CTBUH Journal

International Journal on Tall Buildings and Urban Habitat

Tall buildings: design, construction and operation | 2011 Issue II

Capital City Towers, Moscow

Validating the Dynamics of the Burj Khalifa

Real Life Data to Support Environmental Claims

Vibration Control: A Tower Complex with Sky Gardens

Residential Towers in Central Business Districts

Eyesore to Urban Asset:
Transformation of Railroad Structures

Council on Tall Buildings and Urban Habitat

This Issue

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Front cover: Capital City Towers, looking up. Back cover: Capital City Towers Atrium. © NBBJ

In the USA, I once built a school using a prototype of a design built several times before. The same school design was built repeatedly at different locations, presumably so the school district could save on design fees. Unfortunately, after the school was opened, the teachers and staff complained that the same design problems which had been encountered in earlier versions of the prototype existed in this brand new building. Had the school district invested in a post-occupancy survey, they could have addressed and corrected these issues instead of continuing to duplicate the problem.

Measuring the performance of buildings and environments that we create as a post-occupancy exercise can be a valuable learning tool for all parties. The data collected from users and occupants can be used to measure performance. Does the building or environment actually function as originally planned? Does the energy consumption meet the expectations that were calculated? Are the users or occupants happy?

Sustainability is an important, and therefore reoccurring, theme within the CTBUH. This issue of the Journal is no exception as you will find at least one paper related to this topic – Real Life Data to Support Environmental Claims (see page 24).

In our various professions, we spend an incredible amount of time developing, engineering, designing, and building projects. Upon completion, we immediately move on to other projects. And most of the time, we do not become the end users or occupants.

As we plan to live and work in more sustainable environments, getting feedback on performance will be increasingly more important. This principle applies to both new and existing buildings. At the 2009 Chicago Conference, Adrian Smith, of Adrian Smith+Gordon Gill Architecture, spoke about his work on the Chicago central area decarbonization plan, which includes an assessment of the energy consumption of buildings in the central area and a goal of a 30% energy usage reduction by 2020. Chicago has been a leader in the green movement for major cities in the USA. At the 2008 World Congress in Dubai, Sadhu Johnston, Chief Environmental Officer for the City of Chicago, spoke of the many initiatives that Chicago had undertaken towards the green movement, including the conversion of numerous rooftops to green roofs to reduce solar heat gain.

The Middle East is also active in the green movement. Organizations like the Emirates Green Building Council and the Qatar Green Building Council have recently been formed. They are developing rating systems with which to assess environmentally-friendly buildings while recognizing local climatic conditions, building technologies, materials and traditions. Qatar, which recently was awarded the 2022 FIFA World Cup, made a commitment to host the matches as a carbon-neutral event.

These organizations, as well as others like them internationally, appear to be making a shift from individual buildings to a much larger urban assessment. As these new assessment systems develop, let us continue to assess the buildings and environments that we create and learn as we progress.

To conclude this introduction, we are happy to announce that the CTBUH Journal has been included in the Avery Index to Architectural Periodicals. This Index, the oldest entry record of which dates back to 1741, is maintained by Columbia University, New York and offers the most comprehensive listing of journal articles published worldwide on architecture and realatd fields. This inclusion is great recognition for the qualitative development of the Journal, which now makes it even more attractive as a publishing platform for tall building academics and professionals. Well done to all involved!

Best regards,

William Maibusch, *CTBUH Trustee*

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Case Study: Capital City Towers, Moscow

"As a pioneering project in Moscow, Capital City has forged many new pathways for the city's real estate and construction industries. Through its integrated design and engineering, the project provides a model for mixed-use development, which remains rare in the city, and further establishes a new identity for Moscow."


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The High Life
Residential Towers in Central Business Districts

"These buildings serve growing segments of the population who desire amenity-rich lifestyles and safe urban homes. They serve cities that desire significant real estate tax revenues, as well as local businesses, which desire the potentially substantial purchasing power of new urban residents."

"Is a paradigm shift actually happening? Or, do tall buildings remain rooted in conventional commercial design but with a new image laid over the top?"

Joana Gonçalves & Klaus Bode, page 24

Global News

The CTBUH Global News is an online resource and archive for all the latest news on tall buildings, urban development and sustainable construction from around the world. For comprehensive industry news, visit the Global News at: ***http://news.ctbuh.org***

New York by Gehry, New York, USA © Marshall Gerometta

W57, New York, USA © Bjarke Ingels Group

The recession is over! At least that could be the conclusion one might draw after researching tall building-related news in the last three months. When browsing through recent articles, one finds a lot of tall building activity. Surprisingly one American city stands out: New York City. Could this indeed be another sign of recovery? Let's have a look at some of these developments.

New York City

Probably the smartest of the latest additions to the New York City skyline is the **New York by Gehry** Tower at 8 Spruce Street, previously known as the Beekman Tower. The building offers 903 apartments with over 200 layouts to choose from. Topping New York City's Trump World Tower by three meters (ten feet), the 265-meter (870-foot), 76-story high skyscraper is now the tallest residential building in the Western Hemisphere. New York by Gehry has received a great deal of attention because of its striking rippling stainless steel façade and has been labeled "a turning point from the modern to the digital age." Even though the design of the façade is characteristic of the works of architect Frank Gehry, the appreciation lavished upon it has been comparable to the praise that Aqua Tower in Chicago has received. It has also been observed that, unlike Aqua, the tower is not seeking LEED Certification. Maybe more interesting than this news itself is the tone behind the observation, which seems to suggest that eye-catching buildings such as New York by Gehry really ought to seek LEED certification these days.

One of the hottest contemporary architects around, the Copenhagen based Bjarke Ingels Group (BIG), has landed its first project in New York City. BIG, which is known for its edgy designs, has presented a 142-meter (450-feet) tall complex on a plot in between 57th and 58th Street and 12th Avenue. **W57**, as the project is called, contains over 600 residential units on a podium containing cultural and commercial functions. Seen from the top, the building, which aims for LEED Gold Certification, resembles a typical European perimeter building block around a private courtyard. By lifting up the northeast corner, the building appears to be a pyramid when viewed from the West Side Highway, while resembling a slender spire when seen from West 58th Street. Its shape combines the advantages of both the typical European and American building type: the compactness and efficiency of a courtyard building providing density, a sense of intimacy and security, combined with the airiness and expansive views of a skyscraper. The slope of

...dwarfs

> "Few developers want to build skyscrapers in Israel. The problem is that a developer who wants to build a skyscraper faces opposition from the Israel Airports Authority and other statutory bodies... Israeli citizens will therefore continue to look enviously at skyscraper construction around the world, in ostensibly Third World countries, and will only be left with the option of visiting these skyscrapers as tourists."
>
> *Israel David, CTBUH Israel Country Representative in his interview regarding the lack of skyscraper construction in Israel. From "Israel's Skyscrapers are Dwarfs", www.globes-online.com, March 8, 2011.*

the building also allows for a transition in scale between the low-rise structures to the south and the high-rise residential towers to the north and west of the site. The building also represents the personal life of the 36-year old former OMA employee, Bjarke Ingels, as he resides in both Copenhagen and New York.

Exactly two blocks north of W57, architect Christian de Portzamparc has designed a scheme for a five-tower megaproject which goes by the name of **Riverside Center**. Project developer Extell Development got the green light from City Council to build Riverside Center in December 2010. This is the final phase of the Riverside South developments, which stretches from 59th Street up to 72nd Street on former industrial land along the Hudson River Waterfront. All five towers, of which the tallest one will have 53 floors, will be residential buildings situated on 3.4 acres of landscaped public space. The project includes retail, dining, underground parking, a movie theater, and possibly even an elementary school.

On the other side of the East River, the Landmarks Preservation Commission organized a public hearing on Brooklyn Heights Association's proposal to landmark the borough's **skyscraper district** in an attempt to save 20 of downtown **Brooklyn**'s oldest skyscrapers. As this designation would

Riverside Center Study, New York, USA © Christian de Portzamparc

One Hanson Place, Brooklyn, USA © Marshall Gerometta

bar buildings from being torn down and owners would have to get special permission to make big alterations, not everyone is enthusiastic about the proposal. Building owners are concerned the proposal, if approved, would raise the cost of living for tenants in the area.

Elsewhere in the United States

With a reputation as the ultimate spread-out city combined with a lack of recent tall buildings, one might easily forget that **Los Angeles** actually does have something of a skyscraper-filled downtown area. This reputation may be subject to change in the near future. In 2010, the 203-meter (667-foot) tall **LA Live Hotel & Condominiums** tower was the first project in 20 years to break the 150-meter (492-foot) threshold in LA. On December 17, approval was given by the LA Planning Commission to the **Wilshire Grand Project**, a 232,000-square meter (2.5 million-square foot) mixed-used complex including two towers: a 45-story tower containing a luxury hotel and residential units, and a 65-story office tower. The two buildings were designed by AC Martin, an LA-based architect who has also designed LA's 52-story Two California Plaza and the 53-story Bank of America Plaza. The towers of Wilshire Grand would be connected with a large plaza, while 25,500 square meters (275,000 square feet) of public space will include shops, a spa and meeting spaces. The project will be built on the site of the current yet-to-be demolished Wilshire Grand Hotel.

A bit further West on Wilshire Boulevard and Vermont Street, a two-tower residential complex called **The Vermont** has been proposed in the area widely known as Korea Town. The 464-unit complex, designed by Venice Beach based Jerde Partnership, had been a victim of the economic downturn when initially proposed years earlier. Spurred by positive news about the economy, the developer Jerry Snyder reasons that the apartment market is now very strong and will soon be ready for new units. The ground level on Wilshire and Vermont would house restaurants and shops. The towers, 25 and 30 stories high, will house its lobby, pool, gym and recreation center on the seventh floor, above the garage. As these numbers suggest compact urban units, USC students, members of the Korean community and young

Wilshire Grand, Los Angeles, USA © AC Martin,

Case Study: Capital City Towers, Moscow

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Yuri Starodubtsev
Yuri Starodubstev manages the design of supertall projects for the Capital Group. He oversees the work of design architects and coordinates architectural and planning decisions with other aspects of the development. Mr. Starobubstev is also currently overseeing multifunctional complex on MIBC's Plot 16 designed by SOM, USA. He had participated in the design of a wide array of challenging building projects including Moscow embassies in Australia and the United States, factory facilities for Philip Morris in St. Petersburg and for Nestle in Moscow.

Joey Myers
Joey Myers led the design of the Capital City Towers project. He had worked on some of the NBBJ's most important projects, including Europe's largest wireless headquarters for Telenor in Oslo which received the FIABCI Prix d'Excellence. With 18 years of experience working in 18 countries, Mr. Myers specializes in the design and planning of large, complex projects and has created award-winning buildings in various market sectors.

Larry Goetz
Larry Goetz specializes in managing architecture teams in the design and delivery of complex developments with innovative engineering possibilities. Previous projects include Seattle's Safeco Field, the LEED® Silver Seattle Justice Center and an expansion to the Seattle-Tacoma International Airport. Mr. Goetz moved to Seattle in 2010 to work on NBBJ's Advanced Design Technology changes and advanced BIM development. He was named Principal in 2008.

"As a pioneering project in Moscow, Capital City has forged many new pathways for the city's real estate and construction industries. Through its integrated design and engineering, the project provides a model for mixed-use development, which remains rare in the city, and further establishes a new identity for Moscow."

After more than a decade in the planning, Moscow City, a new mixed-use business district rising 4 kilometers (2.5 miles) west of the Kremlin, is a symbol of Russia's ascent in the global economic playing field. The Capital City mixed-use development (see Figure1), completed in 2010, is the fourth to be realized among more than 20 projects which comprise Moscow City and, at 302 meters (989 feet) in height, it is currently the tallest building in Europe. With its iconic form that recalls Constructivist geometries, Capital City also captures modern Moscow. Its two slender, yet bold residential towers, joined by an office and retail base, are international in quality and performance but still rooted in Russian culture.

With its compressed schedule, achieving this unique structure at this point in Moscow's history required innovation and collaboration. The design introduced advanced engineering and design capabilities while building upon local construction expertise. Developed by Capital Group, a Moscow-based company responsible for more than 5 million square meters (53.8 million square feet) of residential, commercial and mixed-use development, Capital City's completion represents an exchange of high-rise design and construction expertise that will influence future construction and building standards in Russia.

Figure 1. Capital City Towers © NBBJ

Anchoring a New District

Capital City's mix of residential, office and retail distinguishes Moscow City from precedents like Canary Wharf in London and La Défense in Paris, which were planned primarily as commercial districts and are only now working to increase their residential components. Set on the Presnenskaya embankment overlooking the Moscow River, Moscow City was envisioned from the outset as a place for business, living and leisure. More than 3 million square meters (32.6 million square feet) of residential, office, hospitality and entertainment uses – including Capital City's 288,000 square meters (3.1 million square feet) – are planned for the 60-hectare (247-acre) district. Similar to London and Paris, Moscow City is intended to provide a vitalizing expansion of commercial office space while preserving the character of Moscow's historic center.

The idea of a new business district in Moscow first emerged after the completion of the Expocenter in 1980. With the Expocenter drawing new activity to the area, attention turned to the adjacent site, then a declining industrial area. By 1990, a master plan for a new international business center was in place, but it would take the sustained economic growth of the past decade to finally catalyze development.

The plan organizes 20 development plots around a central core serving the entire district. Currently under construction, the central core includes a hotel, retail-entertainment complex and concert hall. Below grade, a retail mall, vehicle access, 2,750 parking spaces, a multi-modal transit hub, and pedestrian walkways will link the central core with surrounding developments and the city beyond. In addition to the completed mini-metro link to the main metro system, future plans include two new metro stations and a high-speed rail connection to the Vnukovo and Sheremetyevo airports.

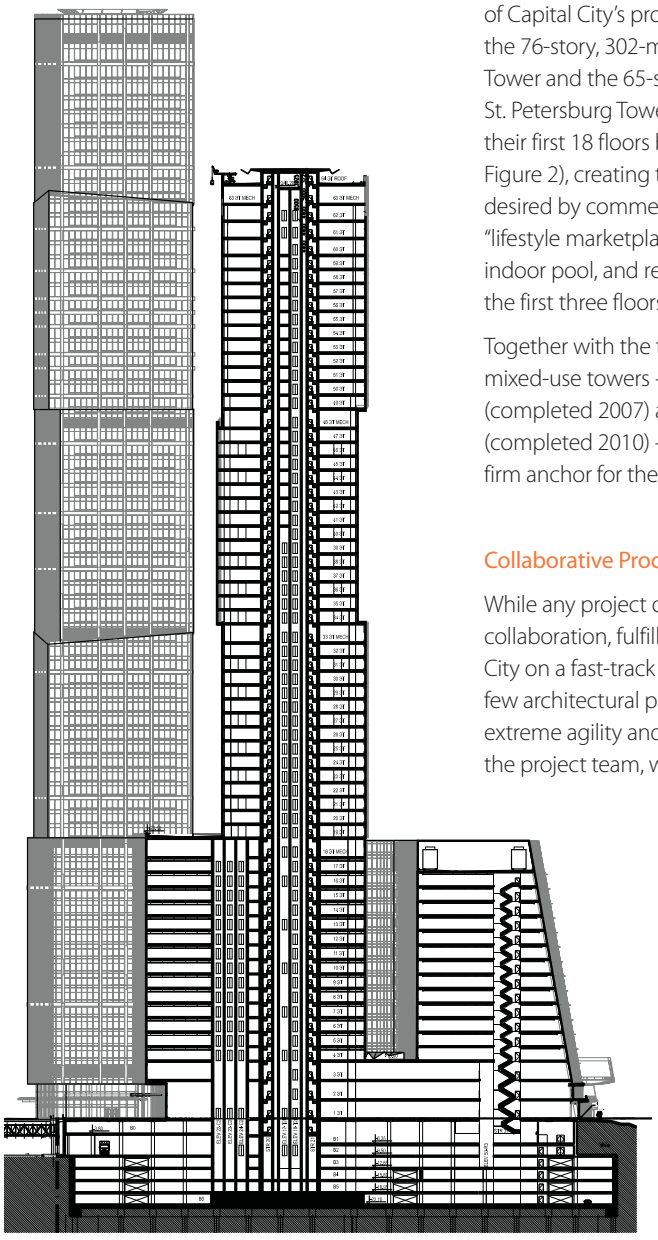

Figure 2. Building Section © NBBJ

The luxury residences that comprise the bulk of Capital City's program are contained within the 76-story, 302-meter (989-foot) Moscow Tower and the 65-story, 257-meter (843-foot) St. Petersburg Tower. Both are joined through their first 18 floors by a podium building (see Figure 2), creating the larger floor plate desired by commercial office tenants. A "lifestyle marketplace," a fitness spa with indoor pool, and residential lobbies occupy the first three floors.

Together with the two other completed mixed-use towers – the Naberezhnaya Tower (completed 2007) and Imperia Tower (completed 2010) – Capital City provides a firm anchor for the nascent Moscow City.

Collaborative Process

While any project of this complexity requires collaboration, fulfilling the vision for Capital City on a fast-track schedule in a district with few architectural precedents required extreme agility and innovation on the part of the project team, which spanned 11 time zones from Seattle, to London, to Moscow.

Another complication was the absence of applicable local building codes. When the development of Moscow City began, local building codes dated back to 1950, when the average building height did not exceed 75 meters (246 feet) and codes for high-rise housing did not exist. In order to address the structural and life-safety requirements for Moscow City's tall buildings, rigorous codes modeled after British standards were adopted for all projects in the new district, including Capital City. These codes establish high standards for fire safety, and include 4-hour structural fire resistance, the use of 30-minute fire-rated glass, ample refuge areas, redundant fire elevators and exit stairs, and rooftop platforms for lightweight refuge cabins that can be delivered by helicopter.

To begin construction on schedule, NBBJ and Arup elected to complete the structural design while the architectural design was still in process. The superstructure and raft foundation design was developed on a fast-track schedule that was locked in place after early design development, allowing architectural façade design to continue while detailed structural design was completed. Refuge floor locations in the two tall towers were finalized along with vertical mechanical and fire separations to allow structural design of the superstructure to be coordinated quickly with the design of the structural out-riggers and core.

After working closely together to develop highly efficient and integrated structural and mechanical systems, the design team worked with Moscow authorities to verify that the project would fulfill the new building codes. Expert panels in structural engineering and life-safety reviewed the proposed design.

Design Concept

Capital City's bold architectural form takes as its conceptual inspiration "Corner Counter Relief" of 1914 by Vladimir Tatlin, often heralded as the father of Russian Constructivism. Tatlin's experimental work in the early 20th century marked an attempt to redefine sculpture's relationship to built space. Slung between two perpendicular walls, Corner Counter Relief breaches the orthogonal shape of a typical room in order to introduce a taut, interstitial geometry. A similar effect is created by the offset rotation of Capital City's tower segments which

Validating the Dynamics of the Burj Khalifa

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Ahmad Abdelrazaq
Since joining Samsung in 2004, Mr. Abdelrazaq has been involved in the construction planning and structural design of several international projects, including Burj Khalifa in Dubai, the Samsung Seocho project in Seoul, and currently the Y22 Project, also in Seoul. Prior to joining Samsung, he was an Associate Partner and Senior Project Structural Engineer with Skidmore, Owings & Merrill in Chicago. Mr. Abdelrazaq currently serves as a lecturer at the Seoul National University, where he teaches a high-rise building design course for graduate students. He also served as an adjunct professor at the Illinois Institute of Technology's School of Architecture in Chicago.

Since 2008, Mr. Abdelrazaq has been involved with the CTBUH in various positions, such as the Advisory Group, the Awards Committee and the Editorial Board of the CTBUH Journal. He has also been a speaker at CTBUH conferences and congresses in New York City (2005), Dubai (2008) and Mumbai (2010).

…free-market

"Basically, it is a free-market experiment… We needed to test densities, scale, and the feeling of material… For us, a pedestrian city is the first measure of sustainability."

KPF's principal James von Klemperer commenting on New Songdo City, South Korea. From "New Songdo City," Architectural Record, October 2010.

"The survey and Survey Health Monitoring programs developed for Burj Khalifa have pioneered the use of these concepts as part of the fundamental design concept of building structures and will be benchmarked as a model for future monitoring programs for all critical and essential facilities."

Historically, tall building design and construction relied solely on minimum building code requirements, fundamental mechanics, scaled models, research and experience. While many research and monitoring programs have been implemented before, these programs are yet to be systematically validated and/or holistically integrated. Involvement in the planning, design and construction of Burj Khalifa, from its inception to completion, prompted the author to conceptually develop an extensive survey and real-time structural health monitoring (SHM) program in order to validate the fundamental assumptions made for the design and construction planning of the tower. This strategy included the monitoring of reinforced concrete bored piles and load dissipation, foundation settlement, core walls and columns vertical shortening, the lateral displacements of the tower and vertical element strain and stresses. Additionally, temporary and permanent real time monitoring programs were installed. These programs have already resulted in extensive feedback and insights into the actual in-situ material properties, the tower's structural behavior and its responses under wind and seismic excitations.

Structural Overview

The Burj Khalifa Project is the tallest structure ever built by man (see Figure 1). The massing of the 828-meter (2,717-foot) tall Burj Khalifa is organized around a central core with three wings, each consisting of four bays (see Figure 2). At every seventh floor, one outer bay retracts a little as the structure spirals into the sky. This tapered massing introduces natural wind spoilers to manage wind engineering aspects by reducing dynamic wind excitation. Integrating these principals into the architectural design of the tower resulted in a stable dynamic response which tames the powerful wind forces.

To maximize the overall structural depth of the tower, the lateral load resisting system consists of high performance reinforced concrete core walls, which are linked to the exterior columns though a series of shear wall panels at the mechanical levels. The core walls vary in thickness from 500 to1,300 millimeters (19.69 to 51.18 inches). The core walls are

Figure 1. Burj Khalifa completed © SOM|Nick Merrick/ Hedrich Blessing

typically linked through a series of 800 to1,100-millimeter (31.50 to 43.31-inch) deep reinforced concrete or composite link beams at every level. Due to the limitation on the link beam depths, ductile composite link beams are provided in certain areas of the core wall system. These composite ductile link beams typically consist of steel shear plates or structural steel built-up I-shaped beams, with shear studs embedded in the concrete section. The link beam width typically matches the adjacent core wall thickness.

Gravity Load Management and Structural System Optimization

While wind behavior of supertall buildings is one of the most important design criteria to be considered, gravity load management is also critical as it has direct impact on the overall efficiency and performance of the tower. The means and methods of mobilizing and redistributing gravity load could have its own inefficiencies and demands. If not addressed early and managed properly, it could result in design and construction complexities.

Gravity load analysis compares the concrete area required to support the tower gravity loads, without considerations to minimum member sizes, to the actual concrete area provided for the tower final design (see Figure 3). It shows that the total material needed to support the gravity load and the material required to resist the combined effect of gravity and lateral loads is one and the same. The only additional material needed for Burj Khalifa was caused by the rounding of member sizes and the additional materials required to redistribute the loads to the building extremities at the hammer head walls (no penalty) and the nose columns (major penalty) through the link beams at every floor and at the outrigger levels. The hammer walls and the nose columns, located at the extremities of the building, add significant contributions to the moment of inertia of the tower and its overall resistance to the overturning moment due to lateral loads. The limitations on the wall thicknesses (500–600 millimeters/19.69–23.62 inches) of the center core and the wing wall's thickness (600 millimeters/23.62 inches) allowed the gravity load to flow freely into the center corridor spine web walls (650 millimeters/25.59 inches) to the hammer head walls and nose columns for maximum resistance to lateral loads. These continuous load flows illustrate the art of the concrete material. Along these load flow lines the strain gages are installed to track the gravity load flow.

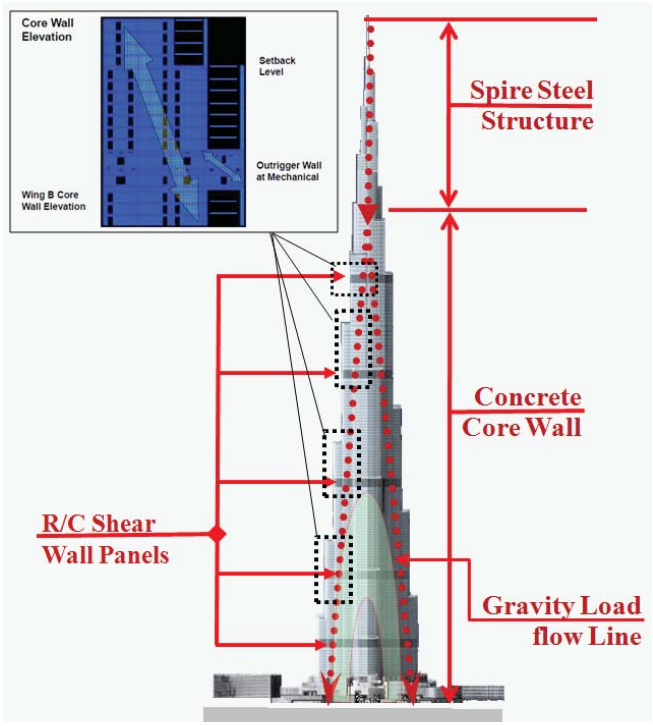

Figure 3. Lateral Load Resisting System © Samsung C&T

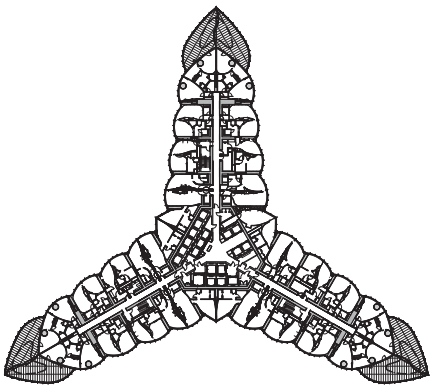

Figure 2. Typical hotel floor plan © SOM

Wind Engineering Management

Several wind engineering techniques were employed into the design of the tower to control its dynamic response due to wind effects. These include disorganizing the vortex shedding formation along the building height (spoiler concept used in chimneys) and tuning the dynamic characteristics of the building to improve its behavior to prevent lock-in vibration.

Floor Framing System

The residential and hotel floor framing system consists of two-way reinforced concrete flat plate or flat slab systems, 200 to 300 millimeters (7.87 to 11.81 inches) thick, with additional 50 millimeters (19.7 inches) hunches at the end, which spans approximately 9 meters (29.5 feet) between the exterior columns and the interior core wall. The floor framing system near the top of the tower consists of a 225 to 250-millimeter (8.89 to 9.84-inch) two-way reinforced concrete flat slab system with 150-millimeter (5.91-inch) drop panels. The floor framing system within the interior core consists of a two way reinforced concrete slab with beams. Figure 4 shows a typical floor framing system at the typical residential and mechanical levels. Note that at the mechanical level, all the vertical elements are tied to equalize the load and stress distribution between vertical supports (walls and columns).

Foundation System

The tower is founded on a 3,700-millimeter (145.67-inch) thick pile supported raft. The reinforced concrete raft foundation utilizes high performance self compacting concrete (SCC), which is placed over a 100-millimeter (3.94-inch) minimum blinding slab, a waterproofing membrane and a 50-millimeter (1.97-inch) minimum blinding slab. The raft is supported on 192 to 1,500 millimeters (7.56 to 59.06 inches) diameter high-performance reinforced concrete, 3,000 metric ton

About the Council

The Council on Tall Buildings and Urban Habitat, based at the Illinois Institute of Technology in Chicago, is an international not-for-profit organization supported by architecture, engineering, planning, development and construction professionals. Founded in 1969, the Council's mission is to disseminate multi-disciplinary information on tall buildings and sustainable urban environments, to maximize the international interaction of professionals involved in creating the built environment, and to make the latest knowledge available to professionals in a useful form.

The CTBUH disseminates its findings, and facilitates business exchange, through: the publication of books, monographs, proceedings and reports; the organization of world congresses, international, regional and specialty conferences and workshops; the maintaining of an extensive website and tall building databases of built, under construction and proposed buildings; the distribution of a monthly international tall building e-newsletter; the maintaining of an international resource center; the bestowing of annual awards for design and construction excellence and individual lifetime achievement; the management of special task forces/working groups; the hosting of technical forums; and the publication of the CTBUH Journal, a professional journal containing refereed papers written by researchers, scholars and practicing professionals.

The Council is the arbiter of the criteria upon which tall building height is measured, and thus the title of "The World's Tallest Building" determined. CTBUH is the world's leading body dedicated to the field of tall buildings and urban habitat and the recognized international source for information in these fields.

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