



# Building Systems Integration

for Enhanced Environmental Performance

Shahin Vassigh ■ Jason Chandler

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for Enhanced Environmental Performance

Shahin Vassigh  
Jason Chandler



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We dedicate this book to our children.

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Silvana Herrera, Fiorella Mavares, Paolo Arce, Amir Melloul, Adrian Heid, Julian Sandoval and Madeline Gannon

# Symbol Legend

## Context



Urban



Suburban

## Climate



Hot and Humid



Hot and Arid



Temperate



Cool

## Elevation



Low: < 700 feet above Sea Level



Medium: 700-3000 feet above Sea Level



High: > 3000 feet above Sea Level

## Temperature



Average High/Low



Cold Air



Hot Air

## Precipitation



Dry



Dry/Wet



Wet

## Lighting



Winter Sun



Summer Sun



Solar Radiation



Daylighting

## Climate Control



Fan



Natural Ventilation



Air Circulation



Cold Air Circulation



Hot Air Circulation



Buffer Zone



Mechanical System



Cooling Mechanical System



Heating Mechanical System



**SHAHIN VASSIGH** is an associate professor in the Department of Architecture at Florida International University and teaches courses in structures and building technologies. Vassigh has built a nationally recognized body of research work focused on improving building technology and sustainable building design education by developing alternative teaching pedagogies. She is a recipient of two major federal grants for "A Comprehensive Approach to Teaching Structures" and "Building Literacy: The Integration of Building Technology and Design in Architectural Education." Both projects developed interactive learning environments using state of the art computing technology. She is the author of *Interactive Structures: Visualizing Structural Behavior* (2005). She received a Master of Architecture, a Master in Urban Planning and a Bachelor of Science in Civil Engineering from University at Buffalo, the State University of New York.

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Acknowledgements & Credits

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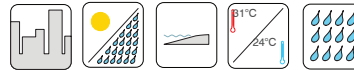
Introduction

1

## 1 Structure + Envelope

### 1.1 Singapore National Library

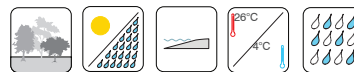
T.R. Hamzah & Ken Yeang  
Singapore  
2005



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### 1.2 William J. Clinton Presidential Center

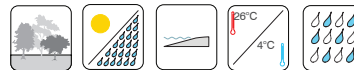
Polshak Partners  
Little Rock, Arkansas, United States  
2004



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### 1.3 Heifer International Headquarters

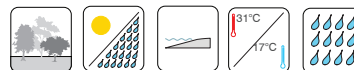
Polk Stanley Rowland Curzon Porter Architects  
Little Rock, Arkansas, United States  
2006



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### 1.4 Paul L. Cejas School of Architecture

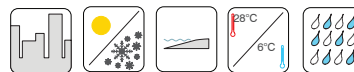
Bernard Tschumi  
Miami, Florida, United States  
2003



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### 1.5 Agbar Tower

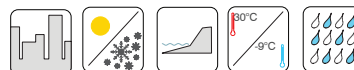
Jean Nouvel  
Barcelona, Spain  
2005



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### 1.6 Rehab Basel

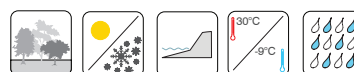
Herzog & deMeuron  
Basel, Switzerland  
2001



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### 1.7 Thermal Baths

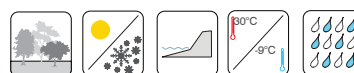
Peter Zumthor  
Vals, Switzerland  
1996



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### 1.8 Arup Campus

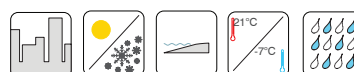
Arup Associates  
Solihull, England  
2001



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### 1.9 Manchester Civil Justice Centre

Denton Corker Marshall  
Greater Manchester, England  
2007



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



















































## 2 Envelope + Mechanical

### 2.1 Caltrans District 7 Headquarters Building

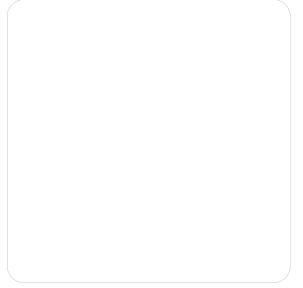
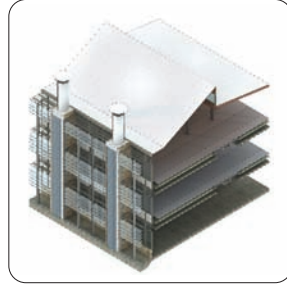
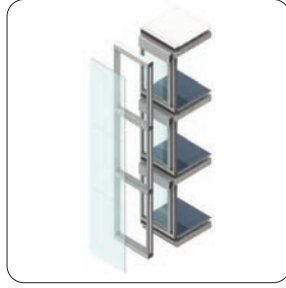
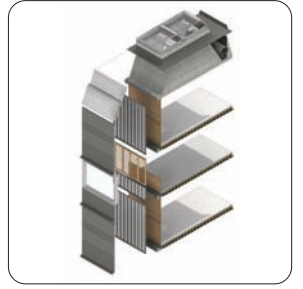
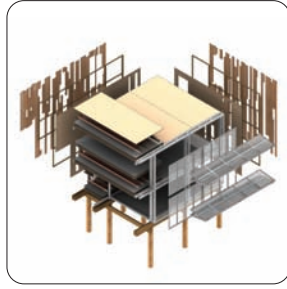
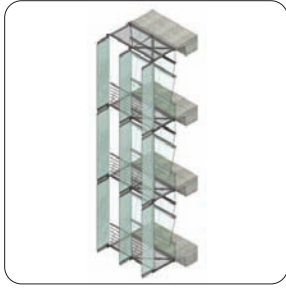
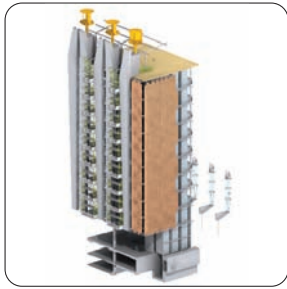
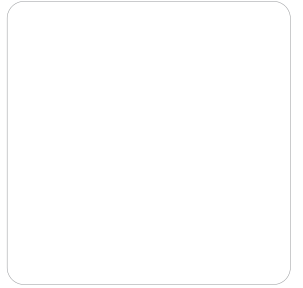
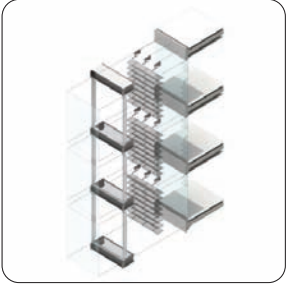
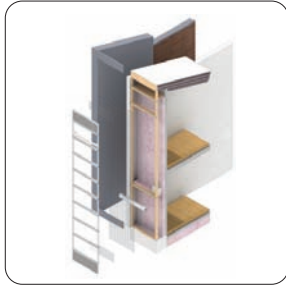
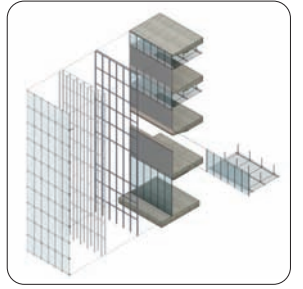
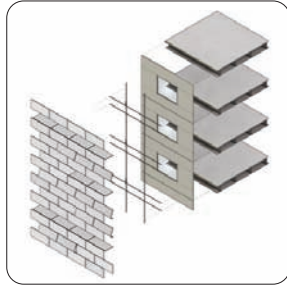
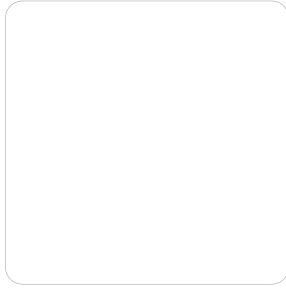
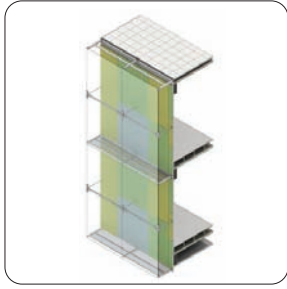
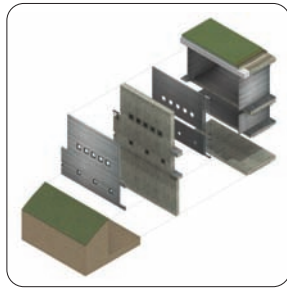
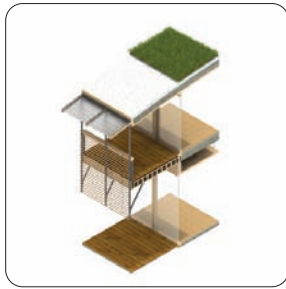
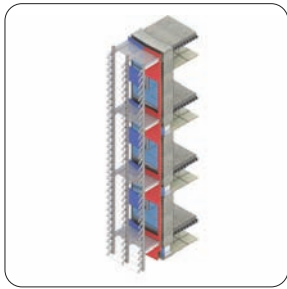
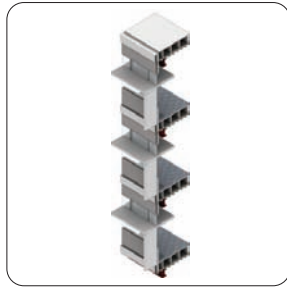
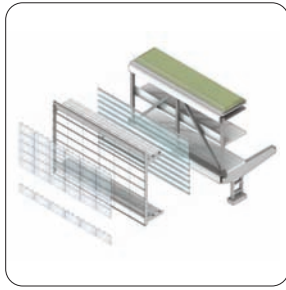
Tom Mayne, Morphosis  
Los Angeles, California, United States  
2004



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**PREAMBLE: CLIMATE CHANGE AND THE BUILT ENVIRONMENT** Among all human activities contributing to climate change, the built environment, particularly the construction and operation of buildings, impacts the environment most. This impact is significant, central, and affects the environment in multiple dimensions. Since buildings are the largest consumers of energy, they are the principal contributors to the greenhouse gas emissions that cause climate change.<sup>1</sup> The building sector consumes over 49 percent of all energy produced in the United States. Of all the electricity produced in the United States, 77 percent is used just to operate buildings. Globally, these percentages are even greater.<sup>2</sup> Building and construction activities consume three billion tons of raw materials each year.<sup>3</sup> Materials utilized in buildings tend to have a high-embodied energy, high levels of toxins and pollutants at the end of production, as well as higher levels of emissions.<sup>4</sup>

Given the size of its contribution to the problem, the building sector has considerable capacity to reduce greenhouse gases and diminish global warming. This problem presents architects, as the primary designers of the built environment, an immense opportunity and a central role in solving the challenges of climate change and environmental sustainability.

**INTEGRATED PRACTICE AS A KEY TO SUSTAINABLE BUILDING DESIGN** Historically, architecture has evolved from an integrative practice that synthesized art and technology. This was often achieved by inventing solutions to solve engineering problems while enhancing human experience through architectural expression. Through the Renaissance, great architects were master builders, artists, sculptors, and engineers who practiced architecture holistically.

However, since the industrial revolution, the rapid growth of technical and scientific knowledge applied to building design and construction created the growing need for specialized professions to master, utilize, and advance applied science and engineering. The industrial application of technology drastically transformed society, introducing fundamental changes in our approach to architecture and the design of the built environment, thus creating a significant rift between artistic and scientific disciplines.

These resulting professional boundaries have defined architecture increasingly as a “design profession” and engineering as “applied sciences.” This has split building design and construction into fragmented disciplines handled by architects, structural, mechanical and electrical engineers, computer scientists, and construction managers. Each of these fields has been institutionalized with widely divergent educational practices, cultural mindsets, and professional approaches to building design and construction.

The architectural practices of much of the latter half of the twentieth century are, therefore, radically different from the past and have revealed the limitation of specialized fragmented disciplines. This book aims to document a recent trend in architectural practice that integrates design and engineering disciplines to create responsible and sustainable buildings. The benefits of integrated practice have created substantial shifts in the professional role of the architect, the education of architects, the innovations of building design, and the accountability of design decisions.

Integrated practice reaffirms the role of architects as multitaskers by providing an overview of the relationship of design, engineering, and construction. In many cases, large-scale practices are led by architects who work with a wide range of in-house professionals from many disciplines that include engineers, construction managers, landscape architects, and interior designers. This holistic approach eliminates substantial inefficiencies from the design and construction process. The synergy between building systems limits the possibility of unintended redundancies and misinterpretation of intentions of the engaged parties.

In architectural education, formally based curriculums have begun to weave technologies into their pedagogy. The new criteria of accreditation, building information modeling (BIM), and the best practices of the profession are mandating the integration of technology into the pedagogy. In the past, building technology curriculums including structural, mechanical, electrical, and other building systems were considered support to design courses and were rarely integrated into the broader architectural curriculum. Today, accredited architectural programs are required to have a “comprehensive design” studio that integrates sustainability, structural, life safety, and

environmental systems in one design project.<sup>5</sup> This new emphasis in architectural education means students are applying technology principles in building design and are learning the pivotal importance of integration as a means to drive innovation and creativity. This educational model contributes to producing architects that understand how the integration of design and technology can lead to the building of an efficient and sustainable built environment.

As architects integrate their design practices, they will again be a part of the innovations of buildings systems, materials, and construction process. In an integrated practice, all disciplines including architects, engineers, and contractors – will be part of earliest phases of a project. In integrated practice, initial design decisions are informed by the ramifications of building energy performance. Initial decisions have the greatest impact on the construction, building performance, and systems efficiencies of buildings. This will not only prevent costly reconsiderations of design decisions, it will also allow for synergistic collaborations that rethink old techniques.

Integrated practice and sustainable design ultimately expands the formal ambitions of architectural design by providing accountability to the environment. The metrics of sustainable design allow architects and other building professionals to measure the outcome of their decisions. Within integrated practice, these quantifiable criteria create a lens through which practitioners can remediate a design decision. In the end, architecture is the reconciliation of an expansive set of influences, not all of which are motivated by purely sustainable aims. These conflicts require analysis from all parties invested in the project development and lead to innovations that satisfy many ambitions.

**THE BOOK APPROACH** This book is a compendium of works of architecture that demonstrate the best practices and principles of designing and constructing buildings that are both environmentally responsible and architecturally expressive. The buildings selected for inclusion in this book exhibit a high level of sustainability and environmental performance and at the same time are complex architectural proposals that go far beyond simplistic instrumentalized notions of design.

The objective of this book is to demonstrate, clearly and unambiguously, three fundamental principles:

First, high performing, highly sustainable buildings can be architecturally significant – achieving high performance and efficiency does not have to sacrifice design and architectural expression. To the contrary, high-performing buildings can embody the unquantifiable concern for beauty and the traditions of the metier of architecture.

Second, improving building performance, efficiency, and environmental sustainability are not always the product of radical, exotic, or even new design ambitions but can be achieved with established architectural design languages that engage with climate, site, orientation, custom, use, and history.

Third, there is an irrefutable and undeniable connection between sustainability, quality design, and the use of integrated practice. Most high-performance and sustainable buildings are the outcome of close collaboration between architects, engineers, construction managers, and building owners who work together to make decisions from the start to the end of the development, design, and construction process.<sup>6</sup> This collaborative process insures better understanding and coordination of building systems operation and their interaction and their synergetic benefits, improving building efficiency and minimizing negative environmental impact.

This book examines the work of a growing stream of architectural practice that produces exemplary models of integrated design that engage climate and context. All the examined buildings are introduced within their context indicating location, climate, and use. The book utilizes two distinct drawing types describing each building: the wall section and the axonometric. The wall section is a partial cut through the perimeter of a building. While it is an isolated moment in the building, it is one of great consequence and has become the site of much attention and innovation in building construction. It describes in a simple and direct fashion a building's enclosure – the locale of the interaction of the interior and exterior. As a drawing, it records the interactions, adjacencies, and connections of a building's enclosure, mechanical, and structural systems. While the wall section serves to present the information about a building's enclosure in a focused way, it does so without providing a complete picture of the system's interactions.

As a complement, axonometric drawings serve to illustrate the spatial configuration of the wall section. There are two types of axonometrics in this book: those that show the complete assembly of a wall section and those that show the assembly exploded. The ambition of these drawings is to represent details within the context of a complete building assembly. The use of both axonometric types allows for the study of interactions of building components and the study of components in isolation.

These drawings attempt to expose the complex layers of the building components, revealing the interworking and the beauty of building systems integration typically hidden in glossy photographs. While the outward expression of a building may remain a sought-after effect, it can now be engaged with energy efficient performance. These drawings examine a myriad of construction issues: the selection and use of materials, the integration of structural and mechanical systems, the use of enclosure and cladding systems, the use of glazing systems and sun control, the detailing of waterproofing, and the weathering of materials. These drawings highlight and celebrate innovations in the development of integrated building.

**ORGANIZATION OF THE BOOK** The book organizes the selected buildings into three sections based on integration of paired building systems including structure, envelope, and mechanical systems. The content aims to demonstrate the performance of each systems pair in terms of interaction and contribution of each individual system and the synergetic benefits resulting from the unique pairing. The last section of the book is devoted to buildings that have a higher degree of integration and cannot be studied as paired systems.

The first section is entitled “Structure + Envelope.” Structure and envelope systems are the principal elements in materializing architectural form; therefore, their integration has a significant impact on the environmental performance of buildings. Each of the selected buildings in this section demonstrates how complementary pairing of these systems has contributed to the admission of natural light, improved energy performance, and reduced embodied energy.

The second section, “Envelope + Mechanical,” demonstrates how

the integration of envelope and mechanical systems can become an efficient vehicle to mediate between the exterior environment and the demands of the interior space. The selected buildings for this section show how the appropriate pairing of these systems contributes to thermal comfort, natural ventilation, natural lighting, and affords the architect highly expressive and energy efficient façades.

The final section of this book, “Structure + Envelope + Mechanical,” includes buildings that represent a significant degree of integration in structure, envelope, and mechanical systems. These buildings demonstrate how comprehensive integration can inform building orientation, configuration, fenestration, mechanical systems, and natural lighting. These buildings are models of interdisciplinary collaboration that solve significant design problems, achieve energy efficiency, reduce impact on the environment, and are beautifully crafted buildings.

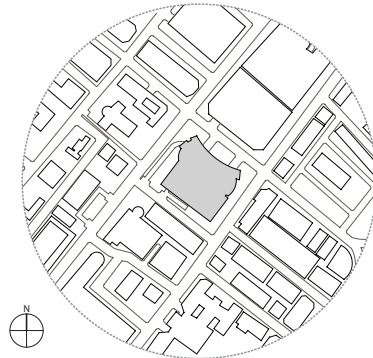
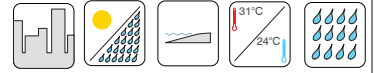
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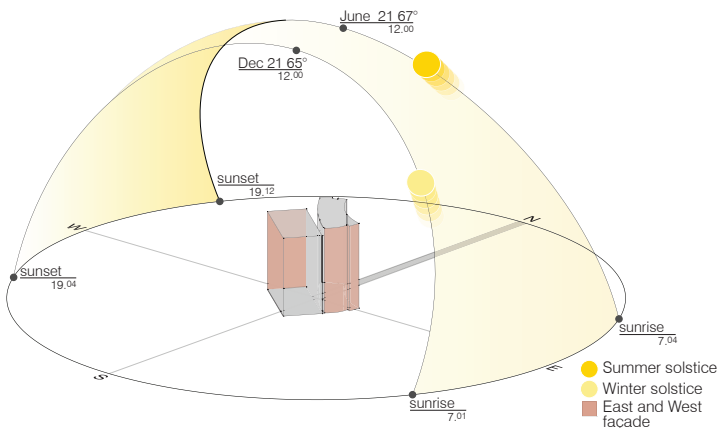
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ARCHITECT T.R. Hamzah & Ken Yeang  
 LOCATION Singapore  
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## LOCATION CONDITIONS



**BACKGROUND** Located in the downtown district of Singapore, the new National Library building is an urban civic icon exemplifying innovative sustainable architecture for the tropics. The building complex consists of a sixteen-storey rectangular block and a fifteen-storey curved structure separated at ground level by a semi-enclosed pedestrian street. The two buildings are linked by a series of bridges at the upper levels. The rectangular block houses the library collections, storage, and study areas, while the curved block accommodates exhibitions, lecture rooms, conference rooms, and a space for other cultural events. The internal street or atrium serves as a communal space for outdoor events and is surrounded by cafés and other retail spaces.



**PERFORMANCE** The Singapore National Library building employs a number of strategies to reduce energy consumption and the building's impact on the environment. The design responds to climatic conditions through its configuration and orientation, the use of sun shading devices, natural ventilation, green terraces, and façade treatment. During the design process, several thermal, daylighting, and wind simulations were conducted to forecast, evaluate, and modify the building's performance. The simulation results have led to reducing electric energy consumption of the building to 31 percent below the country's national average.<sup>1</sup>

The design also integrates landscape elements to further decrease the energy demand. Landscaped areas and gardens located throughout the building reduce the roof temperature and minimize heat transfer into the interior spaces. Thoughtful selection of sustainable local timber, recycled and reused materials, and materials with lower embodied energy for wall fabrics and wooden fixtures all contribute to reducing the building's adverse impact on the environment. The building has received a number of sustainability awards including the ASEAN Energy Efficiency award and Singapore, Silver Award in the Universal Design Award in 2007.

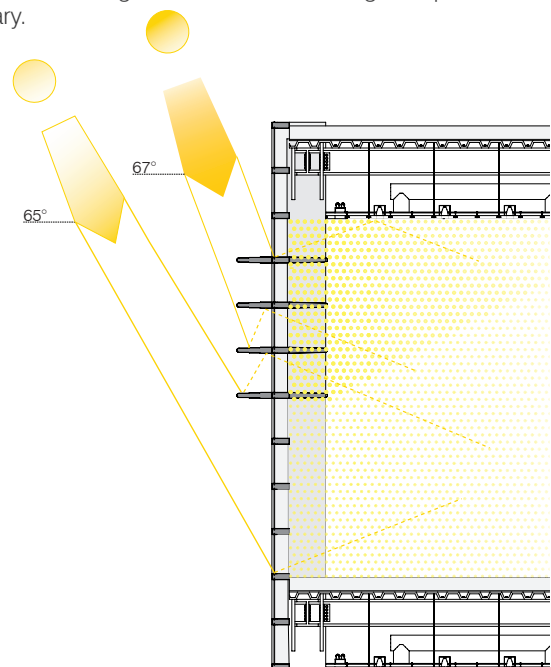
**PLANTED TERRACES** The Singapore National Library building incorporates extensive landscaping within the building to improve the working environment. It has a series of garden terraces and sky courts that insulate the building's interior and lower the ambient temperature for energy efficiency. They consist of fourteen gardens spread between the two blocks dedicated to outdoor activities and green space. These civic plazas are also located in the basement to allow light and natural ventilation underground.

**NORTH** In the north façade, the entry of diffused sunlight is controlled throughout the day by giant metal blades that reflect light off their surface onto the interior space.

**EAST** In summer, large amounts of solar radiation enter the east façade at a shallow angle. This façade is protected from the morning sun by projecting metal blades.

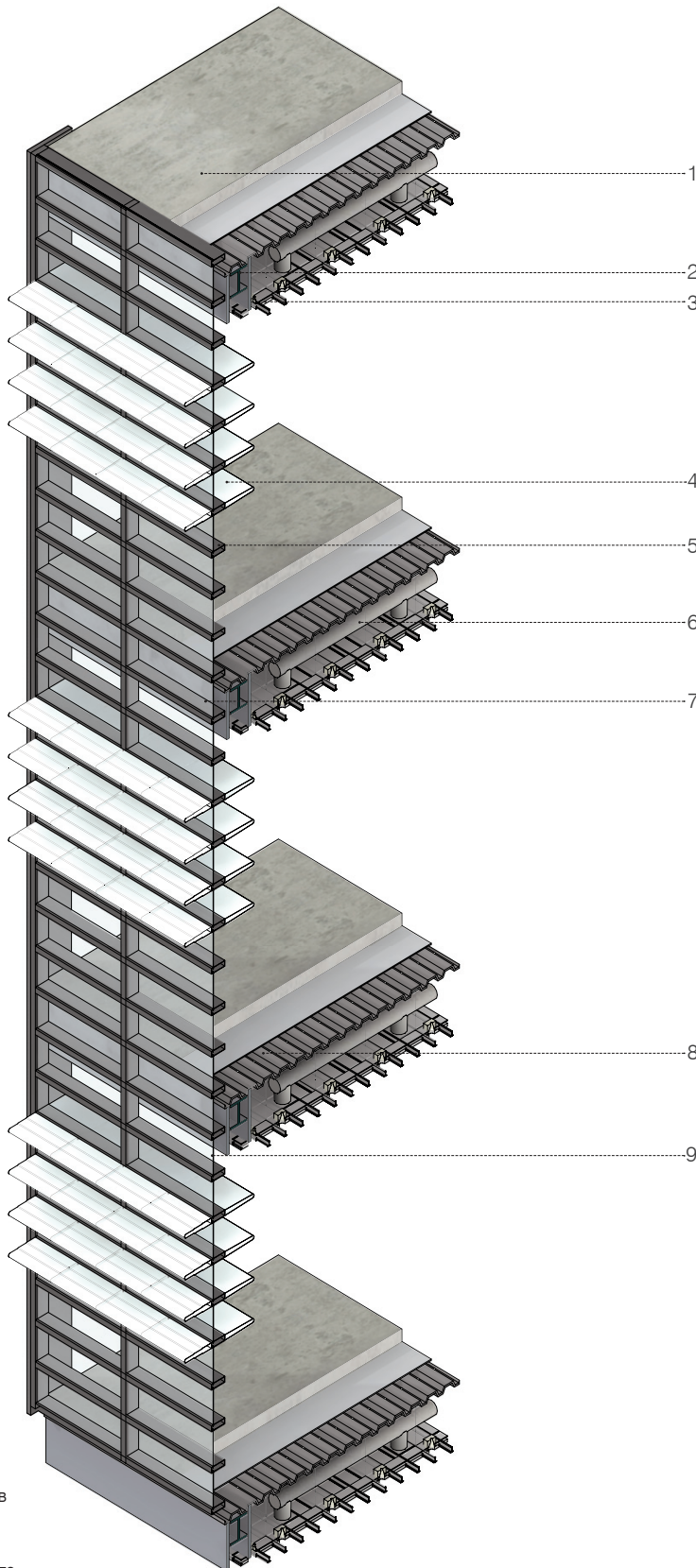
**SOUTH** The south façade receives light at a steep angle during the summer. Shading is provided by giant metal blades that block direct sunrays.

**WEST** In summer, the west façade receives large amounts of solar radiation at a shallow angle during 75 percent of the period of use. Solar screening is provided by the metal blades, which also serve as light shelves that allow light to penetrate into the library.



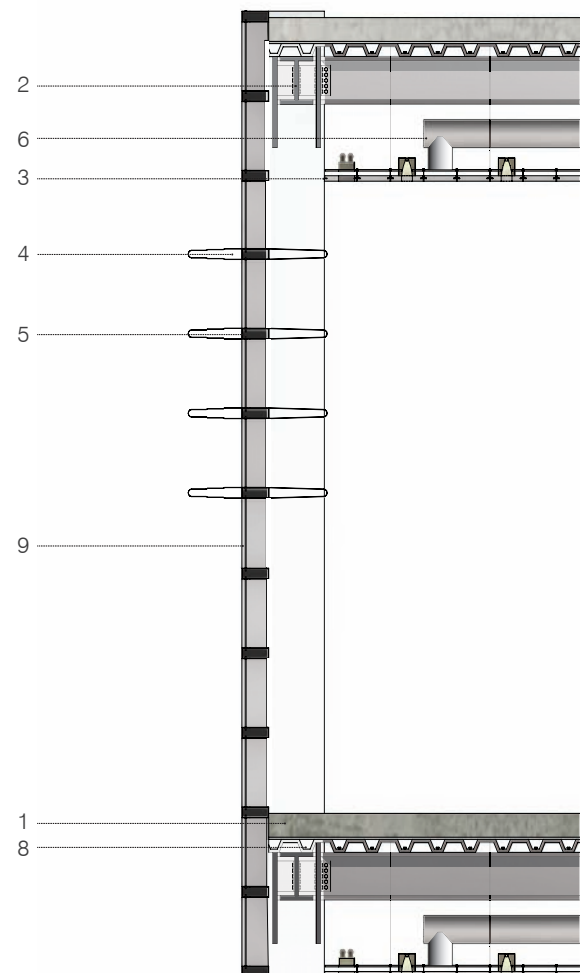
DAYLIGHTING AND SCREENING





## EAST AND WEST FAÇADES

- 1 CONCRETE FLOOR SLAB
- 2 STEEL STRUCTURE
- 3 ACOUSTICAL CEILING
- 4 METAL SHADING DEVICES
- 5 ALUMINUM FRAME
- 6 AIR DUCT
- 7 SPANDREL PANEL
- 8 COMPOSITE METAL DECKING
- 9 LOW-E GLASS CURTAIN WALL

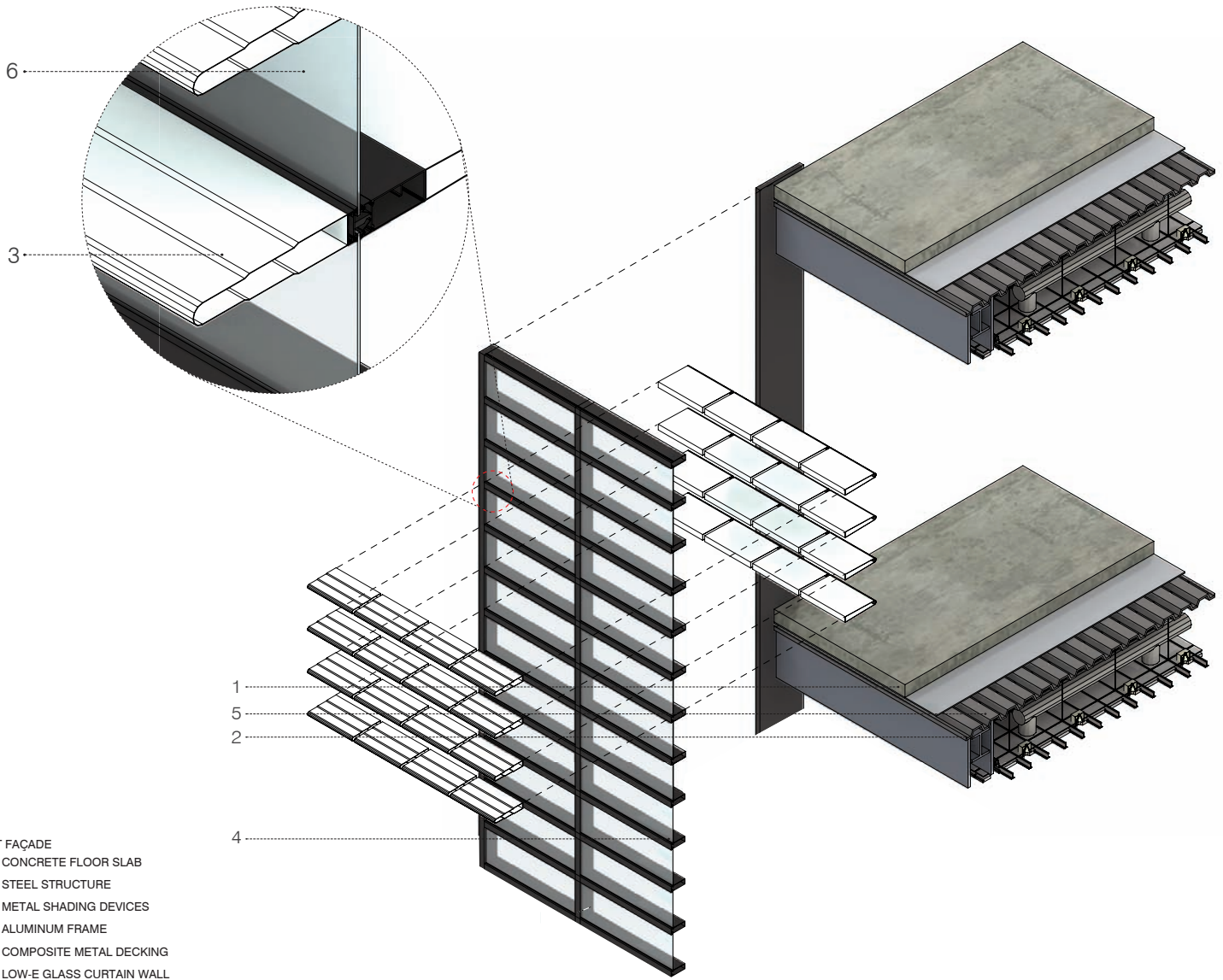
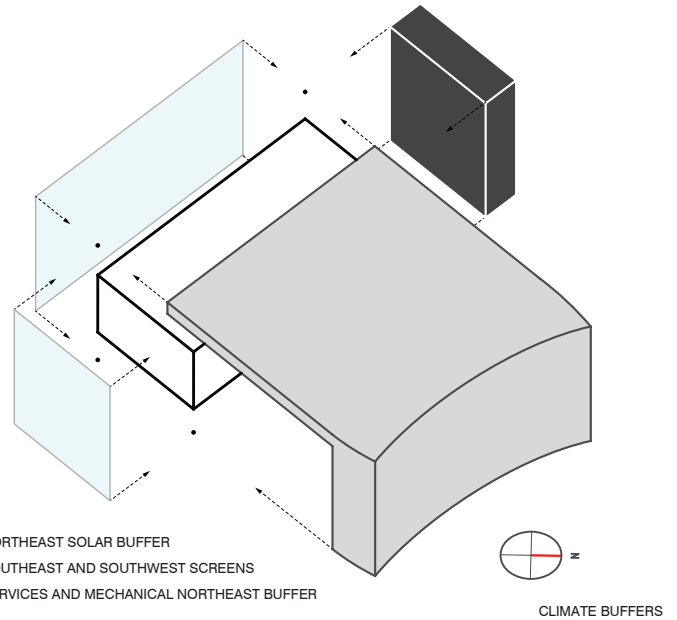




#### BUILDING FAÇADES

In addition to proper building orientation, selecting an environmentally responsive enclosure system is crucial in mitigating the impact of a tropical climate. Both the rectangular block and the curved structure of the Singapore National Library are aligned to face north, the ideal orientation to minimize solar heat gain. The north and south façades of the atrium utilize large metal blades to block direct sunrays while reflecting diffused light off their surface onto the interior space. These shading devices project out from the face of the building about 6 feet (1.8 meters) and are supported by crossing steel cables. On the east façade, the building utilizes a low-E glass curtain wall with a series of protruding shading blades that wrap around the building. The blades protect the east façade from direct solar exposure while allowing ample daylight and views from the interior. The west façade also incorporates the metal blades for shading. These blades extend to the interior of the building to serve as light shelves allowing light to filter into the library area.

The west side of the building accommodates the support and service areas. This area serves as a climate buffer for the reading rooms and book stacks reducing the impact of the late afternoon sun. The building envelope prevents solar heat gain, humidity, and glare to provide a comfortable environment while allowing the use of natural light to minimize the library's dependence on artificial light.



#### WEST FAÇADE

- 1 CONCRETE FLOOR SLAB
- 2 STEEL STRUCTURE
- 3 METAL SHADING DEVICES
- 4 ALUMINUM FRAME
- 5 COMPOSITE METAL DECKING
- 6 LOW-E GLASS CURTAIN WALL

**VENTILATION STRATEGY** The Singapore National Library building utilizes a zoned climate control system to control interior temperature. This system customizes the interior environment in different areas within the building according to their use. The library collections, study areas, and theater operate under the “full mode.” They are fully air-conditioned and lit with artificial lighting. Transitional spaces run under the “mixed mode.” They use a combination of natural ventilation and mechanical systems to achieve a comfortable temperature. The semi-enclosed atrium operates under the “passive mode” throughout the year.<sup>2</sup> It is naturally ventilated and mostly daylight. The atrium is oriented to capture the prevailing breezes and allows fresh air to circulate and cool the space. Glass louvers in the atrium’s roof open and close to create a stack effect to pull hot air up and out of the space.

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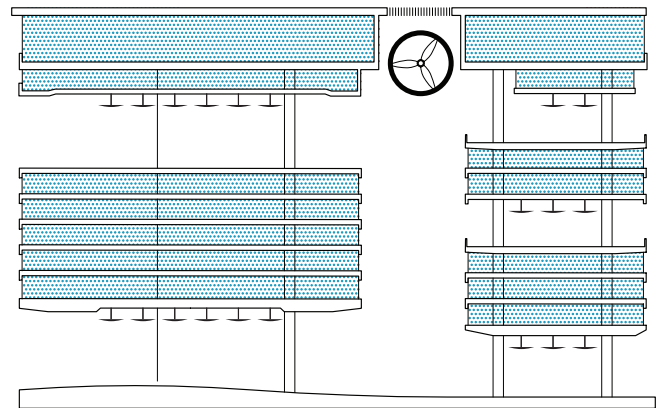
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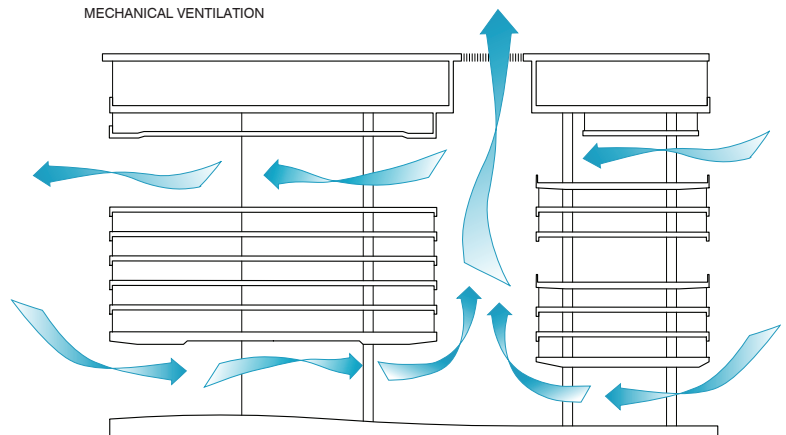
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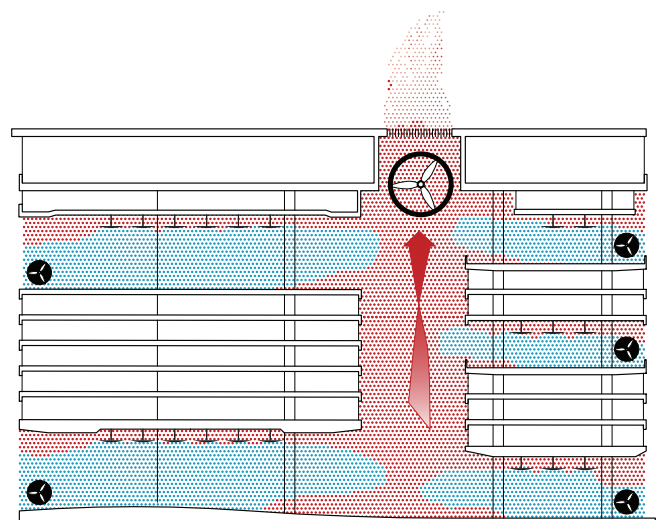
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MECHANICAL VENTILATION



ATRIUM STACK EFFECT The semi-enclosed atrium and the transitional spaces are carefully oriented to capture the prevailing winds and allow natural ventilation within the space.



MIXED MODE VENTILATION