BUILDING ENVELOPE

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INTRODUCTION

The building envelope—the outer walls and roofs that give shape to any habitable structure—has always been part of an architect's repertoire. For centuries, this outer shell was limited in design and construction to traditional materials and shapes. In the late 20th and early 21st centuries, however, construction and information technology evolved to such an extent that architects are able to experiment with more unusual materials, forms, and functions. Yet the basic concepts of shelter, external image, and interior perception of light and space remain.

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TYPES

Today’s building envelope still satisfies the fundamental need for shelter from predators, enemies, and the elements. However, a variety of building envelope types have evolved in response to diverse functional and climatic demands. Many envelope types can be classified according to concepts, rather than by specific construction methods or materials. These conceptual categories include static, operable, tensile, pneumatic, open, and pressurized envelopes. In actual practice, there are innumerable variations, combinations, and hybrids of these general types.

PERCEPTION

The meaning that people read into a building is largely a function of what is expressed by its envelope. This has been particularly true of the building elevation, especially since the Renaissance. The most predominant visual component of a building from the exterior, the envelope also establishes the degree to which the interior appears to be connected to or separated from the surrounding landscape and built environment. Envelopes play a critical role in people’s perception of the built environment.

Key to any discussion of perception is how the mind works. Sigmund Freud stated that the mind perceives either symbolically or experientially. Symbolic perception occurs when an observer has past experiences with a particular image, recognizes that image, and assigns associations to it. For example, a steeple is associated with religious activities, a gable roof with residential use, and a tin roof with agricultural use. Conversely, new architectural forms, new ways of manipulating natural light, new material applications, and other new techniques can cause the mind to experience without the filter of symbolic meaning or to challenge conventional meaning. A sense of joy is often evoked from either form of perception—symbolic or experiential. The symbolic form offers a degree of comfort of the known. The experiential triggers a child-like joy of discovery.

There are eight formal strategies or concepts that can influence the aesthetics of a particular building envelope and, in turn, generate certain intellectual and emotional responses in the mind of an observer. These concepts are:

- Structural expression or concealment
- Opaque, transparent, or translucent
- Natural or man-made materials
- High-tech or low-tech
- Temporal or permanent
- Background or foreground
- Graphic device
- Iconographic entity

For any given project, the architect must decide which of these potential concepts best suits the client, program, and site. More than one concept may apply to a given project; designs may also offer hybrid solutions that mediate between conflicting concepts. These eight concepts may be applied to any or all of the envelope types previously described.

CONTINUING EDUCATION

Use the following learning objectives to focus your study while reading the semi-annual *Direct Connection*/Professional Development (PDU) and AIA Continuing Education (CEU) HSW credit article. To receive credit, go to the NCARB web site: www.ncarb.org, click on “Publications,” then “Monographs,” fill out the registration form and payment information and you will be given an online access number and be able to take the quiz for credit online. NCARB Record holders can take the quiz for free by logging onto “My NCARB Record” and then clicking on “Mini-Monograph Quiz.”

LEARNING OBJECTIVES

After reading this article, you should be able to:

1. Learn how “advanced energy strategies” allow a building envelope to generate energy for use on site and optimize a building’s energy performance.
2. Understand how computers can create unusually shaped envelopes.
3. Identify envelope types according to concepts rather than specific construction methods or materials.

Green Building Materials

Environmental impact is becoming a major determinant in building material selection. Green building principles strive to meet today's needs for shelter and work without depleting resources for future generations.

Green building products and methods do more with less. According to the National Center for Appropriate Technology in Butte, MT, "the construction and operation of buildings consume more materials and energy than any other single activity in the United States." By practicing resource efficiency, the pressure that construction places on natural resources can be reduced. Specifying green building materials involves, among other strategies, choosing products that use the least amount of energy in their extraction, fabrication, and delivery. It requires consideration of materials that are made from recycled products or are likely to be reused or recycled. It also requires consideration of materials that are produced from an easily renewable resource and do not release toxic elements.

Minimize Energy Consumption

In the United States interest in materials that do not contribute to excessive global warming and in materials that have a reasonable energy payback (the length of time it takes a material to save the equivalent energy used in its manufacturing) is growing. Carbon dioxide emissions are a major culprit in global warming. To date, most efforts to reduce these emissions during a building's lifetime focus on the energy required for operation and maintenance. Numerous energy-efficiency measures that significantly reduce energy consumption—such as energy-efficient lighting—are now widely accepted and implemented by the design profession.

Operation, however, represents only one chapter in the life cycle of a building. Carbon dioxide emissions associated with the source (raw material acquisition), transport, process (manufacturing), and distribution life-cycle stages of materials for new construction, maintenance, repair, and remodeling construction can be very high. The U.S. Green Building Council has estimated that upstream carbon dioxide emission (off-site impacts prior to the building's actual use) is roughly five times greater than direct emission (for building construction) and 10 to 20 times the emissions that occur during actual building operation. Materials that require the greatest amount of energy in these upstream phases, and therefore contain the greatest amount of embodied energy, have the greatest negative environmental impact. An understanding of the embodied energy of various materials will enable architects to specify materials with lower levels of embodied energy. In addition, specification of local green building materials can further reduce energy consumption by minimizing transportation.

Reuse and Recycle

Certain green building materials take advantage of recycled products: cement from fly ash; fiber-cement and fiberboard from recycled wood; ceramic tiles from recycled glass; aggregate from recycled concrete; roofing, siding, and framing from recycled metals; and roof shingles from recycled plastic are just a few of the building materials available.

Steel production has a long history of using recycled content. All steel products, including steel framing and siding, contain recycled steel. Steel framing contains a minimum of 25 percent recycled steel. A typical 1,700-square-foot steel-framed house uses the equivalent of six scrapped automobiles. Aluminum is another metal that can be recovered, recycled, and reused. Aluminum produced from recovered scrap and recycled aluminum rather than bauxite ore saves approximately 80 percent of the energy required to make the original aluminum product from the ore.

Plastic is another recycled material that requires significantly less energy to remanufacture into a reuse material than to produce the virgin plastic. Producing plastic products from scrap plastic eliminates 85 to 90 percent of the energy required to produce the same plastic products from virgin resin. Recycled plastic commonly found in building products includes polyethylene terephthalate, high-density polyethylene, and polystyrene. Polyethylene terephthalate (PETE) is a thermoplastic polymer, which is a lightweight, hard, stiff, strong, and dimensionally stable material that absorbs very little water. It is 100 percent recyclable. Recycled PETE is used in the building industry for water-resistant liners, insulating materials, and industrial paints. High-density polyethylene (HDPE) is characterized by rigidity, low cost, ease of forming, and resistance to breakage. It is used to make plastic lumber and siding. Polystyrene (PS) is a versatile resin with a range of physical properties that includes thermoforming. Applications in the building industry include insulation and permanent insulated concrete wall formwork.

William McDonough and Michael Braungart point out in their book, *Cradle to Cradle: Remaking the Way We Make Things* (2002), "most recycling is actually down-cycling that reduces the quality of a material over time." The high carbon-steel used to make automobiles, for example, is down-cycled by melting it with other metals and car parts that lower the steel's quality. Additives are normally required for the down-cycled materials to attain desired performance qualities. These additives may be expensive or toxic. McDonough and Braungart argue for industrial production that produces smaller amounts of useless waste and for the manufacture of materials that are easily separated and recycled without the additives.

Renewable Materials

Wood should be specified from certified, well-managed forests to minimize environmental impact. Alternatives to old-growth lumber include component systems (such as trusses and pre-manufactured elements); stressed-skin insulated-core panel (such as structural insulated panels); reclaimed wood; and composition materials (recycled plastic mixed with wood fibers). Natural fibers include straw bale fibers (corn, wheat, and rice straws); fibers from non-wood sources (kenaf, flax, jute, and hemp); and fibers from leaf sources (sisal, henequen, and pineapple leaf). In addition, optimum value-engineering techniques—including advanced framing systems, detailing for durability, and job-site waste management—should be implemented when possible to increase the efficiency of renewable materials.

Low Toxicity

Materials should be tested to make sure that they are low in volatile organic compounds and other toxic substances, and that any runoff or emission associated with the production or use of the material will not harm the local environment or inhabitants. Temperature and moisture conditions should be considered as well; building materials that do not outgas harmful chemicals when they are hot or wet should be selected. Moisture should be controlled to reduce mold and mildew growth, which cause building materials to deteriorate.

Resource Guides

Each material carries its own set of environmental burdens and benefits. Accurate information about these characteristics can be difficult to obtain and may require research. The American Institute of Architects' (AIA) *Environmental Resource Guide* (ERG), published by John Wiley & Sons, Inc., provides a basis for comparing the environmental impact of building materials, products, and systems.

The Guide to Resource Efficient Building Elements contains product information on materials for a variety of uses from foundations to roofing, along with manufacturer references. Maintained by the Center for Resourceful Building Technology—a project of the National Center for Appropriate Technology—in Missoula, MT, the Guide's online version (e-GUIDE) is available at www.crbt.ncat.org. BuildingGreen in Brattleboro, VT, publishes "Environmental Building News," a monthly newsletter for builders and architects. GreenSpec Directory, a listing of green building materials is available both in print and online (www.greenspec.com). Green Building Pages, a web-based resource guide for sustainable design, was introduced in 2003 (www.greenbuildingpages.com). The Leadership in Energy and Environmental Design (LEED™) rating system developed by the U.S. Green Building Council (www.usgbc.org) and its resources provide a "Building Rating System" that focuses heavily on the growing number of LEED "products." Finally, NCARB's *Sustainable Design II* monograph provides an excellent detailed account of specific tools and techniques that architects need to master in order to design more environmentally responsible buildings.

CONSTRUCTION SYSTEMS

The various types of building envelopes are constructed according to a host of different fabrication and erection methods. A few of the technical, logistical, and financial considerations associated with some of these methods are considered in this article. This is intended only as a very brief overview and not as a comprehensive review of the many potential, and often project-specific, issues of constructability that can arise. As with types and means of perceptions, these methods could be applied to more than one type of envelope.

Categories of fabrication and erection are:

- Prefabricated
- Panelized
- Veneered
- Self-supporting
- Hand applied
- Machine applied

MATERIAL SELECTION

To select the most appropriate building envelope material, it is necessary to carefully plan and analyze material performance specifications for a particular climate and building orientation. The selection process should consider—in addition to the conventional criteria of performance, cost, and aesthetics—the environmental impact of materials. Every approach that considers an environmental assessment uses, either explicitly or implicitly, some form of life-cycle costing (LCC).

Life-cycle Costing

$$LCC = P - S + M + R + E + N$$

LCC = Life-cycle Costs
P = Purchase and Installation Costs
S = Salvage Value
M = Maintenance and Repair Costs
R = Replacement Costs
E = Energy Costs of Operation

Window-Shading Elements

Control of the sun's action on a structure is critical to achieving optimal lighting conditions and energy efficiency. Because the sun's movements are absolutely predictable, effective window-shading devices that precisely limit or permit solar exposure may be designed.

The shading requirements for each face of the building must be considered separately because the pattern of incident sunlight varies with orientation. In the hot season, the west face of the building is especially critical because peak (high temperature) loads and solar loads are concurrent on this face. Here, the glass should be kept to a minimum or properly shaded.

Window-shading devices—from louvers to drapes—are categorized according to their adjustability (fixed or moveable) and their location (exterior, between glass panes, or interior). Considerations in choosing shading devices include effectiveness, cost, and maintenance. Moveable shading devices respond better to the dynamic nature of weather than do static devices. They are, however, more expensive and require more maintenance and more expertise to operate. Automatic controls that make constant adjustments to shading devices may be distracting to interior occupants; override controls may help to minimize distractions.

Elements applied to the exterior of buildings are generally considered more effective in controlling both glare and heat than interior shading. They physically block unwanted light and allow for much of the heat to be vented away before penetrating the structure. Shading devices can also block views—a factor that designers must take into consideration.

FIXED SHADES

Exterior

Examples of exterior fixed shades include horizontal overhangs and vertical fins. A horizontal overhang reduces the amount of solar radiation striking the glass when the sun is higher in the sky during warmer seasons and increases the amount of radiation when the sun is lower in the sky during cooler seasons. Dimensions for an overhang can be determined with sun charts. Overhangs are most effective in controlling the selected shading of south-facing glass. Unfortunately, they also trap hot air below. This problem can be remedied, however, by designing a slot near the plane of the window or by specifying fixed horizontal louvers (trellis) to allow for the free flow of air.

Verandas, balconies, or pergolas—essentially very deep overhangs—can be used to shade east and west elevations. They may, however, still admit very low-angle summer sun, which would require additional adjustable shading. Fixed vertical fins are recommended for shading north windows. Their performance may be improved by slanting them toward the east, thereby shading late afternoon summer sunlight while allowing for more penetration of early morning summer sunlight. Vertical fins are also useful for shading east and west windows. Regardless of the orientation fins may restrict views.

A combination of horizontal and vertical exterior shading devices may be used. One example is the grid of horizontal overhangs and

PERFORMANCE

In addition to conveying architectural meaning, the building envelope must perform myriad technical and functional roles. The building envelope is the filter between humans and the world outside. Typically, it provides views into and out of the building; it illuminates, moderates temperatures, controls moisture, and circulates fresh air. Moisture control, a critical factor in building design, operation, and maintenance, has gained greater attention due to increased demand for building performance, greater building technology, and climatic events such as Katrina and recent flooding in the Midwest. For a more detailed examination of moisture control issues in design and construction see NCARB's *Mold and Moisture Prevention* monograph. Increasingly, building envelopes are also being challenged to mitigate environmental problems such as fossil-fuel dependency, heat-island effect, and storm-water runoff. The building envelope is a critical zone of any building that must be properly designed and detailed to accomplish these multiple and often complex tasks that it is required to address. These include the basic performance tasks architects have come to expect of building envelopes—serving as a visual filter, a light filter, a thermal filter, and an air filter, and accommodating movement.

connecting vertical louvers developed by Le Corbusier for the Unite d'Habitation in Marseilles, France. This type of fixed shading, known as an egg crate, allows for a reduction in the extent of the overhang. However, it restricts panoramic views. For hot climates, egg crate shading devices are recommended for south-facing windows if the shading device is vented to allow for the removal of hot sol-air temperatures. The horizontal overhangs shade the south elevation from the high overhead summer sun angles of midday and the vertical fins shade the south elevation from the lower sun angles of morning and afternoon.

Between panes of glass
Solar-shading devices can be incorporated into the cavity between two glass panes. They are intended to block direct sunlight and prevent glare in summer without reducing light levels or solar heat gain in winter. Solar-shading devices with fixed properties include films and micro-screens, micro-louvers, or similar structures positioned according to a particular angle of solar radiation.

Interior
Examples of interior fixed shades, which block excess radiation and glare, include light shelves, horizontal louvers, and screens. Light shelves have the added advantage of reducing electric lighting costs by bouncing more natural light deeper into the room. These types of solar control are less effective than exterior shading; the heat produced by solar radiation is collected inside the interior space. Because they are easily accessible, cleaning and maintenance of interior solar-control devices are considerably simpler than exterior shading and shading between glass panes.

MOVEABLE SHADES

Some very effective awnings need only be manually adjusted by maintenance personnel a few times a year. Other shading devices are automated to adjust to the sun on a daily basis. Some devices may be adjusted by the occupant to provide shading, sunlight, or particular views as needed. Individually controlled devices are particularly useful in spring and autumn when cooling and heating needs are more variable.

Exterior
Examples of exterior moveable shades for south elevations include rotating horizontal louvers, retractable roller shades, and retractable awnings. For east and west window orientations, adjustable slanted exterior vertical blinds allow users to moderate both shading and view. Additional exterior adjustable systems for east and west elevations include louver screens, moveable shutters, retractable awnings, and adjustable external blinds.

Between panes of glass
Movable acrylic prismatic panels can be inserted between panes as a system of louvers that block direct sun and admit diffuse daylight. The upper surface of such panels can be treated with a reflective coating for the clerestory portion of a window wall. These systems fully or partially block direct sun and redirect sunlight to the interior ceiling plane. The acrylic panels are mechanically moved between the two panes of window glass and an adjacent wall cavity space in a method similar to a sliding screen.

Interior
Examples of interior moveable shades include light-colored or reflective interior Venetian blinds, or mini-blinds, moveable panel screens, textile drapes, and fabric materials. These interior shading devices are widely used for glare and sun control because they are inexpensive, moveable, and easily controlled on demand by building occupants.

Because these shading devices are installed inside rather than outside the window, solar heat builds inside the building. Some sunlight is reflected back outside the window when curtains, draperies, or blinds are closed, but considerable heat may be trapped between the window and shade. The excess heat must then be removed mechanically.

Interior drapes have additional disadvantages. They block views and daylight when closed, and their fabric may fade or deteriorate due to ultraviolet (UV) sunlight. New sheer-weave fabrics are UV-resistant and have light-filtering qualities that reduce fading while continuing to offer the benefits of daylight and outside views.

ADVANCED ENERGY STRATEGIES

The building envelope plays a particularly important role in a building's energy performance. The more effectively the envelope is able to maintain the desired interior temperature, ventilate with natural breezes and airflows, and illuminate with natural light, the less fossil fuel is expended. For more information on energy-efficiency, see NCARB's *Energy-Conscious Architecture, Sustainable Design,* and *Sustainable Design II* monographs. The building skin itself is able to meet much of a building's energy needs with advanced technologies. This may be accomplished by incorporating active solar and photovoltaic technologies into the envelope. These technologies directly tap the sun's energy. In the face of global warming, atmospheric dissipation, and greenhouse gases—caused, in part, by conventional methods of powering, heating, and cooling buildings—responsible design and construction industries should consider these options.

SMART-BUILDING TECHNOLOGIES

One way to reduce a building's energy needs is by using smart-building technologies—electronic systems that can maximize an envelope's energy performance by continuously monitoring environmental conditions and adjusting the building skin to any changes. With computer automation, various electronic devices and systems—from appliances and lights to security and HVAC—"communicate" with each other and may be remotely controlled by time, voice, daylight, motion sensor, telephone, personal computer, as well as manually controlled. This sophisticated interconnection of various systems in a building is commonly referred to as smart-building technology.

Smart-building technologies enable building systems to adjust immediately to various changes in the environment or in the room. In terms of energy and the building envelope, this means that shading responds quickly to changes in sun angles, openings open or close as more or less ventilation is required, and interior lighting responds to changes in daylight. Such sensitivity to existing conditions translates into greater comfort, control, and, ultimately, energy efficiency.

The capacity to send and receive control signals depends on the ability of these devices to speak the same language. In order to be controlled, each device must be capable of receiving signals from other devices, controlling other devices, and sending control signals to other devices. The need for various devices to intercommunicate has led to the development of standards, or protocols, that define the ways in which these devices can and cannot communicate. While a number of different protocols have been established, their success has depended upon their ability to communicate with other protocols. Devices that operate on different protocols are available, so it is imperative that each protocol has the flexibility to communicate with all others.

Maintenance

Over time the building exterior is subjected to many different types of atmospheric conditions and pollutants. Yet, a long period of time often passes before an envelope's exposed surfaces are cleaned or restored. Many exterior wall finish materials are incorrectly thought to be maintenance-free and many are not regularly maintained due to insufficient maintenance budgets. Most materials require regular maintenance to ensure proper lifespan and operation.

A wide range of issues—in particular surface and joint maintenance—govern long-term success within each material type. Recommended maintenance schedules and procedures can vary with the degree of exposure to precipitation, temperature extremes, freeze/thaw cycles, airborne salts (marine environments), airborne pollutants (industrial environments), and acid rain. Specific recommendations, beyond the scope of this article, and industry resources and guidebooks, which may provide recommendations regarding their respective materials, are referenced in the "Resources" section of NCARB's *Building Envelope* monograph.

During the last decade, smart–building technologies were an expensive proposition. An installer typically created a centralized intelligence system, where a dedicated computer was installed and connected to various devices located throughout the structure; the computer location often required extensive wiring to connect it to the devices. The computer was programmed so that input and output from devices with incompatible protocols could be translated to allow for intercommunication. The need for specialized hardware made the system difficult to install, maintain, and use. In addition, the centralized controller could become over-burdened and slow during peak activity periods or could cause system-wide failure in the event of a breakdown.

A distributed intelligence system—that eliminated the need for a centralized computer—evolved from these difficulties. Similar to a PC on each desk, distributed intelligence meant that each system had its own processor and intelligence. With this independence, each processor could manage its own needs and was invulnerable to another processor's failure. The system, however, was expensive and the processor generally did not perform multiple tasks.

The latest evolution of these systems is network intelligence. In a network environment, each system has a dedicated processor and software resources to function independently of other systems, while also communicating and sharing resources. For example, the security system may utilize a motion sensor as a means of securing a particular building envelope. When motion is detected, the security controller checks to see if the motion is an intruder, and if so, it sets off an alarm. In a network environment, that motion sensor can also turn on lights, turn on the heat and air, open windows and drapes, or adjust shading devices. This allows for a series of activities to occur off a single-activity control device that is closely attuned to multiple-function daily patterns.

The most common devices linked in a network include controls for lights and simple appliances, automated control of shading devices, and automated control of windows. Network intelligence systems can be programmed to maintain and operate several scenarios for several different zones in a building. However, controls can be overridden with time, voice, or sensor input. This multiplicity of controls can even be connected to external sensors for day/night or for seasonal changes. For example, a personal computer smart–building control system could be connected to weather station sensors so that it can constantly adjust the shading awning, tilt angle of photovoltaic panels, or heating and cooling systems for continual optimum performance. In essence, smart technologies maximize the efficiency of building performance based on the programmed needs of the building's occupants.

Working with Warp

A warped surface, which simultaneously curves in two directions, is not a ruleable surface. Such surfaces present difficulties at all stages of design, fabrication, and installation. During design, warped surfaces can be generated either by computer or by a physical modeling technique. Practically speaking, the degree of control necessary to document the transitions in such a surface is only obtainable with the use of 3-D computer software such as form ·Z, AutoCAD 3D, 3ds max, Rhinoceros, Maya, and Catia. However, the designer has more immediate and tactile control of the warped surface when it is generated with physical modeling techniques. Physical media can include paper, fabric, modeling clay, or basswood.

Converting to a Database

An additional step is required in the design of a physically generated warped form: its surface data must be converted into a database. A database can be manually created by carefully measuring back to a reference point (x = 0, y = 0, z = 0) with machinist's squares and pointers. A more efficient method to accomplish this, however, comes from the automotive and aerospace industries, where designers have been using optical laser digitizing devices for nearly two decades. These devices, usually mounted on a large mobile pedestal, can track along a post and beam to access any point around the surface of a large model. A Cartesian grid is overlaid onto the complex model. The optical device digitally registers the three-dimensional points in space. Software such as Catia, form ·Z, or 3ds max then interpolates the points to create a streamlined surface.

Verifying the Database

Whether originally designed by computer or physical media, it is important to verify that the warped surface, as defined by the database, does indeed reflect the design model.

A physical model may be made from the computer data by a computer numerically controlled (CNC) milling or laser-cutting machine. These machines carve the model from a soft material, such as polystyrene foam, or cut layers of paper, which are then stacked together like a contour model. The expense of these automated processes must be budgeted into the project cost.

Computer software as mentioned above can also be used to flatten the surfaces defined by the database into templates that can then be printed and used to reconstruct by hand a verification model. The time required to build such a model is the primary consideration for this approach.

COMPLEX GEOMETRY AND FLUID FORMS

Developments in digital design and fabrication technologies allow architects to experiment with the building envelope at an unprecedented scale and level of complexity. Although basic concepts of shelter are consistent, these designs and forms challenge the perception of the built environment.

The complex geometry and fluid forms of computer-generated and documented projects have become a topic of great interest in the architectural community. Major periodicals provide in-depth coverage of both architects who are advancing, either in theory or practice, computer design and documentation. Some sectors of the construction industry are tooling up with mass customization capabilities such as digitally driven milling and cutting machines and assembly robotics. The influence of the computer on the profession of architecture and the profession's evolution is pervasive and long-reaching.

For architects who are not actively involved with "cutting edge" computer use, many ideas and applications can be applied to varying degrees as opportunities arise in everyday practice. A practitioner may find it helpful to first test methodologies, software, and staff aptitude with a relatively small project and with a client who has both an interest in technology and a willingness to financially support the technology. Three dimensional databases and other interim products may be required. The learning curve can be steep, so these initial projects may best be viewed as investments in future projects.

In considering the feasibility of designing and building truly new forms, architects need to understand a variety of issues. These include an understanding of how to define the geometric make-up of complex shapes so that they are technically feasible; understanding of the limitations of specific materials for the structural frame, the skin, and the connection of the skin to the frame; and how to work cost-effectively with fabricators and contractors. As the construction industry continues to adapt to computer technologies, contractors may opt for more sophisticated CAD-driven fabrication methods rather than some of the approaches presented at left. Practitioners should remain open to new possibilities as this evolution progresses.

CONCLUSION

The many topics covered in this mini-monograph provide a diverse range of concepts, typologies, and practical knowledge regarding the building envelope, both historically and in contemporary practice. Looking toward the future, architects may anticipate an even greater influence of computer practice on design and construction, increasing innovations in materials and products, and growing interest in sustainability. As a result, the building envelope will continue to embody ever-new aesthetic experiences while helping to solve actual environmental concerns.

The building envelope offers much more than shelter—it is unquestionably the most important signifier of technology and society. The treatment of building envelopes conveys collective priorities and aesthetic preferences. Architects have a responsibility to imbue every project with its highest potential in terms of function, material, social responsibility, and artistic meaning. The building envelope can be as advanced in form, material, and technological performance as automobiles, furniture, and other industrial design products. It can contribute to energy production rather than burden utility infrastructure. It can re-assert its representative role in the community and culture. And, ultimately, it can serve society and individual alike by lifting the human spirit.

For a more in-depth discussion of building envelope types, construction systems, material selection, performance, and energy strategies please refer to the NCARB *Building Envelope* monograph. It, as well as the other previously cited monographs, can be ordered from the NCARB web site at www.ncarb.org/publications/pdpmonographs.html.

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