CTBUH Journal

Tall buildings: design, construction and operation | 2008 Issue III

China Central Television Headquarters

The Vertical Farm

Partial Occupancies for Tall Buildings

CTBUH Working Group Update: Sustainability

Tall Buildings in Numbers

Moscow Gaining Height Conference

Australian CTBUH Seminars

Council on Tall Buildings and Urban Habitat

Editor's Message

Zak Kostura, Editor

The CTBUH Journal has undergone a major transformation in 2008, as its editorial board has sought to align its content with the core objectives of the Council. Over the past several issues, the journal editorial board has collaborated with some of the most innovative minds within the field of tall building design and research to highlight new concepts and technologies that promise to reshape the professional landscape for years to come. The Journal now contains a number of new features intended to facilitate discourse amongst the membership on the subjects showcased in its pages. And as we enter 2009, the publication is poised to achieve even more as brilliant designers, researchers, builders and developers begin collaboration with us on papers that present yet-to-be unveiled concepts that change the way we think about tall buildings and the urban habitats that develop within, around, and beneath them.

This current issue of the Journal follows suit, as it showcases the research and work of researchers and designers who have envisioned the tall building typology as a vessel for social, cultural and economic activities that have not as yet reached their true potential for enhancing urban life, and in some cases have not to date been implemented in large measure anywhere in the world. The concept of vertical farming for instance, presented in the following pages by Eric Ellingsen and Dickson Despommier, holds promise to revitalize every stage of food production by importing the entire complex system to the city and housing it within highly specialized tall buildings adapted for this purpose. It is a notion that is not without its pragmatic quandaries, but one whose merits more than justify in-depth exploration.

Robert Lau explores a series of novel construction projects involving post-occupancy construction, which has facilitated early revenue generation for developers who have been bold enough to join this emerging trend. A number of very prominent cases are studied, and fundamental considerations for each stakeholder in such a project are examined.

The forward thinking perspectives of our authors in this issue are accompanied by a comprehensive survey of the structural design approach behind the new China Central Television (CCTV) Tower in Beijing, China. The paper, presented by the chief designers behind the tower structure, explores the groundbreaking achievements of the entire design team in such realms as computational analysis, optimization, interpretation and negotiation of local codes, and sophisticated construction methodologies. Many of the considerations made by the design team throughout design and construction are thoroughly discussed, and paint a vivid portrait of many modern challenges facing the most geometrically complex towers of our time.

These papers, presented here in this issue of the CTBUH Journal, represent only a few of the many groundbreaking subjects that are currently being explored by contributors from every corner of the industry, who are today working with our editorial board to develop pieces that will be featured in our future issues. As we continue to grow, we look to our membership to participate in this evolution, by participating in the development of a paper on a topic of interest, or serving on the editorial board as an advisor or peer reviewer. If you would like to contribute to the Council through the authoring of a paper or conducting peer reviews, please contact us at journal@ctbuh.org. On behalf of the Council, I look forward to hearing from you.

Best Regards,

Zak Kostura

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Eric Ellingsen and Dickson Despommier, page 26

Visit www.ctbuh.org for more on the global tall building industry and the Council on Tall Buildings and Urban Habitat

Global News

The CTBUH Global News Archive is an online resource for all the latest news on tall buildings, urban development and sustainable construction from around the world. Each issue, the CTBUH Journal publishes selected feeds from the online archive. For comprehensive industry news, visit the Global news Archive at: www.ctbuh.org/news.htm

Nakheel Harbour & Tower: World's Tallest Building Under Construction

The initiation of foundation works by Nakheel on the new Harbour and Tower development in Dubai has bestowed upon the developer possession of the speculative title of "Tallest Building Under Construction in the World". While the final height for the signature tower has not been announced, the developer has asserted that the structure will reach "more than a kilometer in height", and contain more than 200 occupiable floors.

Designed by architect Woods Bagot and engineered by WSP in conjunction with Leslie E. Robertson Associates, the Nakheel tower bears marks of aesthetic influence from the surrounding Islamic architecture, and integrates an innovative structural design strategy employing a series of individual towers linked at critical floors to create a rigid bundled tube system.

The developer has announced its goal of achieving the highest LEED rating possible for a building of this size. The megaproject includes another 40 towers of substantial, if comparatively modest size, ranging from 20 to 90 stories. In all the complex is expected to reach completion in ten years, with various phases (including the signature tower) coming online at earlier stages.

Songdo City Gateway Center to be designed by KlingStubbins

The 3.4 million square foot Gateway Business Center that will form the entrance to Songdo City – the new 1,500 Acre international business district in Incheon, South Korea – is to be designed by Philadelphia firm KlingStubbins. The Center will consist of five undulating glazed office towers, sitting atop a multi-level retail base with underground parking facilities. Each of the towers will have a rooftop garden sheltered by 12-meter-high glazed walls and a trellis of photovoltaic panels. The gardens will offer building occupants sweeping views of the dramatic Songdo skyline, Central Park and the Yellow Sea. In terms of sustainability, the designers are striving to achieve LEED Silver certification for the building.

Economic Crisis Slows Chicago's High-rise Boom

The tall building boom that has seen 32 of the tallest 100 skyscrapers in Chicago completed or under construction in the last 8 years, has been dealt a blow by the news that construction on two of the city's future supertall towers has been put on hold. The Chicago Spire - set to be the tallest building in North America at 610 meters upon completion – and the 319 meter tall Waterview Tower (pictured) have both halted construction in recent weeks, with little indication as to when they may resume. Shelbourne, the Chicago Spire developers, say they will start working on the superstructure again when the market stabilizes and are in

...density

"Architects have to really embrace density… Policy makers need to put their futurist hat on and understand that density is coming. Instead of fighting it, they need to find ways of making it work."

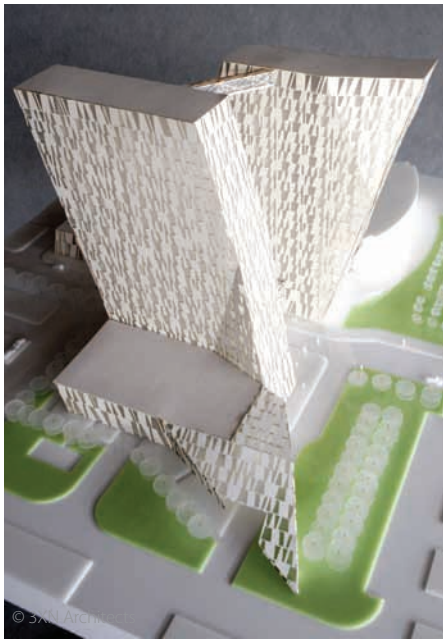
Stephan Reinke, European managing director of Woods Bagot, discusses how further tall building construction is inevitable, following a report from the British Property Federation arguing that tall buildings reap significant productivity gains as people work more closely together through competition, networking and economies of scale. From 'Towers will aid growth, says BPF', Building Design, September 9th, 2008

talks with a general contractor to build it. The building foundations and underground car-park have been already completed.

However, construction on some of the city's other tall buildings is continuing with vigour; in October construction workers reached the 59th floor of the 82-storey Aqua tower, which upon completion next year will be the 12th tallest building in Chicago at 251 meters tall. Meanwhile, November will likely see the installation by helicopter of the 69 meter-tall spire atop the Trump International Hotel & Tower, bringing the building up to its full height of 415 meters. Upon final completion in 2009, it will become the second tallest building in America.

Sky Garden Tower planned for London

Architects Amin Taha Associates and Carey Jones in conjunction with developer Fraser Property Development have released plans for a new 120 meter-tall skyscraper at Vauxhall in London. The scheme – known as the 'Vauxhall Sky Gardens' – consists of a 35-storey tower with over 9000m² of office and retail space on the lower storeys and 178 residential apartments above. The design includes two significant communal skygardens; one on the eighth floor and the second at the top of the tower. These triple-height spaces will provide all residents with access to planting and amenity spaces all year round. In addition all flats will benefit from glazed winter-garden-style balconies. In terms of sustainability, the project plans to utilize a photovoltaic array located on the roof of the tower and a gas-fired combined heating and power unit.



Leaning towers of Copenhagen

The foundation stone for the new four-star Bella Hotel was laid in Copenhagen in September. Comprised of 814 rooms, 32 conference facilities and 3 restaurants split between two dramatically leaning towers, the new complex is already being boasted as the premiere international event venue in what was recently deemed "the best city in the world to live in" by Monocle.

Designed by 3XN Architects, the adjacent towers of the Bella Hotel incline in opposite directions as they rise, permitting dramatic views of the surrounding landscape from both sides of each tower. The modest twist in the wing of each cantilevered tower was included to improve the towers' dynamic performance under the steady winds that persist on the site.

The Bella's towers rise to a height of 76.5m, joined at their adjacent faces by a central, low-rise foyer. Motivated by the desire to maiximize views on all faces of the two towers, the designers have asserted that the added cost of inclining the structure is relatively modest. Addressing the impact of the inclined towers, Kim Herforth Nielsen, Principal Architect at 3XN asserts, "construction costs – only went up 5 per cent."

Tour T1 becomes second tallest building in France

The completion of the 185 meter-tall Tour T1 in the La Défense region of Paris has seen the building become the second tallest in France, behind the 209 meter-tall Tour de Montparnasse. Designed by French architectural firm Valode and Pistre the 70,000m² office tower is conceived as a folded glass plate, cut by an arc on its north face. According to the Valode and Pistre, its distinctive profile changes according to one's vantage point and assures the tower's place within the surrounding context. Seen from the south, the tower appears as a ship's bow, a vertical element and a complement to the skyline of the La Défense business district. Seen from the east and west, T1 is perceived as a large sail, its curving form providing transition to the lower scale of the adjoining neighbourhood. The view given by the north façade is one of a tall staircase, climbing to the sky and disappearing as the façade curves out of view.

Case Study: CCTV Building - Headquarters & Cultural Center

Authors

Chris Carroll, Paul Cross, Xiaonian Duan, Craig Gibbons, Goman Ho, Michael Kwok, Richard Lawson, Alexis Lee, Ronald Li, Andrew Luong, Rory McGowan, Chas Pope

Arup

Arup is a global firm of designers, engineers, planners and business consultants providing a diverse range of professional services to clients around the world. The firm has over 10 000 staff working in more than 90 offices in 37 countries.

Arup has three main global business areas – buildings, infrastructure and consulting – although their multi-disciplinary approach means that any given project may involve people from any or all of the sectors or regions in which they operate. Arup has extensive experience in the field of tall buildings, having provided core multidisciplinary design services for such notable projects as 30 St. Mary Axe in London, the International Commerce Center (ICC) in Hong Kong, and the I.Q. Tower in Doha, Qatar.

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Figure 1. Architect's impression of the building

The new headquarters of China Central Television contains the entire television-making process within a single building. The 234m tall tower redefines the form of the skyscraper, with the primary system comprised of a continuous structural tube of columns, beams and braces around the entire skin of the building. In order to gain structural approval an Expert Panel process was necessary, for which a performance-based analysis was carried out to justify the design. This made extensive use of finite element analysis and advanced non-linear elasto-plastic time history to evaluate the structural behaviour and ensure the building safety under different levels of seismic event. The leaning form and varied programme, including the need to accommodate large studio spaces, posed additional challenges for the gravity structure, and resulted in the introduction of a large number of transfer trusses throughout the tower. Erecting and connecting the two massive towers presented the structural engineers and contractors with further design and construction challenges.

Introduction

This article describes the structural design and construction of the CCTV Building in Beijing, including development of the structural concept, performance-based seismic design and Expert Panel Review process.

"Prior to connection, the two Towers would move independently of each other due to environmental conditions, in particular wind and thermal expansion and contraction. As soon as they were joined, therefore, the elements at the link would have to be able to resist the stresses caused by these movements. "

Architectural Concept

China Central Television (CCTV), the country's state broadcaster, plans to expand from 18 to 200 channels and compete globally in the coming years. To accommodate this expansion, they organized an international design competition early in 2002 to design a new headquarters building. This was won by OMA (Office of Metropolitan Architecture) and Arup, which subsequently allied with the East China Design Institute (ECADI) to act as the essential local design institute (LDI) for both architecture and engineering.

The unusual brief, in television terms, was that all the functions for production, management, and administration would be contained on the chosen site in the new Beijing Central Business District (CBD), but not necessarily in one build-

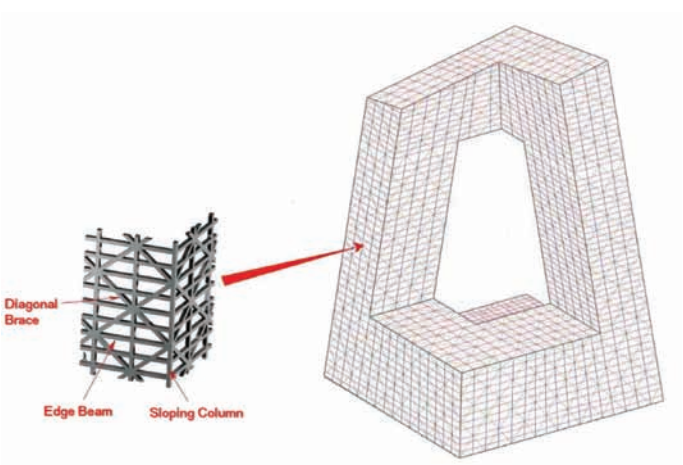

Figure 2. Uniform bracing pattern

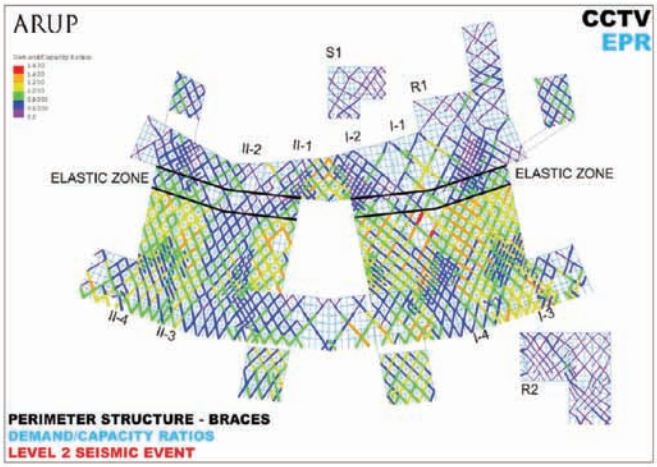

Figure 3. 'Unfolded' view of final bracing pattern

ing. In their architectural response, however, OMA decided that by doing just this, it should be possible to break down the 'ghettoes' that tend to form in a complex and compartmentalized process like making TV programmes, and create a building whose layout in three dimensions would force all those involved to mix and produce a better end-product more efficiently.

The winning design for the 473,000m^2, 234m tall, CCTV building (see Figure 1) thus combines administration and offices, news and broadcasting, programme production and services – the entire TV-making process – in a single loop of interconnected activities around the four elements of the building: the nine-storey 'Base', the two leaning Towers that slope at 6° in each direction, and the nine to 13-storey 'Overhang', suspended 36 storeys in the air.

The public facilities are in a second building, the Television Cultural Centre (TVCC), and both are serviced from a third Service Building that houses major plant as well as security. The whole development will provide 599,000m^2 gross floor area and covers 187,000m^2, including a landscaped media park with external features.

Development of the structural form

From the outset, it was determined that the only way to deliver the desired architectural form of the CCTV building was to engage the entire façade structure, creating in essence an external continuous tube system. This would give the structure the largest available dimensions to resist the huge bending forces generated by the cranked, leaning form – as well as loads from wind and extreme earthquakes.

The 'tube' is formed by fully bracing all sides of the façade. The planes of bracing are continuous through the building volume in order to reinforce and stiffen the corners. The system is ideally suited to deal with the nature and intensity of permanent and temporary loading on the building, and is a versatile, efficient structure which can bridge in bending and torsion between the Towers, provide enough strength and stiffness in the Towers to deliver loads to the ground, and stiffen up the Base to reinforce the lower Tower levels and deliver loads to the foundations in the most favourable possible distribution, given the geometry.

The tube was originally envisaged as a regular pattern of perimeter steel or steel-reinforced concrete (SRC) columns, perimeter beams, and diagonal steel braces set out on a typically two-storey module (see Figure 2). This was chosen to coincide with the location of several double-height studios within the Towers. A stiff floor plate diaphragm is therefore only guaranteed on alternate storeys, hence lateral loads from intermediate levels are transferred back to the principal diaphragm levels via the internal core and the columns.

However, results of the preliminary analysis showed that the forces in the braces varied considerably around the structure, with particular concentrations near the roof of the Overhang and at the connection to the Base. This led to an optimization process in which the brace pattern was modified by adding or removing diagonals (i.e. 'doubling' or 'halving' the pattern), depending on the strength and stiffness requirements of the design, based on a Level 1 earthquake analysis. This also enabled a degree of standardization of the brace element section sizes (see Figure 3).

This was an extremely iterative process due to the high indeterminacy of the structure, with each changing of the pattern altering the dynamic behaviour of the structure and hence the seismic forces that are attracted by each element. It was carried out in close

The Vertical Farm – The origin of a 21st century Architectural Typology

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"While no one questions the value of farming in getting us to this point in our evolutionary history, even our earliest efforts caused irreversible damage to the natural landscape, and are so wide-spread now that it threatens to alter the rest of the course of our life on this planet."

Though often bandied about by architectural form chasers, the invention of typologies are rare. The fortuitous resultant of social imperatives, cultural and economic necessity, intractable environmental pressures and technological prodigality, architectural typologies, like real paradigm shifts, are mostly nothing more than UFO sightings: stories dreamt up in bars and wishfully elaborated for credibility in digital manifestoes.

"The duct is one of the most monumental [innovations] in the history of environmental engineering."

Reyner Banham (Banham, 1969)

However, one such occurrence can be noted at the opening of the 20th century, which did not appear as visibly among all the wonderful—indeed they are extraordinary!—avant-garde manifestoes. It is the modern hospital as a new architectural typology and the untold (and not adequately told here) history of the duct (think of the Vertical Farm as Reyer Banham might, a history of the near future).

In 1906 the Royal Victoria Hospital, by Henman and Cooper, opened in Belfast, Ireland. (Banham, 1969). It was the first modernized, air-conditioned building in the world, and launched the hospital as an apparatus that simultaneously reached across multiple scales of engagement. It addressed and organized the internal needs of a person and the internal control of a building environment, to the mediation of an external population of individuals and the external conditions of the natural environment. It was the functional relationship between parts, rooms, program, mechanical and natural systems of exchange and circulation that allowed the hospital to become a finely tuned and controlled instrument of beauty, very literally an organon of change. (Organic has Greek roots from Organon: instrument, tool. (Rykwert, 1992)). At that moment architecture evolved as a modern enterprise, not merely a structural revolution, but the material embodiment of a networked, technical, spatial assemblage where 19th century structural revolutions of the steel frame could be enmeshed with mechanical technology, the individual, the microbe, the city. It was near this time that the surgical suite replaces the anatomical theater, and the natural environment is linked together in a living mechanical architectural system, which addressed social, societal, political, biological, and individual needs. It was the duct which permitted the reinvention of the hospital, which had been in existence since 4000BC. Thus a mechanism of exchange and environmental controls becomes the impetus for both new typologies, and a new breed of architecturally mediated and controlled environmental possibilities, pressures, and constraints, possibilities which leaps and

mutates from the hospital and proliferated into variations at every architectural scale, from house to office, studio to indoor stadium.

The Vertical Farm is a correlate of the modern city, offering stability while embracing the change. Far from fantasy, the Vertical Farm scoops up the available ducts and technologies at the opening of the 21st century, organizing and redistributing otherwise unrelated parts, grafting together everything available, from NASA Biosphere control systems to Greenhouse technology. What is crucial to understand at the outset is that the Vertical Farm is a complex system rather than a single building. In other words, the Vertical Farm is not merely a building where you grow tomatoes and shortened corn situated in the milieu of an urban setting; rather, the Vertical Farm is a functional part of the urban system itself. The Vertical Farm is not merely a skyscraper with farm plots chopped up like strips of turf and rolled into FAR [foot to area ratio] rationed floorplates. Indeed, the Vertical Farm is not merely about food, but about the unseen circuits of energy and materials, labor and resources, capital and infrastructure, technology and politics upon which our cities depend; food is only a single component of the Vertical Farm, the most visible part, the market and marketable part (imagine the politically marketable 'greenness' of a 1000ft luscious cornicopic living transparent zone of fertility next to the black steel and glass skyscraper in your city); food, the only part of farming which consumers see while the rest of the industrial process remaining invisible, unquestioned, absolved by sheer ignorance. Essentially, the Vertical Farm allows us to address in one ambitious but realistic strategy, the precarious and tricky crisis of modernity between the individual and the city, which French philosopher Paul Ricour stated so poignantly, it allows us to participate in the local place and global flow at the same time, to embrace modernity and simultaneously return to our roots." (Ricour, 1965) Those roots simply exist 1000 feet above the ground. (A ground which would be better served by forests than by feed-stock, as it turns out.)

The Vertical Farm, as perceived by the public, is choreography of food visibility. Food is the most dynamic and complex of systems in the 21st century, requiring a web of interrelationships. Yet we often forget, as Wendell Berry states, that "eating is an agricultural act." (Berry, 1990) Therefore, the first thing the vertical Farm does is mediate the visibility of the production of food. The Vertical Farm helps you realize that your engagement with the world, particularly in terms of what you eat, has consequences.

As you approach the Vertical Farm from a distance, you witness transparent shelves of color and texture cantilevered off the structural core of the living system (see Figure 1). The shelves are agricultural programmed boxes, each striated with modern fields of ripe agricultural foliage: vegetation, fruits, etc. (Note: the particular foods in each shelf would be controlled to cancel the foods traveling the most miles to your now truly sustainable city, and, be selected around the individual dietary and cultural palette of the community). Also, springing from the structural core, you notice residential apartments set like seeds into the more hermitically sealed laboratories in which the agricultural systems would be researched and initially cultivated for control purposes and finally deployed, by way of the core, into the shelves. Apartments to both scientists and students, the Vertical Farm also contains program for private residences, and for those residents, gardens and vertical parks linking the outside of the shelves with the living and the labs (see Figure 2). As you look closer you will notice that some of the programmatic shelves contain grazing colors, which seem to be in motion. Upon closer inspection (see Figure 3) you notice pigs and chickens, not the sour image via noisome smell of the factory farm hidden out of site and attempting to evade the eye, but rather sterile and proud public animal production. Finally, you will notice two systems of tanks; one system comprised of smaller pools filled with fish and shrimp, the other much larger tank linked into a waste water and bio-solid treatment facility, looking much like active industrial

Figure 1. The Vertical Farm model from above as seen in the Museum of Science and Industry, Chicago.

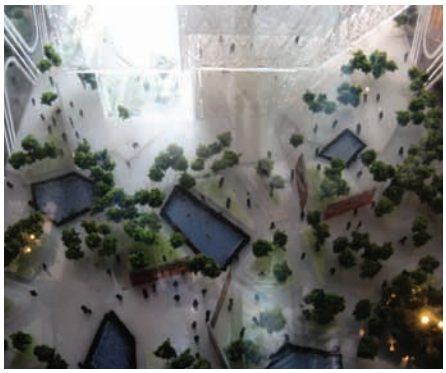

Figure 2. The Vertical Farm Park at base of model

Figure 3. A vertical Farm in Dubai. Design by Eric Ellingsen and Dickson Despommier. Image by Eric Ellingsen, Homero Rios, and Mo Phala.

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 actively undertakes research into relevant fields in conjunction with its members and industrial partners, and has in place an international 'Country Representative' network, with regional CTBUH representatives promoting the mission of the Council across the globe.

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.

Council on Tall Buildings and Urban Habitat

Council on Tall Buildings and Urban Habitat

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