure the horizontal rods to the vertical rods, and terra-cotta end caps finish the ends of each blade. Regularly spaced horizontal braces tie the pairs of vertical rods together to control deflection.

FIGURE 6 **UNIVERSITY OF TEXAS AT DALLAS STUDENT SERVICES BUILDING: SECTION AND INTERNAL ATRIUMS**





A longitudinal section through the building illustrates the three atriums. The diagram at left shows their volumetric distribution within the building and their relationship to the façade shading elements. The combination of solar shading and internal light harvesting limits solar heat gain and provides three-quarters of the interior spaces with daylight.

1 Shading Devices **2** Atrium 1 **3** Atrium 2 **4** Atrium 3

Courtesy of Charles Smith

This view to the exterior shows the terra-cotta shading elements and supporting rods.

Conclusion

Design strategies for sustainable, high performance façades highly depend on the building's location and climate. The primary purpose of high performance sustainable façades is to provide a barrier between the interior and exterior environment, while creating comfortable spaces for building occupants and significantly reducing a building's energy consumption.

Strategies that work best in hot and arid climates are different from those that work in cold, temperate or hot and humid regions. This article provides two examples of buildings that incorporate high performance façades—one located in a mixed, and one located in a hot climate. Designers of sustainable façades should use the specific characteristics of a building's location and climate, as well as its program requirements and site constraints, to create high performance building envelopes. ●

ABOUT THE AUTHOR

Ajla Aksamija, Ph.D., LEED AP BD+C, is an assistant professor at Architecture+Design (University of Massachusetts Amherst) and a building technology researcher (Perkins+Will). Her book, "Sustainable Facades: Design Methods for High-Performance Building Envelopes," was recently published by John Wiley & Sons.