Title:	**A Tall Building Ethos of Integration**
Author:	Brian Lee, FAIA, Partner, Skidmore, Owings & Merrill LLP
Subjects:	Architectural/Design Civil Engineering Façade Design Urban Design Wind Engineering
Keywords:	Performance Based Design Technology Urban Design
Publication Date:	2018
Original Publication:	International Journal of High-Rise Buildings Volume 7 Number 1
Paper Type:	1. Book chapter/Part chapter 2. **Journal paper** 3. Conference proceeding 4. Unpublished conference paper 5. Magazine article 6. Unpublished

International Journal of High-Rise Buildings
March 2018, Vol 7, No 1, 47-64
https://doi.org/10.21022/IJHRB.2018.7.1.47

International Journal of
High-Rise Buildings
www.ctbuh-korea.org/ijhrb/index.php

A Tall Building Ethos of Integration

Brian Lee†

FAIA, Partner, Skidmore, Owings & Merrill LLP, 224 South Michigan Avenue, Chicago, IL 60604, USA

Abstract

The last decade has seen great design opportunities for tall building construction around the globe. The best designs represent a new generation of skyscrapers that go beyond willful preconceptions of building form and iconography, trying instead to simultaneously address interrelated issues of program space utility, structural efficiency, and environmentally sustainable systems. The resulting identities of these towers are unique because of their search for the intersection of spaces tuned to people's needs, expressive optimized structures, and high performance, site-responsive systems. This paper, through examples of recent SOM towers, both built and unbuilt, will discuss how a design becomes content-driven, how ideas create value, and how the typology of the tall building is advanced through the integration of architecture design and engineering systems.

Keywords: High performance design, Structural design, Collaborative design, Interdisciplinary design, Technology, Digital design, Tall buildings, Legacy buildings, Urban design

1. Introduction

Skidmore, Owings & Merrill LLP (SOM) has a storied legacy of designing and helping build some of the most influential buildings in the world. Throughout its 82-year history, SOM's portfolio of towers, which features early, innovative modernist gems such as Lever House in New York, Inland Steel in Chicago, and former Crown Zellerbach (One Bush) in San Francisco, has grown to include some of the most significant and tall buildings in North America. Many of those buildings have not only responded to the decades long growth of urban America, but they represented the highest level of building technology at the time and became symbolic landmarks in our cities - John Hancock Center and Sears (Willis) Tower in Chicago, Bank of America in San Francisco, and most recently One World Trade Center in New York.

Globally, SOM has been able to author many significant tall buildings that have responded to the world's rapid urbanization over the last 20 years. The Middle East and Asia have embraced tall towers to concentrate density and express a new modernity for those settings. We have found the most successful buildings, in addition to embodying functional and technical advancements, also attempt to consider culture, context, and sense of place. The National Commercial Bank in Jeddah, Jin Mao Tower in Shanghai, and the Burj Khalifa in Dubai are potent examples of bold architectural and engineering concepts that are technically highly sophisticated, seem rooted in their locale, and have captured the imagination of their cities.

Reflecting on the history of SOM tall buildings, the firm has collectively tried to understand what makes some designs more successful than others. We have questioned how well buildings fit into or enhance their context. We have looked at the engineering performance and architectural aspirations of decades of built works. We have studied the evolving typologies of office, residential, and hospitality both domestically and abroad. Finally, we have compared the narratives of the best SOM tall buildings to see how they have stood the test of time. Not surprisingly, because of the complex nature of the tall building, we have found that singular formal conceptions are not enough to distinguish a design without a depth of interrelated content from multiple disciplines brought together into a cohesive whole.

2. Close Collaboration Facilitates Integration

At SOM, while the Design Partner bears responsibility for the design direction of the building, a multi-disciplinary team is assembled early to learn about the problem, understand the site and program, and contribute to a process that continuously searches for appropriate and consequential ideas. This collaborative team is led by architectural design, with in-house urban design, structural engineering, sustainable building systems, and interiors disciplines contributing expertise and experience to inform the concepts and inspire alternative solutions. We have found that multi-disciplinary teams working in intentional proximity accelerates interaction, avoiding sole reliance on scheduled meetings and workshops. Not only is there more time to gestate ideas together, but there is also more opp-

†Corresponding author: Brian Lee
Tel: +1-312-360-4843; Fax: +1-415-812-3294
E-mail: brian.lee@som.com

ortunity to champion concepts and question approaches informally through daily discussions. Famously, Bill Baker, a Structural Engineering Partner, asked a talented senior designer to count the steps from his desk to Bill's office so everyone knew how simple it was to collaborate.

Today, many tools facilitate the integration of architecture and engineering concerns. Digital platforms are sharable, architectural designers have access to simplified graphic engineering programs, and engineers can run optimization software to show both preliminary results and continued computational refinement to the designers. In Chicago, we have learned the importance of early wind

Figure 1. Guangzhou Chamber of Commerce Headquarters.

engineering in our tall building work and subsequently built an in-house wind tunnel to conduct testing of conceptual tower forms and building orientations. This simplified, but effective, use of physical modeling and preliminary sensor data comparison has allowed architecture and engineering designers to move quickly, finding ways to mitigate wind forces by shaping and adjusting form.

From this interdisciplinary work, we have found certain traits consistently manifest themselves in the best tall building design. These commonalities and differentiators (as discussed in *Considering Place in an Integrated Approach to Tall Building Design*, Lee and Baker, 2012 CTBUH) often touch on the themes of site constraints and responses, program driven form, structural efficiency and appropriateness, considerations of climate and comfort, and finding deeper value in the design.

We have asked ourselves whether an ethos of site, program, performance, and meaning might guide our work. We work in an iterative process that simultaneously considers the building's effect in the setting as well as how it works from within its interior spaces. We propose building forms that have natural structural efficiencies learned from past performance in design optimization software, wind tunnel tests and construction. We search for new ways to improve the human experience within the buildings, going beyond building regulations and performance standards, to address health and wellness for the inhabitants. Finally, we believe buildings have the power to affect our quality of life and inspire generations.

The following projects are a small sampling of recent towers that have multi-faceted attributes developed carefully using our interdisciplinary and collaborative team strategy.

3. The Urban Tower and Public Square

The Guangzhou Chamber of Commerce Headquarters tower sits on a small urban block in the new Pazhou dis-

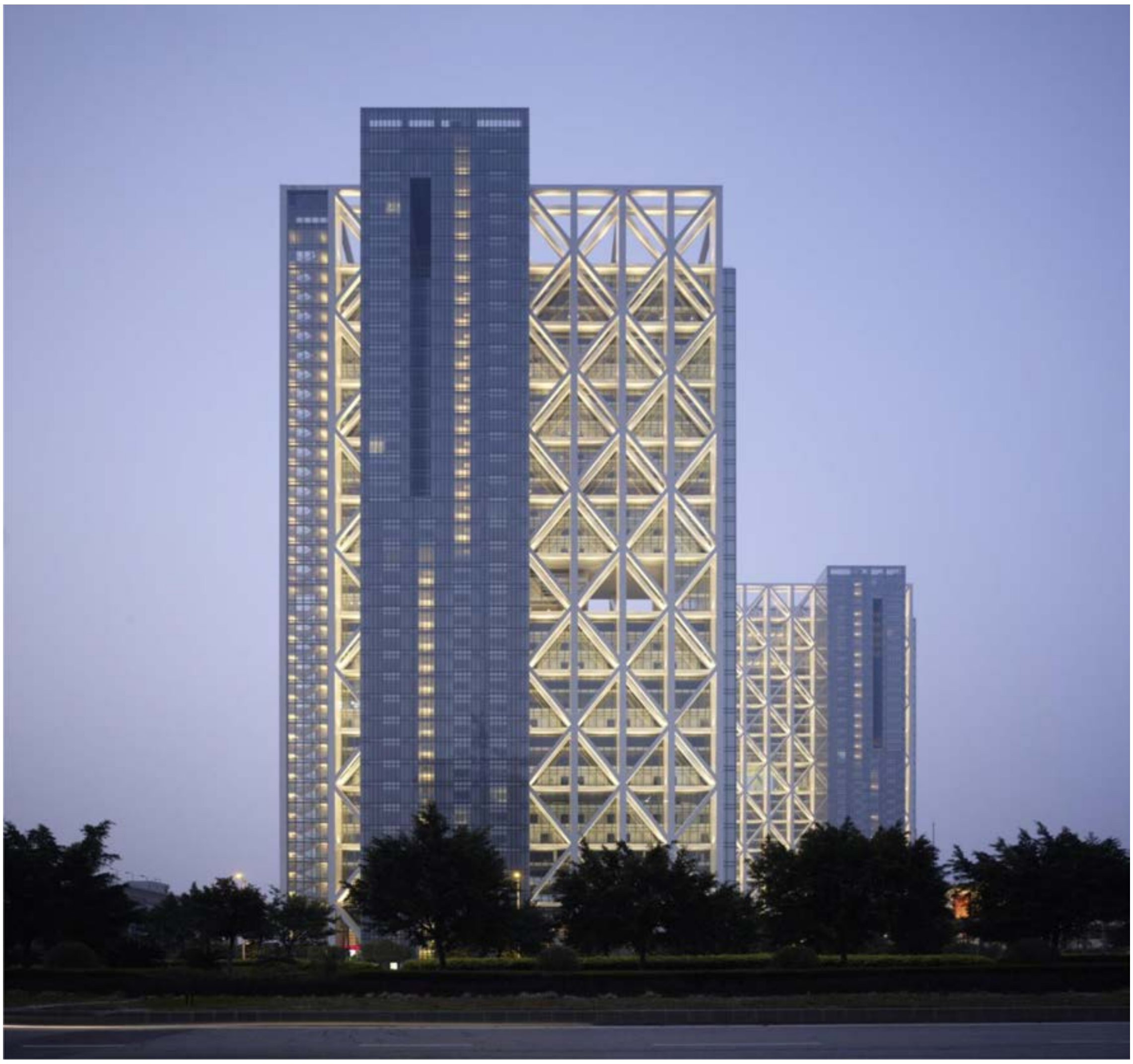

Figure 2. Poly Real Estate Headquarters Guangzhou.

trict of Guangzhou. Because of the dense master plan and proximity to the adjacent block development, the tower was developed as an offset core structure with large efficient office floors biased to the best views (Fig. 1).

Because of a concern with eccentricity in what would be one of the tallest offset core buildings in the world, the core was not proposed as a primary structural element. Instead, mega-columns were developed at the corners of the office block with diagonal bracing linking each corner and a braced frame across the inside of the core. With this robust system, the tower could apply ideas developed at the earlier SOM-designed Poly Real Estate Headquarters

Figure 3. San Francisco Transbay Tower Competition.

Figure 4. Guangzhou Chamber of Commerce Headquarters public plaza beneath tower.

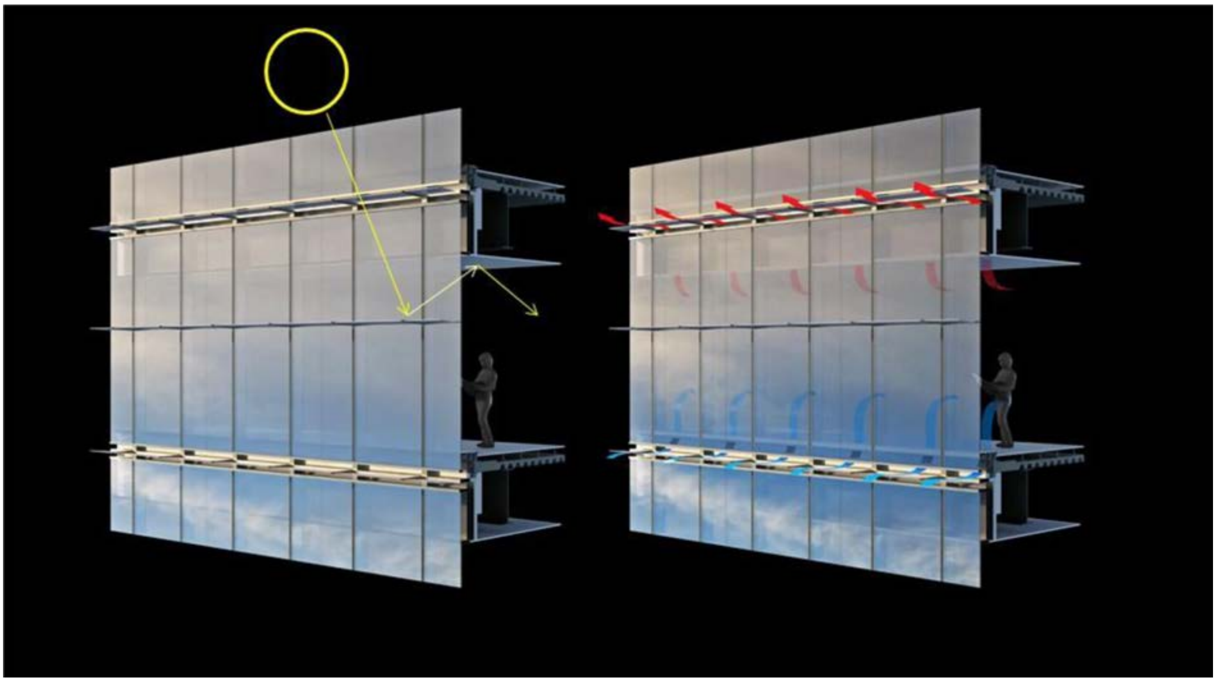

Figure 5. Guangzhou Chamber of Commerce Headquarters exterior wall with light shelves and ventilation slots.

in Guangzhou, with all-glass cores that allowed light into the elevators, elevator lobbies, toilets, and stairwells (Fig. 2). Additionally, our work on the unbuilt San Francisco Transbay Tower competition (Fig. 3) explored a structural system that would open the ground plane for public space. While that project utilized a Michell truss concept and split core, the new Guangzhou project, with its offset core, could clear most of the ground level for a large public plaza space and forecourt to the lobby beneath the office tower. Typical office floor interior columns are sloped within the 22 m high plaza space forming a dramatic expression of the structural transfer of forces (Fig. 4).

The offset core allowed small atria, centered in the floors, to connect the unique ownership of seventeen three-floor modules. To address the loft-like and efficient, but deep floor plate, light shelves are configured to bounce day lighting far into the office lease span. Operable vents incorporated into the exterior wall at the sill and head locations provide natural ventilation on demand and a measure of resiliency to the interior spaces. Both the light shelves and curtainwall ventilation were extensively digitally modeled to optimize effectiveness (Fig. 5).

The Guangzhou Chamber of Commerce Headquarters tower provides very desirable open office configuration

Figure 6. Kula Belgrade.

with ambitious technical and performance features for a new model of the tall tower workplace that considers the health of its occupants. Responding with a structural design that considers site and program, this 280 meter tall building creates a distinctive new urban space with great identity and value in the city.

4. Program and Wind Shape the Tower

Kula Belgrade is a mixed-use residential and hotel tower on the redeveloped Sava River riverfront, part of a larger master plan for the city of Belgrade (Fig. 6). Our recent experience with mixed-use towers such as the Tianjin CTF

Figure 7. Tianjin CTF Finance Center.

Finance Centre taught us that idealized floor plans for multiple program uses need not be compromised into a single shape. Additionally, we found that tapering and surfacing the tower dramatically reduced wind forces and loads to the structure (Fig. 7). For the Kula project, the efficient, upper residential rectangular floors are rotated ninety degrees over the efficient, lower hotel rectangular floors, effectively twisting the slab tower in half. This tower form has less surface area at the upper tower when the base portion has less footprint to resist wind forces. Conversely, where the broad face of the upper tower is exposed to greater wind loads, the lower tower is turned so its full

Figure 8. Poly International Plaza Beijing.

length can resist those forces. A well-coordinated central core occupies the common vertical space in plan.

We believe there are further explorations in configured buildings that can respond specifically to program requirements and natural external forces. In the end, a planning reduction in height meant the benefits from reducing wind forces on the rotated Kula Belgrade were offset by the structural complications from the column paths and framing at the transition floors. However, with its changing orientation, the building provides both long-range countryside views for the upper residential portion and river and plaza views at the lower hotel portion. Additionally, the tower's rounded corners and tapering form disrupts wind forces on the building and eases wind patterns at the ground level pedestrian spaces. With a strong civic presence, the novel but purposeful tower form provides a unique symbol for new development in Belgrade.

5. Structure as Expressed Form - the Braced Tower

Our practice has celebrated expressed structural concepts in many of our tall buildings. The previously mentioned Poly Real Estate Headquarters and recently completed Poly International Plaza in Beijing have made the articulation of the structure as their defining identity (Fig. 8). Often, the purest representation of the tower is its structure without cladding. A new generation of SOM towers explore the direct relationship between form and structure and how they create new innovative environments for living and working.

For a proposed tower in Mumbai, the project utilizes a concrete exoskeleton around an oval, loose fit plan. The residential tower was intended to create a flexible framework for one, two, or three homes per floor. Per Hindu Vastu Shastra principles and Indian customs, the residential configurations within the expressed open frame permit natural ventilation to the individual homes, shared lobby, and circulation areas; generous outdoor balconies; and unique multi-story units. The exoskeleton is composed of gravity and lateral load-bearing diagonals that do not intersect to provide a measure of ductility and reduce non-axial stresses, facilitate construction, and improve views from within the units (Fig. 9).

The concept of an exoskeleton is not unusual. However, independent plans within the long span ductile diagrid allows new freedom in residential design to respond to how a multi-family housing unit to be more like a single-family home. Here, the structural concept allowed the architectural interior and landscape design to promote new ideas about tall building living. Daylight permeates all rooms, gardens are available to all, and the individual unit has an identity while remaining part of a high-rise community.

The Nanning Tower follows many of the advances in current mega-column structured towers. However, a transfer arch at each of the four sky-lobby and amenity zones, elegantly and efficiently guides forces to the corner mega-columns and creates dramatic clear-span openings at the tower face of those public levels. At those floors, the enclosed spaces are also set back from the face to permit wind forces to flow through the arched openings, reduc-

Figure 9. Residential Tower Mumbai.

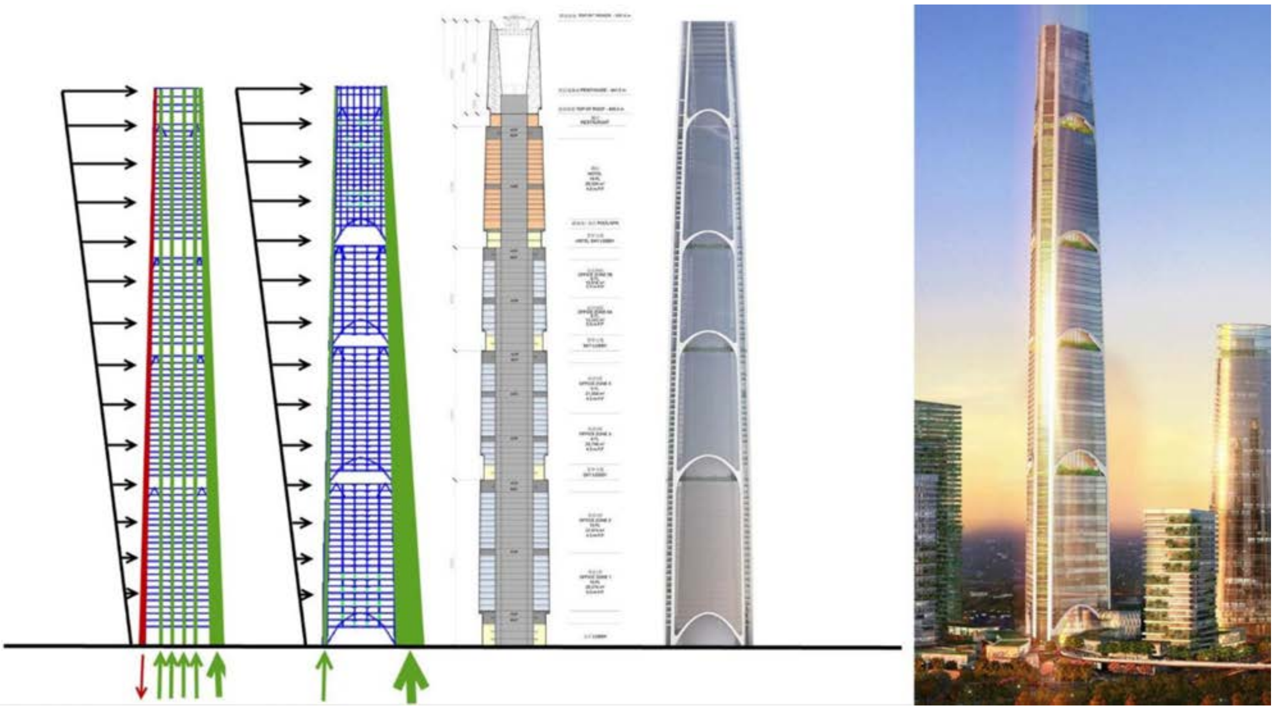

Figure 10. Nanning Tower structural diagrams, section, and elevation.

Figure 11. Chicago "Leaf Brace" Residential Tower.

ing façade loads and tower vortex shedding. Expressed on the façade, the arched openings effectively distribute forces to the corners illustrating the integration of structural efficiency and architectural benefit (Fig. 10).

For a 457 meter tall residential and hotel tower in Chicago, we proposed an eccentric braced frame tower with strong corner columns that was 50% more efficient than a convention concrete moment frame structure. The economy of a concrete core and frame was combined with the efficiency of steel "leaf bracing" to be installed independent of each other. The out-of-plane leaf brace is an optimized organic geometry that allowed for the least amount of material for the 12:1 aspect ratio and allowed the exterior wall and views from the residential units to be free of interference with the brace (Fig. 11). Building on the Hancock tower's early influence, this structural innovation was

Figure 12. Takshing House Hong Kong.

essential to improve the viability of the tower's construction costs, the quality of the interior residential spaces, and visual openness to the city views, representing a new Chicago School of Architecture and Engineering integration.

6. Structure as New Form - the Cantilever

Several SOM towers have explored floors cantilevered from a central core to provide unencumbered views from within or to create purposeful openings in the tower form. The Takshing House in Hong Kong cantilevered small floors from a strong core to rise above the city context (Fig. 12). Nozul Tower in Doha carved luxurious shaded terraces out of the tower by cantilevering hotel suites in a stepped pattern of solids and voids (Fig. 13). A 1 kilometer tall proposal in Jeddah, "aSpire", sought to reinvent the components and spaces within the tall tower by using a hollow shell core with cantilevered floors for a mixed-use tower in the desert (Fig. 14).

Similar to those proposals, our submission for supertall tower in Dubai recognized the value of column-free perimeter at the office floors and developed a cantilevered, tapered beam supported floor system, attached to a triangular center core with piers at the lower corners. Speed and simplicity of construction were important considerations, thus no outriggers or belt trusses that might slow construction were required. The architecture and engineering team met with concrete subcontractors to understand formwork and staging considerations. Because there was no perimeter frame, the cantilevered system allowed for uniform core shortening due to creep and shrinkage.

The resulting triangular floor plate was an efficient shape for the 673 meter tower and also had the flexibility, with no perimeter columns, to step back the plan at the corners to taper the tower form. This triangular shaped tower worked well by orienting the point towards the predominant wind direction and creating a dynamic facet on the façade directed at best views with the least amount of solar gain (Fig. 15).

With the cantilevered floor system, smaller amenity floors grouped around three sky lobby and transfer floors could be freely planned to create special interlocked volumes distributed at quarter points on the tower. At each, large landscaped terraces are connected to shaded atria containing meeting and conferencing areas, spiritual spa-

Figure 13. Nozul Tower Doha.

ces, food venues, and wellness clinics. These distinctive notched portions of the tower disturb vortex formations, and together with the chamfered corners and perforated top, reduce wind induced accelerations by 50% over a conventional square plan tower (Fig. 16).

The interior spaces of the tower are composed of consistent 11 meter lease spans and usable core areas for tenant spaces, yielding a 72% floor efficiency over 127 floors, a number higher than our other benchmarked towers of similar height. The column-free perimeter provided far greater usable area that was uninterrupted and contiguous for greater flexibility and efficiency in office space plan-

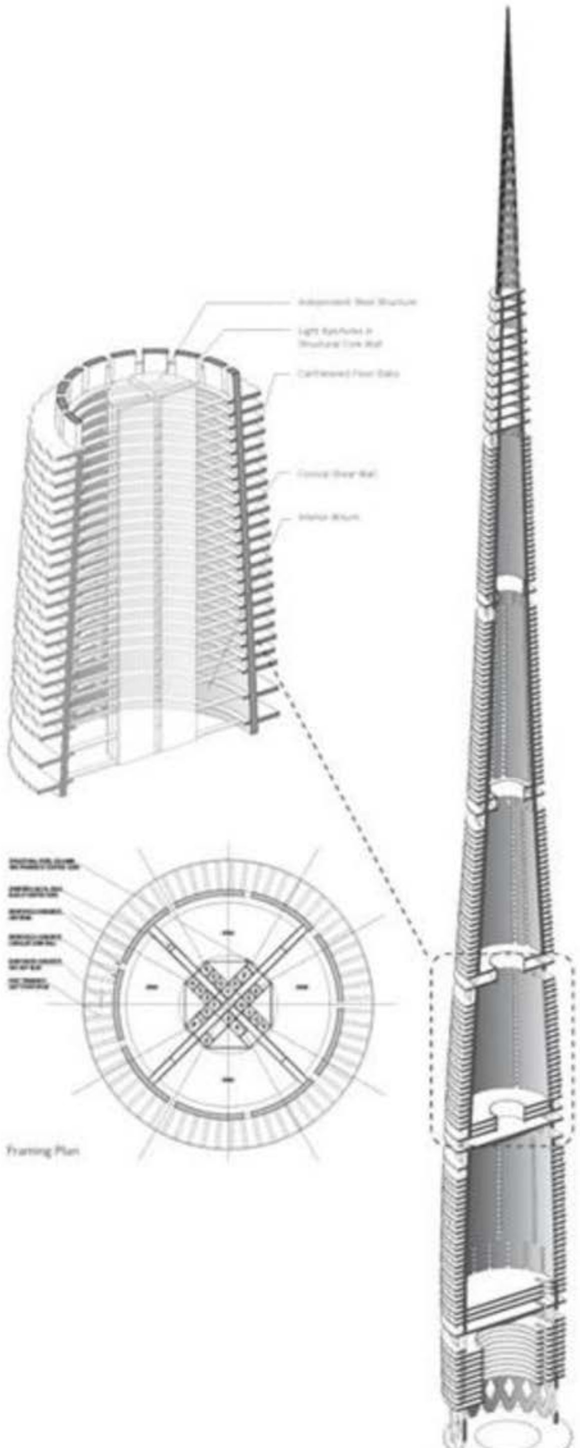

Figure 14. One Kilometer "aSpire".

Figure 15. Dubai Supertall Office Tower.

ning. Structural innovation was tied to construction methodologies leading to better interior space design and usability (Fig. 17).

7. Performative Enclosures

The Dubai tower was to be clad in an exterior enclosure responsive to the harsh desert climate. Like the wall of the recently completed CWTC 3B tower (Fig. 18), a tilted glazed curtainwall on the Dubai tower creates a self-shaded wall assembly that reduces about 20% of direct solar gains. When combined with exterior electrochromic glass, the glazed portion of the wall, 50% of total, provides a controllable vision area that mitigates heat gain and glare without a loss of the expansive panoramic view. The upward-facing spandrel portion of the wall has integrated solar collection panels that are connected to absorption chillers for building cooling (Fig. 19). Here, the team rel-

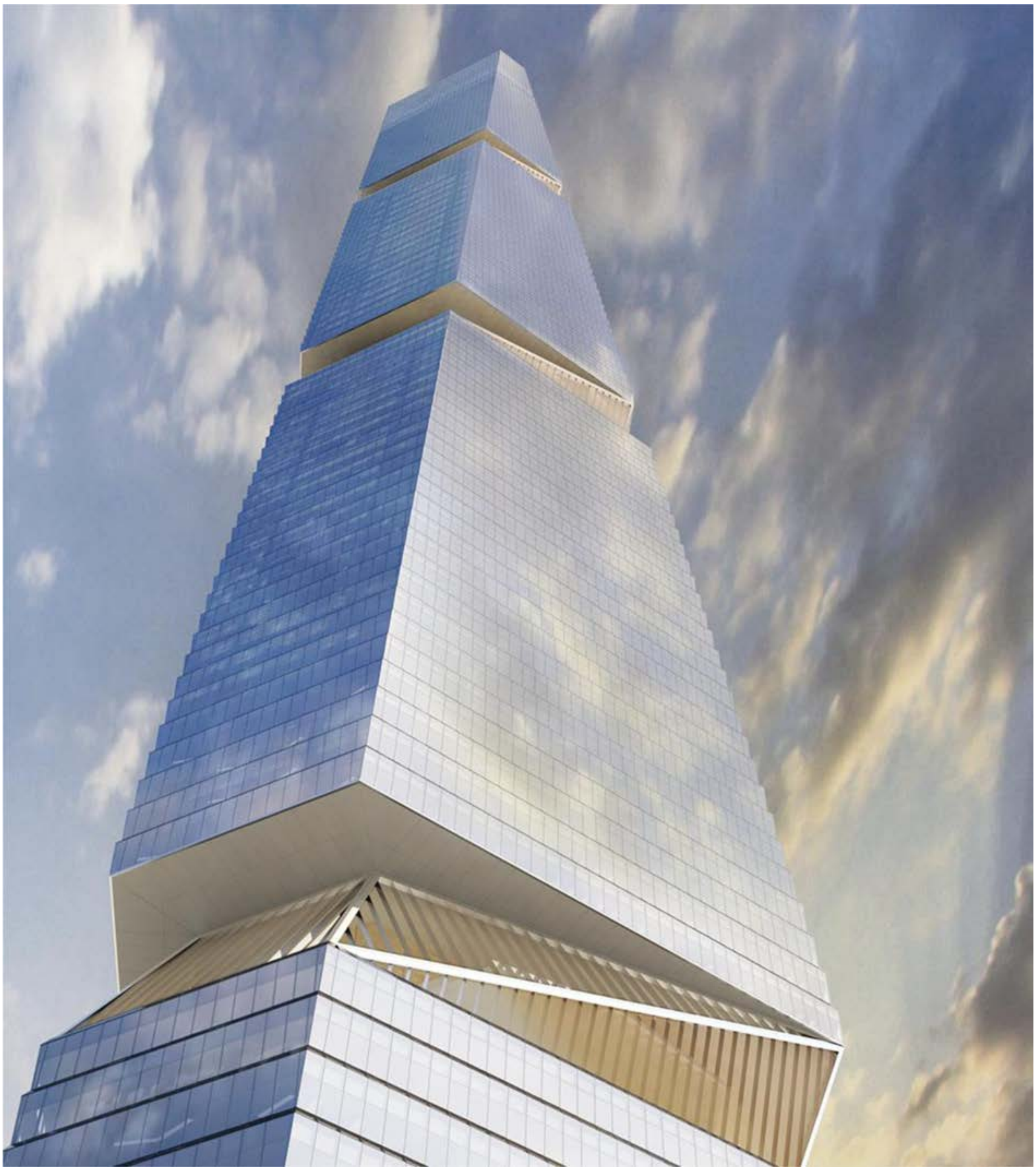

Figure 16. Dubai Supertall Office Tower notched amenity floors.

ied on extensive coordination with sustainability engineers and designers to quantify the performance of the sophisticated façade in the demanding climate.

The need for better insulated facades has pushed exterior wall glass to solid ratios to lower glass amounts. Until advances in typical glazing U-values increase dramatically and become cost effective, more solid wall and glass assemblies will be the norm. For a 343 meter tall residential tower in Chicago, an integrated tube frame and glazed bay window was proposed to address combined structural and enclosure goals. A 4.5 meter module, 3 meter openings flanked by 1.5 meter columns, creates a strong perimeter frame quickly constructed by self-advancing forms. The 36.5 meter square plan has reentrant corners to diffuse wind vortices. Within each 3 meter by 3 meter opening, a prefabricated and unitized, angled window bay with a single sheet of double glazing or set of vertical jalousie type windows were inserted to create both an intimate

Figure 17. Dubai Supertall Office Tower column-free perimeter.

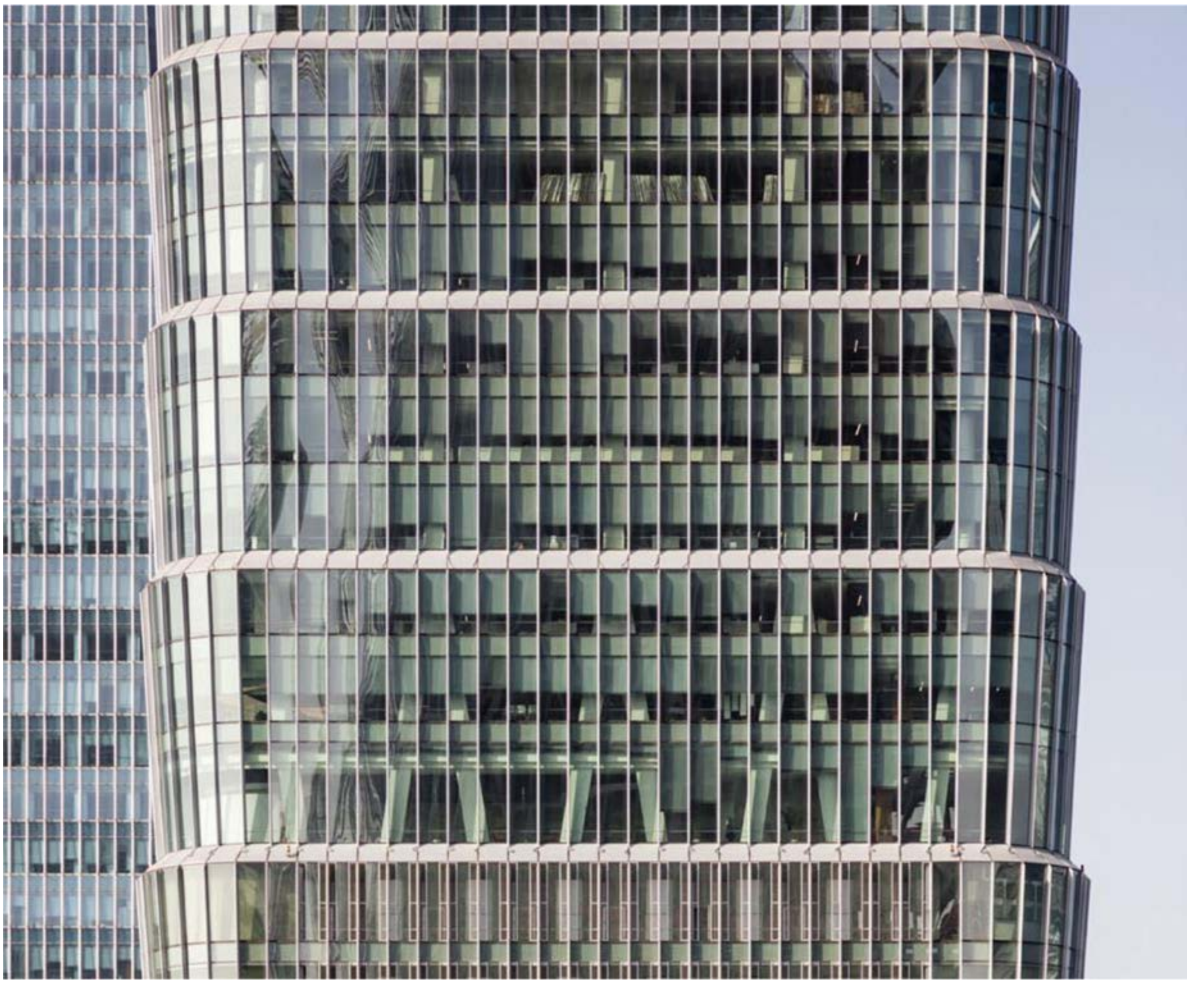

Figure 18. CWTC 3B exterior wall.

Figure 19. Dubai Supertall Office Tower high performance exterior wall.

Figure 20. Chicago Residential Tower tube frame structure with operable and fixed bay windows.

and grand experience at the window. Monumental in size compared to a human scale, each angled bay is tilted in and out depending on the adjacent bay orientation and views to the surrounding city. This undulating ribbon of glazing results in a dramatic vertical reading to the tower and demonstrated how a simple structural concept could be combined with a modest and energy efficient wall to become a fresh tower expression of structure, form and habitation (Fig. 20).

8. Conclusion - Meaningful Architecture

An approach that simultaneously considers site responsiveness, program strategies, structural innovation, building systems for wellness, and high performance enclosures will lead to a highly intelligent, comprehensive design. To conceptualize, develop, and refine complex tower designs requires diverse experience and expertise from talented individuals working closely together. In our studios, teams of skilled, multi-faceted individuals working with high design ambitions will self-select the most rational designs. Quite simply, the design of tall buildings requires engineering and architecture to be a seamlessly integrated to make the vision a reality.

In addition, to distinguish the truly meaningful from something good requires best efforts to synthesize the many project issues into singular, memorable designs. SOM's most powerful buildings are distinctive designs that find some unique quality in beautifully-crafted structures that are more than assembling technically sophisticated buildings, but are informed by place and the values of our time. Buildings that have lasting presence embody bold notions of scale, light, and materiality, with authentic, coherent statements coming from a thoughtful ethos of integrating programmatic invention, inspiring structures, and environmental and human sustainability.