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International Journal on Tall Buildings and Urban Habitat

Tall buildings: design, construction, and operation | 2015 Issue II

Special Issue: Focus on Japan

Case Study: Abenos Harukas, Osaka

Advanced Structural Technologies For High-Rise Buildings In Japan

Next Tokyo 2045: A Mile-High Tower Rooted In Intersecting Ecologies

Application of Seismic Isolation Systems

In Japanese High-Rise Buildings

Innovative Façade Systems of Japan

Fire-Resistant Design of Tokyo Sky Tree

Talking Tall: Hiroo Mori



Inside

News and Events

- 02 This Issue Daniel Safarik, CTBUH Editor
- 04 CTBUH Latest Antony Wood, Executive Director
- 05 **Debating Tall:** Should Nakagin Capsule Tower Be Preserved?
- 06 Global News Highlights from the CTBUH Global News archive

Case Study

12 Case Study: Abenos Harukas, Osaka Tetsuo Harada & Masaomi Yonezu

Research

- 22 Advanced Structural Technologies for High-Rise Buildings in Japan Masayoshi Nakai
- 30 Next Tokyo 2045: A Mile-High Tower Rooted in Intersecting Ecologies David Malott, Leslie E. Robertson, Keisuke Hiei & Heidi Werner
- 36 Application of Seismic Isolation Systems in Japanese High-Rise Buildings Kentaro Nakagawa, Dai Shimazaki, Satoshi Yoshida & Ken Okada
- 42 Innovative Façade Systems of Japan Tomohiko Yamanashi
- 48 The Fire-Resistant Design of Tokyo Sky Tree Tomoyuki Someya

Features

- 52 **Tall Buildings in Numbers** Japan: A History of Tall Innovation
- 54 Talking Tall: Hiroo Mori The Vertical Garden City Grows into the 21st Century
- 58 Ask a CTBUH Expert: Ron Wood Edible Plants at Height?

СТВИН

59

59

60

- 56 China Office Launch Report CTBUH China Office Kicks Off With Board Meeting, Reception
 - **CTBUH on the Road** CTBUH events around the world
 - Diary Upcoming tall building events
 - **Reviews** Review of new books in the CTBUH Library
- 61 Comments Feedback
- 62 Meet the CTBUH Daniel Safarik
 - CTBUH Organizational Member Listing

22







66By Building vertically, we create compact cities where people have enhanced mobility and accessibility, often on foot, for the enjoyment of fuller, more rewarding private and professional lives.**9**

Hiroo Mori, page 54

Global News

Americas

Tall tales continue to emerge from **Toronto**, one of the most active skyscraper cities in North America. If a proposal from Foster + Partners is realized, **The One**, an 80-story mixed-use tower with exposed diagonal structural bracing, would become Toronto's and Canada's next tallest building at 318 meters. Further west, in **Calgary**, BIG's big plans have come to fruition. The **Telus Sky Tower**, set to rise 59 twisting, faceted floors to a height of 222 meters, broke ground in February and is set to complete by 2018.

As always, New York was abuzz with skyscraper news early this year. One of the more distinguished designs planned for the city is a 65-story condo tower at 8 East 37th Street, which would be festooned with interstitial garden amenity spaces along its height. The market in the metro area is so intense that Manhattan island no longer can solely claim its superlatives. Across the Hudson, plans were announced for New Jersey's first supertall building – the 302-meter 99 Hudson Sreet in Jersey City.

On the US west coast, **San Francisco** will this summer see the groundbreaking of the

THEY SAID

6 The utter capitulation of London's planning system in the face of serious money is detectable right there in that infantile, random collection of improbable sex toys poking gormlessly into the privatized air. Public access? Yeah, we'll definitely put a public park at the top (by appointment only).

lan Martin, comedy writer on the growing privatization of London. From "The City that Privatised Itself to Death," The Guardian, February 24, 2015.



The One, Toronto. © Foster + Partners

US\$500 million **706 Mission Street** complex, which will include a luxury condo and office high-rise, and the future home of the Mexican Museum. The timing reflects a desire by Millennium Partners to push forward with the project in the South of Market Area (SoMA), despite an ongoing



8 East 37th Street Residential Tower, New York. © MIR/ Perkins+Will



Telus Sky, Calgary. © BIG

legal battle with neighbors concerning the height of the building.

The news in the US was not dominated entirely by the coasts. Word emerged that **Chicago**'s long-planned **Solstice in the Park** by Studio Gang Architects may still see the light of day. Originally designed in 2006, the 26-story project was to be located on the northwest corner of East 56th Street and Cornell Avenue, just across the street from Jackson Park and the grounds of the Museum of Science and Industry. The revived project switches programs to a choice of 250



706 Mission Street, San Francisco. © Handel Architects



Solstice in the Park, Chicago. © Studio Gang

apartments or a mix of apartments and a new hotel, versus the originally planned 145 condos.

Not to be outdone by the Windy City, the tornado-prone Tulsa saw a proposal for a tower that would not only resemble the shape of a twister, but would include a severe weather research center and museum as part of its program. Plans for the funnel cloudshaped Tornado Tower currently range from the equivalent of 20 to 30 stories in height, and would feature multiple floors with outdoor terraces.



Torre Insignia, Monterrey. © HKS Architects

Further south, the Mexican city of Monterrey was digesting plans for its first supertall building, the 330-meter Torre Insignia, which would contain a luxury hotel with 300 rooms, 180 apartments, and 18,000 square meters of grade-A office space, plus cultural facilities and retail that would be integrated with the surrounding landscaped area.

Rogers Stirk Harbour + Partners (RSHP) has

unveiled a proposed twin-tower scheme in

Signature Tower, Kuala Lumpur. © BIG





Bandra Ohm, Mumbai. © James Law Cybertecture



Atrio, Bogotá. © Rogers Stirk Harbour + Partners

towers will provide more than 250,000 square meters of office space and shops, while public space will make up two-thirds of the site.

Asia and Oceania

Less than two decades after its skyline was redefined by the twin Petronas Towers, Kuala Lumpur may be redefined yet again by a curious proposal which, from some angles, appears to fill the void between its predecessors. The Signature Tower inverts the traditional skyscraper model by widening at the top, rather than tapering to a point, turning the typology "upside down." The proposal features an open-air hotel courtyard at 381 meters. The façades are designed as double skins, creating a chimney effect for natural ventilation, which allows for spectacular views without resulting in overheating.

Mumbai is continuing to redefine itself as a city of luxury skyscrapers. The Bandra Ohm, in addition to its distinctive curving form, will feature a private, crescent-shaped swimming pool on the balcony of each of its 100 units. Meanwhile, sales have begun for the 442-meter World One, India's future tallest building, which will feature 300 units. The tower's lavish apartments and penthouses,

Forging a Supertall Compact City





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Tetsuo Harada

Tetsuo Harada is the general manager of the architectural design department of Takenaka Corporation in Osaka. The projects he has led – including Hep Five, Hilton West, as well as other cutting-edge commercial buildings – have been featured in a variety architectural magazines. In all of the buildings that he has designed, the connection of architecture, city, and nature is the main theme. The background of his design approach is Machiya, or the wisdom in Japanese traditional urban dwellings, as represented by highly sophisticated environmental architecture in the high-density city.

Masaomi Yonezu

Masaomi Yonezu is the manager of the architectural design group of Takenaka Corporation in Osaka. He has designed a number of distinctive buildings based on careful observation of the city.



Figure 1. Abeno Harukas with the Osaka Abenobashi – Tennoji Station. © Nakamichi Atsushi

Abeno Harukas is the tallest building in Japan and one of the world's tallest buildings directly over a railway terminal. It connects the metropolitan area railway network to a new vertical urban network, reducing energy consumption and providing a variety of activities and services. Abeno Harukas is a high-density urban complex incorporating a department store, art museum, school, hospital, office, hotel, observatory, and rooftop gardens above the railway station. This supertall "compact city" demonstrates a way forward for reorganizing cities to optimize the value of the city center and integrate it with the surrounding area through the railway network.

Countering Suburbanization

To understand this building and its significance, it is important to first reflect upon the context in which it is built.

Despite its reputation as a crowded and highly-dense country, population decline has become a serious problem in Japan. Additionally, suburbanization has taken hold here as elsewhere, and this has resulted in under utilized city plots and infrastructure, and poorly distributed commercial and government services. To rectify this, the roles of Japan's suburbs, which became highly dependent on automobiles during the period of population growth after World War II, and its city centers need restructuring. In a sense this has already begun; in recent years, development of commercial facilities connected to stations and housing within walking distance of rail stations has increased in Japan's provincial cities. Such development is one approach to increasing the compactness of these areas, which have become increasingly integrated with railway networks. Now, the practice of increasing the use of land around railway hubs in city centers - in other words, creating cities that are more vertical and more compact - is gaining traction.

The GDP of the Keihanshin metropolitan area (Osaka, Kyoto, and Kobe) is second only to Tokyo among Japanese metropolitan areas, and is ranked seventh-largest in the world. The region has an extensive passenger rail network, comprised of numerous national and private lines, and the city subway. The Abeno project site is a busy rail hub in Osaka (see Figure 1), of comparable importance to the Osaka and Umeda stations in Umeda, and the Namba Station in the Namba district. The Osaka Abenobashi – Tennoji Station serves as a terminal for trains bound for southern Osaka and Yoshino (southern Nara prefecture) on the Kintetsu Railway. The number of passengers exceeds 70,000 per day, and an additional 34,000 people per day visit the department store, pass through the area on local streets, or enter the subway here.

Abeno is situated on the Uemachi Plateau, the backbone of the Osaka Plain. The plateau has



Figure 2. Abeno Harukas – "Supertall Compact City."

many historic buildings, including Shitennō-ji Temple, Naniwa Palace, and Osaka Castle, and is the historical and cultural center of Osaka. Abeno is also near an upscale residential district. In recent years, however, it has been greatly outstripped by Umeda and Namba with regard to commercial development. The original goals for this project were therefore to revitalize Abeno and the areas along the railways, and to reorganize Osaka's city structure by establishing Abeno as a place with a unique character that functions as a "third pole" of Osaka (the other two being Umeda and Namba). To achieve these goals, the developers proposed a supertall building of formidable volume, in which various uses would be networked and built directly above an existing rail terminal that would bring traffic to the site.

A Supertall Compact City

Abeno Harukas is a 60-story building with five basement levels, built directly above Abeno station. It has a total floor area (TFA) of approximately 306,000 square meters and contains a university, a day nursery, advanced medical facilities, and a small theater, in addition to office space, a department store, hotel, museum, and an observatory (see Figure 2). At a height of 300 meters, it is the tallest building in Japan and the nation's first supertall building.

The main tower portion of the building, with a TFA of approximately 212,000 square meters, was treated as an extension of an existing building with a TFA of approximately 94,000 square meters. This enabled the developers to use the local "Act on Special Measures Concerning Urban Reconstruction" advantageously, affording a zoning variance such that Abeno Harukas has a floor area ratio of 16.0, rather than the usual 8.0.

A "Supertall Compact City" such as Abeno Harukas integrates the wide range of activities normally found throughout sprawling cities into supertall buildings (see Figure 3). By accessing the railway network, these buildings can have an impact that is sufficient to reorganize not only the surrounding buildings,



Figure 3. Abeno Harukas, Osaka – overall view from North. © Suzuki Hisao

6CThe following three architectural elements are key to converting the possibilities inherent in the innumerable *encounters* in supertall compact cities into *effects:* three-dimensional routes affording various choices, networks of voids, and three-dimensional networks of greenery. **99**

Advanced Structural Technologies For High-Rise Buildings in Japan



Masayoshi Nakai

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Masayoshi Nakai

After completing the master course at Graduate School of Engineering, Kyoto University, Nakai joined Takenaka Corporation in 1984 and has been in charge of advanced structures such as large space structures, base isolation and vibration control. Notable works include the Fukuoka Dome, Odate Jukai Dome, Sapporo Dome and Kaohsiung Stadium (Taiwan). In 2004, Nakai received three major Japanese awards for the structural design of an iconic base-isolated building, Prada Aoyama. Nakai leads Takenaka's Advanced Structural Engineering division and is responsible for structural scheme design, expert support for design/construction teams and R&D activities relevant to special structures including supertall buildings. In 2013, he received a PhD in engineering from Kyoto University.

This paper reviews the development and current status of seismic design for high-rise buildings in earthquake-prone Japan. Additionally, it briefly describes two important areas of wind-resistant design for high-rise buildings in typhoon-prone areas of Japan. Third, through the example of three recently completed high-rise buildings, Japan's advanced structural technologies are explored, focusing mainly on structural frameworks, high-strength materials and response-control damping systems.

Progression of Seismic Design In Japan's High-Rises

In 1924, one year after the Great Kanto Earthquake that devastated Tokyo, Professor Toshikata Sano (1880–1956) added to the Urban Building Law a new requirement: the static horizontal seismic factor should be set as 0.1 or more. Ten years later, Professor Ryo Tanabashi (1907–1974) published an article in July 1934 stating that the seismic resistance of a structure cannot be adequately assessed simply by providing ample strength against a static horizontal force. Tanabashi contended that the seismic impact should be expressed using the energy squared by the maximum ground velocity, and that the resisting capacity of a structure should be assessed by using the strain energy absorbed by the structure itself. Tanabashi's confidence in this formulation was underscored when, in March of the same year, he suggested that research should be started on the construction in Japan of high-rise buildings like those seen in New York.

In an article published in April 1963, Tanabashi insisted that high-rise buildings should be possible in Japan in light of the following examples.

Given that seismic motion works on small and large structures with identical amplitudes, a flower vase might fall over in an earthquake, but a large high-rise building would not, Tanabashi argued, even if both objects were proportionally identical. Put another way, contrary to small boats, large ships are resistant to capsizing in rough seas.

Around the same time, Professor Kiyoshi Muto (1903–1989) promoted research on a high-rise building at Tokyo Station. While his effort in this case was not rewarded, the Hotel New Otani (see Figure 1) was completed in Tokyo in 1964 with a building height surpassing 45 meters. In 1968, the Kasumigaseki Building (see Figure 2), designed by Muto, at 156 meters and 36 stories in height, was completed as Japan's first high-rise building to surpass 100 meters. On every story of the building frame, precast concrete walls with many vertical slits were incorporated in order to maintain their initial structural stiffness while absorbing energy during a strong earthquake. Accordingly, it can be said that the concept of passively controlled structures was already being applied at the initial stage of high-rise building in Japan.



Figure 1. Hotel New Otani, Tokyo. © Rs1421. Source: Wikipedia

Introduction of Advanced Seismic Design

Entering the 1970s, most high-rise buildings were constructed using a seismic design method that relied on the plastic rotation capacity of steel-frame beam ends to provide energy absorption. However, several structural designers believed such designs would leave these buildings with residual deformations in frames subjected to large plastic deformation, thereby making post-quake restoration difficult. In response to this, the concept of damage-controlled design began to grow (see Figure 3).

In Japan, following the implementation of the New Seismic Design Codes in June 1981, extensive research has been conducted on seismic-isolation structures.

The Northridge Earthquake of January 1994, Los Angeles, and the Great Hanshin Earthquake of January 1995, Kobe, caused fracture phenomena in many steel-structure beam-ends, resulting in considerable concern about the feasibility of restoring damaged buildings.

In 1995 a seismic-isolation structure was put into practical use that adopted energyabsorption members such as steel and lead dampers, and also employed laminated rubber bearings as elastic supporting members. Since then, another concept has been increasingly applied, whereby the beam-column frames of high-rise buildings bear vertical loads in a manner similar to the



Building structures



Primary structures (support gravity weight) Seismic members

laminated rubber bearings in seismicisolation structures. This design produces

earthquake, so that the seismic energy is

Japan, many kinds of passive damping

dampers, viscous wall dampers, friction

devices, such as hysteretic dampers using

standard steel or low-yield-strength steel, oil

dampers, visco-elastic dampers, and so on,

buildings in Japan, several types of damping devices are combined and arranged in

highly integrated ways within their structural frameworks, in order to optimally control and

reduce the building vibration due to seismic

have been developed over four decades.

With respect to most recent high-rise

or wind load. It can be said that this a uniquely Japanese innovation and

represents an advanced approach for the

In addition to the seismic designs mentioned

structures is steadily being enhanced due to

provision of upper and lower limits for yield

the adoption of haunches to prevent the plasticization of beam-end welds. Another

column members with sufficient stiffness

contributing factor is the utilization of

stresses, progress in welding technology, and

above, the seismic safety of high-rise steel

following factors: higher strength and

sufficient ductility of steel materials, the

structural design of high-rise buildings.

Enhanced Seismic Resistance

absorbed by the energy-absorbing members

incorporated in the framing of each floor. In

mainly elastic behavior during an

(absorb earthquake energy)



Figure 2. Kasumigaseki Building, Tokyo. © Joe Jones. Source: Wikipedia

and strength, made possible by the use of concrete-filled tubular (CFT) steel columns.

In addition, remarkable progress in computer-aided structural analysis technology has made it possible to use a dynamic response analysis that can accurately predict the dynamic behavior of columns, beams, shear walls, and various dampers. This, in turn, has resulted in the construction of high-rise buildings with complex framing.

6 CDamping devices are combined and arranged in a highly integrated way within their structural frameworks, in order to optimally control and reduce seismicand wind-induced building vibration.**9**

Figure 3. Damage-controlled design.

Architecture/Design

Next Tokyo 2045: A Mile-High Tower Rooted in Intersecting Ecologies





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David Malott specializes in the design and planning of supertall buildings and large-scale mixed-use developments. With over 17 years of experience as an architectural designer and project director, he has contributed to KPF's strong presence in China, Japan, and Hong Kong.

Leslie E. Robertson has been at the forefront of structural engineering design for nearly 60 years, responsible for the structural design of some of the world's tallest buildings. In addition to the Shanghai World Financial Center, he is responsible for the structural design of the original World Trade Center, New York and the Bank of China Tower, Hong Kong.

Keisuke Hiei has been involved in a range of largescale urban projects in the United States, Hong Kong, and mainland China. Specializing in supertall buildings and curtain wall systems, he contributed to the design of both the tower and podium for the Shanghai World Financial Center and the 490-meter International Commerce Centre in Hong Kong.

Heidi Werner specializes in software development that engages with contemporary issues impacting the future growth of global cities. She has been involved in the generation of performance evaluation tools that provide analytics for large-scale mixed-use projects negotiating complex urban issues. "Next Tokyo" imagines a resurgent megacity, adapted to climate change through the realization of a high-density ecodistrict built on resilient infrastructure. The archipelago of reclaimed land supports transit-oriented development for a half-million occupants, while improving the resilience of Tokyo Bay against waterborne risks. Rising sea levels, seismic, and increased typhoon risk have raised consensus on the need for a strategy that offers protection to the low-elevation coastal zones surrounding Tokyo Bay. Next Tokyo addresses this city-wide vulnerability by providing coastal defense infrastructure that offers protection to the shoreline of upper Tokyo Bay. These resilient infrastructural elements function as the foundations for clusters of recreational open spaces and for high-density development across the bay, including the Sky Mile Tower, reaching over 1,600 meters in height. As a development strategy, a portion of the value generated from this new, desirable waterfront real estate would in return contribute to the cost of the municipal infrastructure needed to support it.

Urban-Scale Considerations

Coastal defense

Next Tokyo is a linear district strategically situated at a bottleneck in the bay, where multiple phases of land reclamation encroachment along the east side have reduced the waterway passage to only 14 kilometers across. By continuing this narrowing progression, Next Tokyo creates a protective border across the bay between the engineered edge of Kawasaki and the naturally protruding shoreline of Kisarazu. Hexagonal infrastructural rings, ranging from 150 to 1,500 meters in width, are arrayed to disrupt wave action intensity in multiple layers, while still accommodating shipping routes. Faceted breakwater bars on the ocean-side of the district provide additional defense for the most vulnerable mid-bay portions (see Figure 1). Additional operable floodgates stitch the primary clusters together for the activation of a temporary flood barrier during extreme storm surges. Tokyo Bay is currently dominated by industrial use and shipping activity; the



Figure 1. Land use diagram of the proposed Next Tokyo district.

protection offered by Next Tokyo creates the potential to viably introduce more mixed-use development and recreational activity into its upper portion.

Transportation links

Next Tokyo serves as a mid-bay transit hub for the city by running parallel with the existing Aqua Line bridge-tunnel combination. Prior to the completion of this roadway connection in 1997, Kanagawa and Chiba Prefecture were only accessible by a 100-kilometer drive around the coast of Upper Tokyo Bay. To reinforce this crucial transit route for the city, Next Tokyo provides tunnels to accommodate additional forms of mass transit between the shores, including regional rail lines and a new "Hyperloop" Maglev/vacuum-tube transport system, using technology currently being developed by Elon Musk. These cross-bay linkages assist in completing regional transportation rings and further reduce travel times for the commuting population. The primary station services the Sky Mile Tower, four kilometers off the coast of Kisarazu and is adjacent to the existing junction of the Aqua Line bridge-tunnel. Secondary stations are proposed for both ends of the district to provide additional transfer connections to the Next Tokyo monorail system and water bus network.

Figure 3. Aerial view of proposed Next Tokyo district.



Figure 2. Reclamation over time in Tokyo Bay, including proposed Next Tokyo in 20452

High-density district

The coastline of Tokyo Bay has experienced radical modification since the sixteenth century. At present, nearly 250 square kilometers of reclaimed land has accumulated along the shores of the 1,300 square-kilometer bay (see Figure 2). In total, the Next Tokyo district occupies 12.5 square kilometers; however, artificial land accounts for only a quarter of this total area. The smallest hexagonal rings accommodate nearly all of the high-density development. These islands cluster around the major transit exchanges and provide waterfront open space for the predominantly residential Sky Mile Tower and a range of secondary mixed-use towers (see Figure 3). Occupancy

for the new district would draw from both regional- and national-scale demand, by accommodating a half-million residents seeking to reduce their commute times or leave aging, at-risk suburban and coastal areas. The medium-sized rings remain water-filled to buffer the high-density zones from wave action and retain various shared water resources for the district, including freshwater reservoirs and public beach harbors. Terraced low-density development occupies the perimeter of these rings, with linear open spaces providing pedestrian routes safely above the flood line.

Renewable resource strategies

Energy will be generated on-site through a



Seismic Design

Application of Seismic Isolation Systems In Japanese High-Rise Buildings





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Kentaro Nakagawa has directed a variety of structural engineering projects for office buildings in Japan, including Fuji Xerox R&D Square and Shimizu Corporation's Tokyo Headquarters. Both buildings adopted seismic isolation systems, and he received JSSI (Japan Society of Seismic Isolation) awards in 2011 and 2014 for his work on these projects.

Dai Shimazaki has engaged in several significant projects in Japan, the UK, and the UAE, and became a group leader of the structural engineering department for office buildings in 2014. He received a JSSI Award in 2014 for his work on the Shimizu Corporation Tokyo Headquarters.

Satoshi Yoshida is the chief structural engineer of the Nakanoshima Festival Tower project. He joined Nikken Sekkei Ltd. in 2007 and continues to work there as a structural engineer. He received a JSCA (Japan Structural Consultants Association) Award in 2014 for his work on the Nakanoshima Festival Tower.

Ken Okada received a Dr. Eng. degree in 2003 in the seismic performance of steel structures. He joined Nikken Sekkei Ltd. in 2005. For the Nakanoshima Festival Tower project, he worked as a structural engineer and as a construction administrator. In this paper, state-of-the-art technologies and design methods for seismic isolation systems are introduced in detail, through two practical examples of newly-built high-rise buildings. In both cases, seismic isolation systems contribute to minimize the seismic responses of high-rise superstructures and, as a result, enable the exploration of new structural systems that can mitigate structural damage from earthquakes.

Impetus Behind Seismic Isolation Technology Development

Over the decades, structural engineering and technologies on buildings have advanced drastically in Japan, as the nation experienced more earthquakes. The Great Hanshin Earthquake that struck the Kansai Region in 1995 is considered the seminal earthquake that changed Japan's overconfidence about earthquake resilience and increased public interest in structural safety. In order to meet the needs, for both mitigating damage due to earthquakes and sustain living standards in densely settled cities, high-rise structures and seismic isolation systems were to be considered the most appropriate and favorable technologies.



Figure 1. Sendai MT Building, Sendai. © Neuropower. Source: Wikimedia Commons

The number of high-rise buildings with seismic isolation systems has been increasing in Japan since the debut of the Sendai MT Building in 1999 (see Figure 1), which is 85 meters tall (18 floors) and was the first newly-built high-rise building with this system. The main reason for this trend is supported by recent developments in structural engineering and seismicmitigation technologies, which enable us to widen the capacities of isolation devices and produce high-strength steel and concrete. The merits of connecting high-rise superstructures and isolation devices in series are remarkable, and will lead to more robust and redundant structural systems.

Recent High-rise Buildings With Seismic Isolation Systems

Nakanoshima Festival Tower, Osaka

The original Festival Hall in Osaka was constructed in 1958. The hall boasted 2,700 seats and was characterized by excellent acoustics, referred to as "sound from the heavens." However, in December 2008, it was torn down on its 50th anniversary, to be rebuilt as a new hall.

Nakanoshima Festival Tower (see Figure 2) is a 200-meter-high skyscraper complex comprising offices and the rebuilt Festival Hall. The building is comprised of three major sections (see Figure 3). The lower-level floors include the performance hall. The intermediate-level floors directly above the hall and the upper-level floors are used for offices.

Structural features

The most important proposition from a structural planning aspect was how to achieve the construction of high-rise offices above the large hall while maintaining high structural performance. The following structural strategies were employed:

- Giant trusses to transfer the load of the upper-level floors to the perimeter of the hall and secure the large open space of the hall.
- Mid-story seismic isolation systems on the boundary between the hall and the office floors.

Megatruss/belt truss/prime columns Between the intermediate-level and upper-level floors, two major types of trusses – megatruss and belt truss – are installed (see Figure 4). Through the giant trusses, the entire weight of the upper-level floors was transferred to the 16 columns, which project practitioners referred to as "prime columns," standing outside of the hall.

The megatruss is a gigantic three-dimensional truss structure with a height of approximately 20 meters, extending from the floor of the Level 13 to the floor of the Level 15. It supports a total load of approximately 38,000 metric tons, borne by the nine concrete-filled tube (CFT) columns of the core of the upper-level floors That load flows down to the prime columns.

On the other hand, the belt truss is a planar truss installed as a strip around the perimeter of the 14th floor, and performs the work of consolidating the axial forces of the 128 columns standing around the perimeter of the upper-level floors into the prime columns.



As a result, the prime columns become the columns that support the entire load of the 13th floor and above, and by causing all of the load for the upper-level floors to concentrate via the megatruss and the belt truss into the prime columns, the large hall space of the lower-level floors was realized.

The megatruss diagonals are box braces with a

Figure 2. Nakanoshima Festival Tower, Osaka. © Nikken Sekkei

parallelogram cross section (see Figure 5). The unique shape of the diagonals was designed to place the upper and lower surfaces of adjacent diagonals in the same plane, and, in addition, allow the vertical surfaces on both sides to complete within the skin plates of the box columns. The trapezoid and parallelogram shapes of the prime columns were also decided through consideration of the continuity of the plate materials of the diagonals and lower chords. By employing this cross-section shape, simplification of the joint section and



Façades

Innovative Façade Systems Of Japan



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Tomohiko Yamanashi graduated from the Tokyo National University of Fine Arts and Music and completed his Master Course in Urban Engineering at theUniversity of Tokyo.

He joined Nikken Sekkei in 1986 and is currently the Executive Officer and Deputy Head of the Architectural Design Department, and also heads the BIM & computational design initiative. His works range from offices to museums, and have won many prizes, including the 2014 CTBUH Innovation Award, the 2014 Grand Prix of the Architectural Institute of Japan, and the 2011 Grand Prix of the Japan Institute of Architects.

6 CIn contemporary Japan, *engawa, tategu,* and *arawashi* are extended to the fanatical level, beyond the framework of rationality that normally dictates the design of high-rise building façades.**9** Japanese architecture has traditionally provided for tight integration between the façades of buildings and their overall form, as well as their interiors. Through a combination of traditional vocabularies and sophisticated contemporary technology, new paradigms in façades are being established, with implications for use at much greater scales and heights than before.

Contemporary Japanese Architecture: External Characteristics

In the façade design of contemporary architecture, American, European, and many Asian architects commonly tend to emphasize symbolism in façades, sometimes to the point where it is independent of the overall building form.

Japanese architects have tended not to separate the façade from the overall building form, because the façade is recognized as something that cannot be given its shape independently from the entirety.

For Japanese architects, the façade is where the internal space of the architecture and the external environment intertwine. Furthermore, the façade is where the geographic, climatic, and cultural aspects – which cannot be separated from the structural and environmental systems – also intricately intertwine. A façade is recognized as something that should be "generated" by various conditions that make the architecture possible, rather than something that an architect gives its own independent form.

Five Vocabularies

Five vocabularies are important in considering Japan's tradition-inspired façade design:

Engawa (internal and external continuity)
 As the weather is mild throughout the four seasons in Japan, the façade is considered as an interface that connects the internal and external space, rather than as a boundary that separates the internal from the external. Engawa (veranda) is one of the typical examples. Contemporary Japanese architects are trying to find a way to realize this internal and external continuity within large-scale buildings in contemporary architecture (see Figure 1).

2 Engawa (multi-purpose)

A belief that architectural elements should serve multiple purposes is at the core of Japanese design culture. For example, the *engawa* (veranda) acts not only as an interface that physically connects the internal and external space, but also as a bench where people can sit. Furthermore, it forms a kind of transition space that connects to the back corridor. During winter, it becomes a double skin by closing both the fittings facing the exterior corridor and the fittings facing the rooms. It



Figure 1. Engawa (veranda) in traditional Japanese architecture.



Figure 2. Multi-purpose Japanese *engawa* (veranda). © Mizuho Watanabe



Figure 3. *Tategu* – façade in traditional Japanese architecture, which consists of exposed pillars, beams, and fittings.



Figure 4. Kojo-moe (factory infatuation) in action. © Takuro Watanabe

prevents heat in the room from escaping to the outside (see Figure 2). On the other hand, during summer, both fittings are opened to let the air in. Eaves that cover a large section above the corridor block high-angle sunlight. This is a Japanese aesthetic, in which the exterior has multiple purposes, not only as a boundary between the internal and external space, but also as a circulation path and furnished place of repose. Contemporary Japanese architects aim to imbue this aesthetic in large-scale architecture.

3 *Tategu* (variable adjustments to the environment)

Japanese architecture, which was nurtured through the tradition of wooden structure and earthquakes, is based largely on orthogonal framing that consists of linear pillars and beams. Therefore, exterior or internal partitions are considered as *tategu* (fittings), rather than walls. Fittings that form façades are freely opened and closed. They change and vary the relation of the internal to the external condition in accordance with the season and time. This variety in adjusting to the environment is what Japanese architects look for in the contemporary façade (see Figure 3).

4 Arawashi (exposure)

In traditional Japanese architecture, basic components, such as pillars, beams, and fittings are not hidden, but instead are exposed to compose a design element. This is called *arawashi*.

This ideology of *arawashi* still has a great influence on today's Japanese design

culture. Japanese architects resist to the idea that a façade should be mere "cladding" – external finish material that hides the structure. It is the basic ideology of Japanese architects to compose architectural exteriors with minimum requirements by using only structures and fittings, such as pillars or beams, in exposed status, while the required insulation is provided from the environmental point of view.

5 Suki (refined taste)

Suki is a term that means "complex aesthetic sense," dating from the end of the 16th century to the beginning of the 17th century, when tea-ceremony houses were established. This is one of the concepts that forms the foundation of Japanese aesthetics. Taking some liberties, the author would advocate for strengthening its meaning to be "fanatical inclination in the material beauty or structural beauty that the Japanese people prefer." While the previously mentioned four vocabularies still have the most influence on Japanese architecture, they sometimes tend to be implemented to a fanatical level beyond the framework of rationality.

An analogue for this architectural condition can be found in *kojo-moe* (factory infatuation), in which the display of an industrialized aesthetic is implemented, exposing pipes and other equipment that is normally hidden away (see Figure 4).

In contemporary Japan, *engawa, tategu,* and *arawashi* are extended to the fanatical level, beyond the framework of rationality that

normally dictates the design of high-rise building façades.

These characteristics are obviously seen in the design of Kenzo Tange and the Metabolists, the Modernist movement in Japan in the 1950s and 1960s, which translated International Style into a special kind of localism. For example, the façade of Kagawa Prefectural Government Office (1958) is considered one of Tange's masterpieces (see Figure 5).

In general, the pattern of joists used on the underside of the eaves, reflected in the reinforced-concrete (RC) structure, is often treated as an architectural aesthetic inspired by the joinery used in traditional wood architecture. Although it is polished to be extremely thin, the joist is actually not a cosmetic feature. It is in fact the *arawashi* of the physical structure, and also communicates the theme of "internal and external continuity." Moreover, the balcony surrounding the exterior of the joist bridges the exterior and interior of the building as a modern *engawa*,



Figure 5. Kagawa Prefectural Office, Kagawa.

Fire and Safety

The Fire-Resistant Design of Tokyo Sky Tree



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Since receiving a Bachelor's and Master's of Engineering degree from Chiba University, he has been working for Nikken Sekkei Ltd. for more than 20 years. In 2006, he received a Doctorate of Engineering degree from Chiba University, based on a study of evaluation methods for the ultimate temperature of aluminum alloy structures exposed to fire. His previous works include a number of award-winning buildings, such as NIKKEI Tokyo Headquarters and Ishinomaki Red Cross Hospital.

6 CThe area within about 1,000 square meters surrounding the Sky Tree has a high fireproofing ratio of about 60%, the highest score in the 13.75-square-kilometer Sumida Ward.**9** As a critical asset for the city of Tokyo and its international reputation, the Tokyo Sky Tree was required to incorporate fire safety strategies that matched the importance of its superlative height and unique features. Two significant studies were conducted on Tokyo Sky Tree during the design phase to determine how to evacuate visitors in the event of a fire, as well as how to ensure that structural collapse does not occur. The two studies dealt with characteristic aspects of the building: the "Study of Urban Fires" and "Experimental Verification of the Glass Floor in the Sightseeing Section."

Introduction

Tokyo Sky Tree has an architectural height and height-to-tip of 634 meters, and serves primarily as a broadcasting and observation tower (see Figure 1). Under the provisions of the building standard law in Japan, the tower is classified as a "building within a structure" (see Figure 2), though it does not meet the CTBUH standard of qualifying as a "building," which must have 50% of its height or greater consisting of occupiable space. The tower is divided into two functional sections: a lower section that contains commercial establishments, and a tower section, which serves as an observation facility.

In the event of a fire in the building, the first priority is to ensure that all visitors are evacuated safely. A subsequent concern is that flashover – the near-simultaneous ignition of the directly exposed combustible material in an enclosed area – may lead to structural collapse, depending on the scale and location of the fire. The purpose of fire-resistant design is to prevent this type of collapse.

In fire-resistant design, it is crucial to accurately establish the properties of the fire that will occur at each location. Fires are generally classified according to whether they occur inside or outside the building. For fires inside the building, the design must assume flashover and other fire events. For fires outside the building, the design must anticipate fires that occur near the tower.

During the design of Tokyo Sky Tree, both internal and external fires were considered,

and appropriate fire-resistant coverings and other means were provided to prevent structural instability.

Going Above and Beyond

The fire-resistant design of Tokyo Sky Tree is sufficiently safe for all assumed fires, as required by law. Due to the size and importance of the tower, however, assumptions above and beyond those required by law were used for the design, to enable the building to cope with unexpected fire scenarios.

One example of extensive fire safety design was the strategy undertaken to enable the building to cope with an urban fire that would engulf the area around the tower. The fire-resistant design adopted for Tokyo Sky Tree ensures that there would be no structural problems, even in such an extreme situation. A brief overview of this aspect will be presented in this paper.

Another unique feature of this building is the glass floor of the observation deck, which enables visitors to look down at the ground 300 meters below. If this glass floor should come loose and fall as the result of a fire, it could cause serious damage to the surrounding area, as well as fatalities. To ensure that this will not occur, a fireresistance test was conducted by inserting a full-scale glass floor into a fire-resistance testing furnace, to verify that it can withstand the predicted fire. The results confirmed that no problems would arise. An overview of this test will also be presented.



Figure 1. Tokyo Sky Tree, Tokyo. © Orghi Dean

Verification of the Tower's Integrity During an Urban Fire

An urban fire assessment begins by assuming the degree to which the buildings in the area have been fireproofed. There are many wooden residences in Japan, and major cities such as Tokyo are densely settled. For this reason, it is very important to conduct the assessment based on the location in question: whether it is an area packed with wooden structures that will burn easily, or an area with buildings that will not burn readily – in other words, to determine the degree to which the region has been fireproofed.

This area contains many sections that were subjected to aerial bombardment during the Second World War, and many buildings that would not burn readily were constructed in the reconstruction effort. The area within about 1,000 square meters surrounding the Sky Tree has a high fireproofing ratio of about 60%, the highest score in the 13.75-square-kilometer Sumida Ward.



Figure 2. Distinction between Tokyo Sky Tree's building and structure sections, as well as its low-rise and tower sections.

The next step in the urban fire assessment is to assume where fires will occur near the site, based on the fireproofing ratio of the area. The final step is to assume the temperature of the heat received by the tower section from the heat source of the urban fire, and to study whether or not the framing is safe when exposed to such temperatures. To calculate the temperature of the heat received by the tower section, it is necessary to calculate the maximum temperature distribution of the air currents produced from the fire source. Wind velocity has a particularly great effect on the maximum temperature distribution of air currents. Figure 3 shows the model used to calculate the maximum temperature of the air currents produced by the assumed fire. If the



Japan: A History of Tall Innovations

Japan is one of the world's most densely populated nations, at an average of 339 people per square kilometer.³ It is also one of the world's most active seismic zones. More than 140,000 people died in the 1923 Great Kantō earthquake, which leveled Tokyo. The Tōhoku earthquake and tsunami of 2011 was the world's costliest natural disaster to date, at \$235 billion. The combination of these factors has driven sophisticated design and engineering innovations that responded to Japan's uniquely challenging conditions, including in the tall building field, which continue to this day. This survey examines a number of the most significant tall achievements in modern Japanese history.

silhouette of country's tallest building examines a number of the most significant tall achievements in modern Japanese history. by the end of 2015 average height of all buildings 150 m+ Mapping Japan: Population and Skyscrapers n country by the end of 2015 Map shows data on skyscrapers and population (see key for details). Building outlines show the tallest building in each city projected for the end of 2015. 101,441,830 Footnotes 1. The focus on buildings over 150 meters is driven by the need to ensure accuracy of data, 173 m rather than suggesting that this is the threshold for a tall building. 6 All tall building data is taken from the CTBUH Skyscraper Center as of March 30, 2015. 3. All population data and land mass data is taken from the Statistics Bureau, Japan, 2010 Census, .5% of pop Sapporo 3% Japan Totals JR Towei 2003 **Rest of Japan** Total Population:³ **128,057,352** Total Land Area:3 377,962 km² 256 m 8,949,447 Regional Population Density: 338.8 people/km² 168 m 161 m 0∕₀ 180 m Cities of 1,000,000+ Population:³ 12 Projected by end of 2015... of pop 1% 114 Buildinas Cities with at least one 150 m+ building: 22 City with the most 150 m+ buildings: Tokyo-ku* (114) % Land Axis Tower 2002 Total 150 m+ buildings: 192 Toranomon Hills 2014 Tokyo-ku Tallest building height: 300 m Saitama of total Average height of 150 m+ buildings: 178 m 204 m 168 m 0 Buildings 474.47 190 m 165 m 0% Kobe of total **Kyoto** Park City Musashi-Kosugi Mid Sky Tower 1 2009 City Tower Kobe Sannom 2013 Kawasaki' 234 m 296 m Fukuoka 300 m Nagoya 32 Buildings 176 m 247 m 6 199 m 2.263.907 177 m Fukuoka Tower **Q%** 8% 1989 2 666 37 * The Tokyo Urban Agglomeration is often cited as the most of por of pop % Landmark Tower populous city in the world at 39.5 million people. For this study, 1993 Osaka however, we considered Tokyo-ku (which consists of the 23 central wards that exist within the historical boundaries of Tokyo City; 1889 – 1943), Kawasaki, Yokohama, and all other of pop Yokohama^{*} Abeno Harukas 2014 Midland Square 2007 sections of the Tokyo Urban Applomeration as individual cities Nakagin Capsule Tower, Osaka World Trade Center, 256

meters tall, contained the world's

permanent use in 1972

and became the tallest building

Key

of region population

number of **buildings** 150 m+ in height in city and **percentage** of region total by the end of 2015

height of city's tallest building by the end of 2015

total population of city and percentage

Timeline of Important Skyscrapers in Japan



Note: We can predict 2015 building completions with some accuracy due to projects now in advanced construction.



52nd floor of Shinjuku

March 11, 2011 – Tōhoku Earthquake and Tsunami (magnitude 9.0) kills damage, due to strict Shin-Taishin Building Code introduced in 1981

Japan has had bold skyscraper visions, including Sky City 1000 taller than Mt. Fuji, it is the tallest

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Talking Tall: Hiroo Mori

The Vertical Garden City Grows Into the 21st Century



Hiroo Mori

Interviewee

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Hiroo Mori

Previously with the Industrial Bank of Japan since 1986, Hiroo Mori Joined Mori Building Co., Ltd. in 1995. He was appointed Managing Director in 2000, Senior Managing Officer in 2003, and Senior Executive Managing Officer in 2011. He has held his current position of Executive Vice President since June 2013. Mr. Mori has also been Chairman of Shanghai World Financial Center Investment Co., Ltd. and Chairman of Shanghai World Financial Center Co., Ltd. since 2005. He was appointed President and CEO of the Mori Hospitality Corporation in 2012. Mr. Mori is a graduate of Tokyo University, Faculty of Economics.



Figure 1. ARK Mori Building, Tokyo. © Chris73. Source: Wikipedia

As host of the 2020 Summer Olympics, Tokyo is undertaking a major redevelopment effort, giving long-planned projects new energy under the political impetus of the games. At this auspicious time, Mori Building, the developer of the ARK Hills, Roppongi Hills, and Toranomon Hills tall building complexes, and the host of the inaugural CTBUH Japan Symposium, *Vertical Habitat – Vision 2020 and Beyond,* is in a strong position to shape the future urban landscape of the city. CTBUH Journal Editor Daniel Safarik interviewed Hiroo Mori, Executive Vice President, Mori Building, who has led the construction of several critical projects in Japan, as well as the Shanghai World Financial Center in China.

Mori Building has created some of the best-known tall buildings and public-private spaces in Japan. What is the guiding philosophy behind its tall building projects? We always ask ourselves, "what makes an ideal city, one capable of thriving in the midst of fierce competition with other global cities?"

The key question that follows is, "how can a city generate the 'magnetic power' it needs to attract people, goods, money and information from around the world?"

Our answer is what we call the "Vertical Garden City" concept. Since it is not usually possible to add new land to cities, our concept opens up existing space in urban environments by building vertically, both into the sky and into the ground. Replacing countless low-rise structures with a relatively small number of massive high-rise structures efficiently concentrates diverse urban functions for residences, work, commerce, education, leisure, culture, human interaction, and more. By building vertically, we create compact cities where people have enhanced mobility and accessibility, often on foot, for the enjoyment of fuller, more rewarding private and professional lives.

Mori Building first implemented its Vertical Garden City concept in 1986 with ARK Hills, Japan's first privately built large-scale mixed-use urban complex. Centered on the 37-story ARK Mori Building (see Figure 1), ARK Hills also offers residences, a hotel and a concert hall. Thereafter, in 2003, we opened Roppongi Hills (see Figure 2), a mixed-use cultural complex. Revolving around its centerpiece, Roppongi Hills Mori Tower, a skyscraper crowned with a museum and observation deck, Roppongi Hills combines diverse urban functions, including residences, a hotel, and a TV station. And in 2014, we launched Toranomon Hills, which is catalyzing Tokyo's Toranomon-Shinbashi area as a new international hub. Toranomon Hills (see Figure 3), rising 52 stories and 247 meters as Tokyo's newest landmark, the project encompasses offices, residences, hotels, international conference rooms and shops, plus Loop Road No. 2, a key Tokyo



Figure 2. Roppongi Hills Mori Tower, Tokyo. © KPF

thoroughfare, routed efficiently underneath the complex.

Why does Mori consider it important to develop major public areas?

Urban complexes offer diverse functions ranging from work and residence to leisure, shopping, culture, and human interaction. We want to enrich urban life by creating large public spaces where people can enjoy their time together, as well as enjoy the outdoors, abundant greenery and cultural facilities, such as museums and concert halls.

What kind of role does Mori expect to play in the upcoming Tokyo Olympics in 2020? Can you attribute any current or future projects to the Olympics? What kind of partnerships will Mori undertake with the government to assist with issues like transportation, accommodation of visitors and athletes, and redevelopment of Olympic sites after the event?

Tokyo plans to significantly redevelop its urban infrastructure. The city's selection as host of the 2020 Summer Olympic and Paralympic Games has created a shared focus and timeline for all of us involved in this undertaking. This is very significant, because it will be like a powerful wind at our backs, helping us to accelerate ongoing efforts to redesign and redevelop Tokyo.

As one example, Toranomon Hills, which Mori Building opened up in June 2014, has an Olympic connection. The complex is integrated with the newly extended Loop Road No. 2, a key trunk route that had been planned for many years. In a public-private partnership led by Mori Building and the Tokyo Metropolitan Government, the road was extended underground through the Toranomon-Shinbashi area, with Toranomon Hills built over and around it. Ultimately, this "Olympic Road" will tie together Haneda International Airport, the Tokyo 2020 Olympic Village, and the main Olympic Stadium. Moreover, directly above the tunnel is a surface street that is being transformed into Tokyo's version of L'Avenue des Champs-Élysées.

The Japanese economy has been a subject of concern recently. How does this affect or change Mori's plans for future developments?

A key to Japan's continuing economic revitalization is urban redevelopment. Indeed, urban redevelopment is an integral part of Prime Minister Abe's national growth strategy. Tokyo is the starting point; and in fact, redevelopment projects in the city are accelerating. Mori Building, an expert on urban redevelopment, is making the most of this opportune timing to push forward with initiatives that ultimately will contribute to the revitalization of Tokyo and thereby the economy of Japan.

Asia is not a monolithic place. Even though Mori predominantly has worked on tall buildings in only three countries - Japan, China, and Malaysia – how would you describe Mori's efforts to produce tall buildings that make sense culturally as well as economically in these countries? Yes, Mori Building has concentrated its development of high-rise buildings in countries such as Japan and China. Asian cities tend to be congested with residences and offices, so by applying our Vertical Garden City concept to make efficient use of vertical space, we are creating compact urban settings where people can enjoy shorter commutes and richer, more varied lives. Going forward, we believe that our urban design concept can be applied in other emerging cities of Asia where urbanization is advancing rapidly.

Do you have expansion plans outside of these countries? Outside of Asia?

Mori Building is looking beyond Japan and China into Southeast Asia. In 2014, we opened a new representative office in Singapore, which joins our existing offices in Shanghai, Dalian, Seoul, and Hong Kong. Rapid urbanization and economic growth in many Southeast Asian cities are creating growing demands for high-quality buildings and development. Our new Singapore Representative Office will engage in research and marketing, targeting real estate investment, development, and consulting. At



Figure 3. Toranomon Hills, Tokyo. © Kanazawa1999. Source: Wikipedia

this point, however, we do not have any specific plans for business outside of Asia.

With the recent passing of Jon Jerde – who designed the public spaces and shopping areas of Roppongi Hills as well as several other successful projects in Japan – what architects do you think share your philosophy about developments that are integrated into cities and feel like neighborhoods? Who have you not worked with yet, but would like to?

Mori Building undertakes major projects in collaboration with some of the world's most renowned architects and designers, including Jon Jerde, Terence Conran, KPF, Cesar Pelli, Tadao Ando, Fumihiko Maki, and SAANA. We will continue to work with such top innovators, sharing our urban design concepts and philosophies in a joint effort to develop highly advanced cities.

What role should tall buildings have in making their cities?

High-rise buildings play a very important role in relieving urban congestion. By vertically concentrating urban functions in tall buildings, we open up ground space for more practical uses, including greenery, transportation networks and much more, thereby creating compact cities where people can enjoy enhanced accessibility. While it takes time to design such cities, the 2020 Olympics are creating an opportunity to apply these benefits in an accelerated fashion, driving Tokyo's development.

About the Council

The Council on Tall Buildings and Urban Habitat is the world's leading resource for professionals focused on the inception, design, construction, and operation of tall buildings and future cities. A not-for-profit organization, founded in 1969 and based at the Illinois Institute of Technology, Chicago, CTBUH has an Asia office at Tongji University, Shanghai, and a research office at luav University, Venice, Italy. CTBUH facilitates the exchange of the latest knowledge available on tall buildings around the world through publications, research, events, working groups, web resources, and its extensive network of international representatives. The Council's research department is spearheading the investigation of the next generation of tall buildings by aiding original research on sustainability and key development issues. The free database on tall buildings, The Skyscraper Center, is updated daily with detailed information, images, data, and news. The CTBUH also developed the international standards for measuring tall building height and is recognized as the arbiter for bestowing such designations as "The World's Tallest Building."



Council on Tall Buildings and Urban Habitat

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