Title: **A New Skyline Vision: CTF Towers in Guangzhou and Tianjin**

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A New Skyline Vision: CTF Towers in Guangzhou and Tianjin
天际线的愿景: 广州与天津两地的周大福大厦

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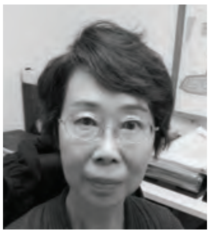

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Abstract

This paper presents the thinking behind the design of the two supertall towers of Chow Tai Fook Enterprise– the Guangzhou CTF Finance Center and the Tianjin CTF Finance Center. With similar mixed-use programs for Office/Hotel/Serviced Apartment/Retail development, the two towers adopted different design approaches. Located along the main axis of a new burgeoning CBD of Guangzhou, CTFGZ tower's dynamic setbacks integrate well with the various program types and acknowledge the heights of nearby towers. CTFTJ Tower adopts a more vigorous integration of architecture and structural engineering, where the tower tapers dramatically to suit different lease spans of the mixed-use program. The aerodynamic shape, including sloping columns aims to produce a cost-effective structural design, reduction of vortex shedding and seismic reaction. Both designs have made the best endeavor to respond and contribute to the urban context, cultural environment and sustainable development.

Keywords: CTF, Tall Buildings, Integrated Design, Composite, Terracotta, Sustainable

摘要

本文介绍周大福企业在中国的两栋超高层建筑的设计概念——广州周大福金融中心和天津周大福金融中心。两项目在相近的"办公楼/酒店/服务式公寓/零售"的发展功能要求下，采用了不同的设计方法。位于蓬勃发展的广州珠江新城中心商务区主轴线上，广州周大福金融中心的动态退台设计完美包含了各种功能性空间，其高度呼应了周边的建筑。 天津周大福金融中心的设计进取地融合了建筑美学和结构力学，其中塔楼优美的体量竖向收分满足了各种功能性空间的使用要求，其富流线的外形，以及倾斜柱的设置都提供了具成本效益的设计，有效益地减少风涡流和地震反应。这两项目设计为城市肌理，文化氛围和可持续发展提供莫大的贡献。

关键词: 周大福，高层建筑，综合设计，合成材料，陶瓷板，可持续发展

Guangzhou CTF Finance Center

Location and Development Program

Guangzhou, the capital of Guangdong province, is China's third largest city and the de facto cultural hub of the 13-million inhabitant Pearl River Delta megalopolis. When completed, Guangzhou CTF Finance Center (CTFGZ) will be the city's tallest building, an icon that represents the staggering urban growth and new prosperity of the entire region (see Figure 1).

CTFGZ is a 530-meter tall, mixed-use tower located along east of the central axis of Zhujiang New City of Tianhe District. Together with Guangzhou IFC at the west, the two form a dramatic and elegant pair of towers on Guangzhou dynamic skyline, echoing the focus of the central axis - Canton (TV) Tower at the south (see Figure 2). Zhujiang New City is a burgeoning CBD that is quickly becoming Guangzhou's new recreational, commercial and lifestyle center. Cultural icons such as the Guangzhou Opera House, Guangdong Museum, Guangzhou Library are in the near vicinity.

广州周大福金融中心

位置及发展计划

广东省省会广州位于珠江三角洲，是中国第三大城市及拥有1300万人口的大都会文化枢纽。广州周大福金融中心落成后，将成为全广州最高的建筑物，这一地标，象征着惊人的城市发展速度及整个地区的繁荣昌盛 (见图1) 。

广州周大福中心位于珠江新城天河区中轴东侧，楼高530米，与西侧的广州国金中心一起构筑了广州富有动感和美感的天际线，与位于南面中轴上的中心建筑——广州电视塔形成呼应 (见图二) 。珠江新城作为迅速发展的中心商务区是广州市新的休闲、商业及生活中心，毗连文化地标广州歌剧院，广东博物馆及广州图书馆。

毗邻一个大型的中央公园和附设交通换乘站的地下商场，广州周大福中心的塔楼及裙房将提供221,000平方米的甲级办公楼，71,000平方米的服务式公寓，41,000平方米的豪华酒店和62,000平方米的零售空间。阶梯式裙房与螺旋形屋顶平台设有酒店宴会厅、多功能室、餐厅和电影院。建成后，在日常高峰期可容纳超过三万人。

CTFGZ is adjacent to a large central park and a subterranean retail concourse with transportation interchanges. The tower and a podium will house a mix of programs including a 221,000 m^2 Grade-A Office, 71,000 m^2 of Serviced Apartment, 41,000 m^2 of Luxury Hotel and 62,000 m^2 of Retail. A stepped podium with spiraling roof terraces houses the hotel ballroom, function rooms, restaurant and cinema. At its daily peak, the completed development will accommodate more than 30,000 people.

Architect's Design Concept

The design of CTFGZ derives naturally from an efficient integration of various program types and sensitive responses to urban context. The tower is sculpted at four major transition points, they are: Office to Serviced Apartment; Serviced Apartment to Hotel; Hotel to Crown and Crown to Sky. These dynamic setbacks are also sculpted to acknowledge the varying heights of the nearby towers and to pronounce a crescendo on the city's ever-expanding skyline. The overall effect of the tower is of a crystalline form ascending to the sky. This formal vocabulary extends to the podium, with stepping terraces that frame a large atrium skylight.

A simple, elegant tower form reflects its multiple uses and urban context. Rooftop spaces and setback terraces compliment a luxury lifestyle hotel and serviced apartment duplex villas in China's third largest City's skyline.

The tower's façade is designed to emphasize its verticality. Long serrated strips of terracotta extend from the tower base and wrap around the tower's chiseled setbacks. Terracotta-integrated mullions with operable vents, and low ratio of vision glazed area enable achievement of a high environmental-performance design, and at the same time capturing of the desired architectural language.

Kohn Pedersen Fox's (KPF) design responded and contributed to the urban and cultural environment. CTFGZ has been designed to LEED® Gold standards.

Tallest Terracotta Clad Tower

CTFGZ, when built, will be is the tallest terracotta clad tower in the world. The use of terracotta at this great height is beyond any jurisdiction of the PRC Codes. Thus an Expert Panel Review (EPR) was held to procure approval from the authority. Testing and justification evidences were carried and produced, these include additional quality assurance inspections, destructive testing, and wind tunnel testing.

As a landmark for a city of multiple cultures, the tower's façade material is expected to play an important role to bridge the Eastern and Western cultures. Terracotta was used as a building material back in Roman times. It's application was very popular during the American's early 20th Century skyscraper boom. China has a long history of white glaze and "crackle-effect" terracotta, dating back to the Han and Song Dynasty – here CTFGZ uses this effect in the façades, imaging a traditional Chinese vase (see Figure 3).

Environmental-wise, the embodied energy of terracotta is far less than that of aluminum, glass, or steel. It is self-cleansing and extremely corrosion-resistant. Being clad in renewable resource that is so close to nature, CTFGZ symbolizes a future where sustainable strategies drive economic development.

Structural Design

The structural form of 530m tall CTFGZ adopts a mega-column outrigger core system which promises the advantage of uninterrupted views when compared with other structural options such as tube-in-tube and mega bracing systems (see Figure 4).

Figure 1. Guangzhou CTF Finance Center (CTFGZ) (Source: Kohn Pedersen Fox)
图1. 广州周大福金融中心（CTFGZ）(来源: Kohn Pedersen Fox)

Figure 2. CTFGZ Anchoring Zhujiang New City In Guangzhou's Tianhe District (Source: Kohn Pedersen Fox)
图2.广州周大福金融中心锚固珠江新城在广州市天河区 (数据源: Kohn Pedersen Fox)

The square core (32m side length) together with 8 nos. of concrete-filled-tube mega-columns are supported by a mat and pad foundations sitting directly on the relatively high bedrock. There are four levels of steel outriggers and six sets of double-layer belt trusses, all located within the mechanical and refuge floors of the tower. The perimeter belt trusses along with the mega-columns form a secondary lateral load resisting system. C80 concrete after EPR special approval, is used for the infill of the CFT mega-columns as well as the core wall with the approval of the expert panel, allowing the core wall thickness to be reduced by as much as 300mm against conventional C60 concrete and yielding more usable floor space on each of the floors. (see Table 1).

Wind tunnel tests were conducted to obtain the design wind forces and accelerations for occupants' comfort under wind effect. Test results were found to be satisfactory without the need for an expensive damper device. Computer analyses confirmed the building would meet the seismic design and performance criteria under frequent, moderate and rare earthquakes. A shaking table test with a tower model in 1:40 scale to simulate the earthquake motion was conducted in Beijing. The test demonstrated satisfactory seismic behavior, as predicted by computer analyses.

The construction sequence was carefully planned to avoid excessive stresses in the outriggers due to differential shortening between the mega-columns and the central core by stage delayed final connection of the outriggers with the mega-columns.

Levels	C60	C80
L23~L32	1,600	1,500
L16~L22	1,700	1,500
L7~L15	1,800	1,500
L1~L6	1,800	1,500

Table 1. Comparison of Core Wall Thickness(mm) for C60 & C80 Concrete (Source: Arup)
表1.核心筒采用C60和C80混凝土的墙体厚度 (数据源: 奥雅纳)

Figure 3. A Traditional Chinese Vase (Source: Kohn Pedersen Fox)
图3.传统的中国花瓶 (来源: Kohn Pedersen Fox)

建筑师的设计理念
广州周大福中心的设计有效整合了不同功能空间和回应了所处的城市环境。建筑师为塔楼塑造了四大转接空间: 办公楼至服务式公寓、服务式公寓至酒店、酒店至塔冠和塔冠至天空。这些动态退台呼应了附近大楼的不同高度以及城市不断扩大的天际线，同时利用外墙和灯光设计创造出一个向天际伸延的水晶视觉效果。这种形式语言延伸到裙房上，其阶梯式的平台配合了商场巨大的中庭采光天窗。

简单优雅的塔楼形态反映了广州周大福中心在城市脉络中的多种功能。屋顶和退台式平台空间为中国的第三大城市提供了代表高端生活品位的天际酒店和别墅式公寓。

塔楼的外墙设计强调其垂直性，长条锯齿形陶土板从塔楼底部延伸并包围了整栋建筑及轮廓分明的退台。揉合陶土板外墙的竖框不但提供了可开合的通风口和低能见比率玻璃面积以达至高效环保性能，同时也表达到所渴求的建筑语言。

对广州城市和文化环境，Kohn Pedersen Fox建筑事务所 (KPF) 在设计中作出了很大的努力和贡献。在可持续发展方面，项目是按LEED®金奖标准来设计的。

最高的陶土板外墙塔楼
广州周大福中心建成后，将是全世界采用陶土板外墙的最高塔楼。在这种超高层情况下使用陶土板外墙超出了中国现有规范标准，因此，需要进行专家论证以获得政府机构的批准，包括提供测试及理据证明，额外保证质量的检查措施，破坏性试验以及风洞测试。

作为一个多元文化城市的地标，塔楼的外墙材料有望发挥融合东西方文化的重要标志性作用，陶土板早在罗马时代已被用作建筑材料，它在美国20世纪初的摩天大楼热潮中被普遍使用，而中国有使用带裂纹白釉的悠久历史，时间可追溯到汉代和宋代。这里广州周大福中心就像传统的中国花瓶，设计出一个内含历史文化的外墙 (见图3) 。

从环保的角度来看，陶土板的能源消耗远远低于铝、玻璃或钢。它拥有自洁性及耐腐蚀性，广州周大福中心采用的这种自然可再生的幕墙材料象征着一个宏观视野，以可持续发展战略来带动经济发展。

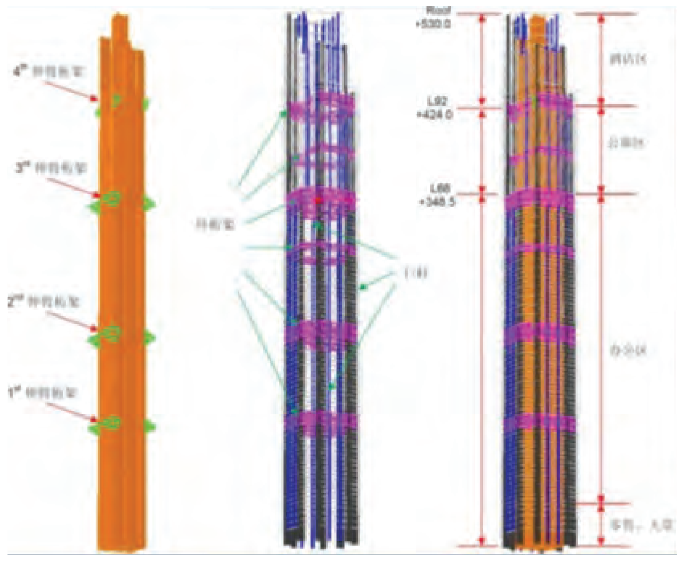

Figure 4. Structural System of CTFGZ (Source: Arup)
图4.广州周大福金融中心结构体系 (来源: 奥雅纳)

Figure 5. CTF TJ in Tianjin Economic Technological Development Area (TEDA) (Source: Skidmore, Owings & Merrill LLP)
图5.天津周大福金融中心在天津经济技术开发区 (TEDA)（来源: Skidmore, Owings & Merrill LLP)

Tianjin CTF Finance Center

Architect's Design Concept

Many tall buildings today are the result of willful exercises searching for iconic shapes. Too often these sculptural forms require reactive and expensive engineering to make them work. There are also many tall towers that settle for a "one size fits all" approach to multiple programs. These generic structures create a bland sameness in the city and are ill-suited to the variety and complexity of vertically mixed-use density.

Skidmore, Owings, and Merrill's (SOM) design for the Tianjin CTF Finance Center (CTFTJ) is based on three principles - a programmatic determinism that allows the tower form to accommodate the distinct needs and requirements of the uses and users within a rigorous integration of structural engineering and architectural development to achieve the highest efficiencies in material conservation and performance.; A sophisticated articulation of the exterior enclosure system to efficiently clad the complex geometries of the tower surface, yielding a spectacular interaction of light and materiality worthy of a landmark structure.

Location and Development Program

CTFTJ is located in the Tianjin Economic-Technological Development Area (TEDA), an outer district of Tianjin, China (see Figure 5). The project supports the TEDA master plan by anchoring the dense office, hotel, retail, and housing district with a 530 meter tower and retail structure on the axis of the government center and local transit station. The 97-story skyscraper will house Grade-A Offices for multi-national and domestic companies, Serviced Apartments, and a Luxury Hotel.

The Office program brief sought clean, consistent lease spans of approximately 13 to 15 meters from the core to the exterior wall. With an efficient, square, the central core contains local elevators serving three zones of 36 office floors; the 3,800 m^2 to 3,500 m^2 plans were shaped with rounded corners to reduce the structural span at the corners. The Serviced Apartments were efficiently planned with smaller lease spans of approximately 12 to 13 meters from the core. These apartments have private elevators with access from shuttles to a sky lobby, ample space for generous room layouts, and a proper perimeter to floor space relationship. Because of the dropping off of office elevators and telescoping core elements, the tower plan logically reduced to a smaller Service Apartment floor plate of approximately 2,000 m^2 with softly

结构设计

530米高的广州周大福中心，结构形式采用巨型柱和混凝土核心筒体系，与筒中筒和巨型支撑体等其他结构形式相比，具有无阻挡的视觉效果 (见图4) 。

四方形的核心筒 (边长32米) 连同八条以混凝土填充的钢管巨柱 (CFT) ，由直接坐落在比较高位基岩上的筏板和墩形地基支持。塔楼设置了四道钢结构伸臂桁架和六道双层环带桁架，全部位于塔楼的设备层和避难层。外围环带桁架沿着巨型支柱形成第二个抗侧力系统。C80混凝土用于巨型钢管柱的填充，并在得到专家论证会审批后用于核心筒墙体，相对传统的C60混凝土可令核心墙厚度大幅减少300毫米，使每个相应楼层得到更多可用楼面面积 (见表1) 。

通过风洞测试得到了设计风压以及考虑塔楼使用者舒适度所需的风振加速度，试验结果令人满意，不需要昂贵的阻尼装置。计算机分析证实了该塔楼满足在小、中、大震作用下的抗震设计性能要求。用按1: 40比例建造的塔楼模型，在北京进行了模拟地震振动台试验，所得结果与计算机分析一致。

施工顺序也是经过精心策划的，为避免因巨型柱和中央核心筒之间不均匀沉降对伸臂桁架产生过度应力，延迟了伸臂桁架和巨型柱最终连接的时间。

天津周大福金融中心

建筑师的设计理念

许多近代高层建筑都非理性地追求标志性的形态。往往这些雕塑形态的建筑为了满足设计要求需要被动和昂贵的结构工程设计。其他高层建筑以"一刀切"的方式去解决多个功能空间并存的问题。这些通用的建筑造成城市景观平淡无奇，千篇一律，并且不能满足复杂及多功能性的用途。

SOM建筑设计事务所设计的天津周大福金融中心巧妙地围绕三个原则发展: (一) 满足一个复杂及多功能建筑要求; (二) 利用和融合建筑美学和结构力学，让大楼竖向优美地变化，满足不同面积功能要求; (三) 精密的幕墙有效地将复杂的几何形体包裹，达到光学和物料高度有效的互动。

位置和发展计划

天津周大福金融中心坐落于天津市外围的泰达经济技术开发区的一个混合了办公、酒店、零售和住宅的高密度地区内 (见图5) ，并位于政府行政中心及交通枢纽中轴上。这座高530米、97层的超高层塔楼将提供甲级办公楼，吸引跨国企业和国内企业进驻，并提供服务式公寓和豪华酒店。

办公楼的设计提供了从核心筒到外墙13至15米的可租用空间。一个有效率的方形核心筒包含了电梯设备，连接了36层办公楼中的三个分区。建筑师将3,800平方米至3,500平方米标准层的四个方角打造成圆角，以减少结构跨度。服务式公寓则是由核心筒到外墙伸延出约12至13米较小的跨度。这些公寓设有专用升降机可将客人由空中大堂运送至每一公寓楼层。公寓宽敞的空间为大气的房间布局创造了条件，并提供了合适的楼层高度。由于高层没有了办公楼空间所需的电梯及机房，服务式公寓楼层面积向上收窄至约2,000平米空间。同样，酒店由独立的空中大堂连通收窄至1,800平米的酒店楼层，并在角落提供了优美环回景观房间 (见图6) 。

建筑师的设计

大楼优美竖向变化的设计不但在外观上减少了外墙面积，还优化了不同功能要求跨度和周长关系。

富流线型的建筑外形大大减少了风旋涡的影响及减少了能引起结构共振的风荷载。

rounded corners. Similarly, the hotel program, accessed from its own sky lobby, was also best suited in smaller floor plates of 1,800 m^2, with eased corners for panoramic views (See Figure 6).

Architect's Design

In stacking the reducing floor plates, the tower tapers dramatically to minimize the surface area exposed to the external elements, and optimizes the relationships between the structural leasing spans and the perimeter wall of each of the major programs.

The tower's aerodynamic shape greatly reduces the vortex shedding and disrupting the opportunity for any resonating wind forces and loads on the structure.

The gently curving glass skin integrates eight sloping columns that follow a lyrical line that connects the centers and corners of all four elevations. These sloping columns in the primary bends of the elevation are integral to both the gravity and the lateral systems. Thus greatly increasing the stiffness of the tower.

CTFTJ is designed to LEED® Gold standards. In addition to energy reduction systems and water conservation, the sustainable strategies include a high-performance envelope that creates windows 3.7 meter high at the Office and 3.15 meter high at the Serviced Apartments and Hotel for excellent day lighting and views.

The exterior wall surface was parametrically modeled to optimize panel sizes and façade curvature. Of over 24,910 total units, there are only 339 unique panels for an efficient repetition of unit sizes. The Architect worked closely with the manufacturers to provide options for either offset flat glass unit or cold bent glass unit wall system for cost, installation, and quality evaluation. The curtain wall features a "U" shaped double mullion to reduce vision glazed areas to 70% in meeting code requirements for window/wall area ratio and create a curved solid surface to sparkle in the day light and be gently illuminated at night (see Figure 7).

Structural Design

The 530m tall CTFTJ tower is supported by a core with a surrounding perimeter sloping columns following the turning curves of tower (see Figure 8), giving an aspect ratio of 7.26 and a primary natural period 8.53s. The core-walls of 1800mm to 800mm thickness are composed of concrete casting steel plates with thickness varies from 30mm at B4~L23 to 25mm at L45~L54.

The tower sits on a 5.5m thick pile cap which is supported by 434 nos. of 100m long 1.0m diameter bored friction pile with post-grouting.

3 belt trusses and 1 hat truss are positioned strategically at the refuge and mechanical floors, with the 86m tall porous steel tower crown sitting on the hat truss to 530m summit. No outrigger has been employed for more efficient construction.

C80 concrete has been chosen for Concrete Filled Tube (CFT) columns at lower floors and C60 above for the SRC columns at upper floors. The perimeter frame consists of steel spandrel beams with moment connection to perimeter columns.

Glass canopies with 21m cantilever span address the main arrivals in the south and north of the tower. They are individually suspended by pre-stressed tendons taking support from the perimeter columns (see Figure 9).

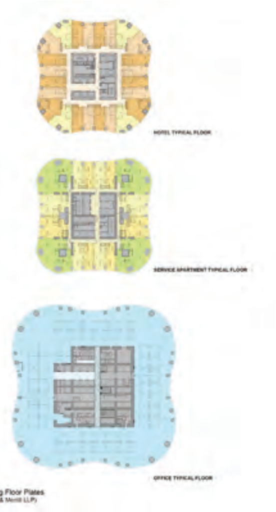

Figure 6. The Reducing Floor Plates (Source: Skidmore, Owings & Merrill LLP)
图6.减少楼板图 (来源: Skidmore, Owings & Merrill LLP)

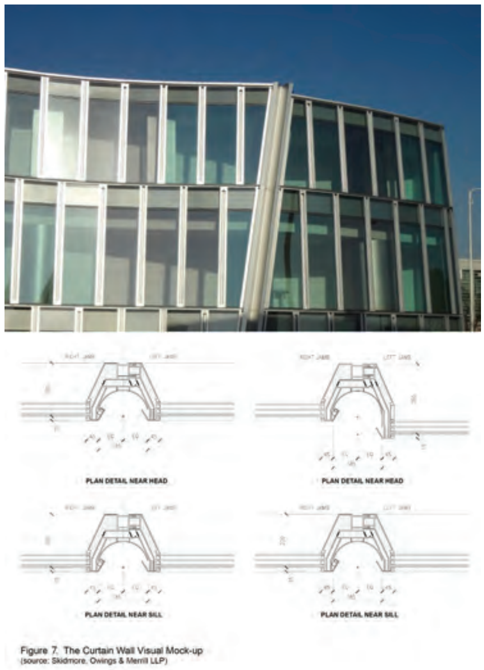

Figure 7. The Curtain Wall Visual Mock-up (Source: Skidmore, Owings & Merrill LLP)
图7.幕墙视觉仿真机 (来源: Skidmore, Owings & Merrill LLP)

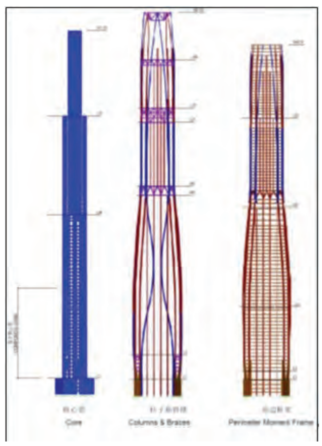

Figure 8. Structural System of CTFTJ (Source: Skidmore, Owings & Merrill LLP)
图8.天津周大福金融中心结构体系 (来源: SOM)

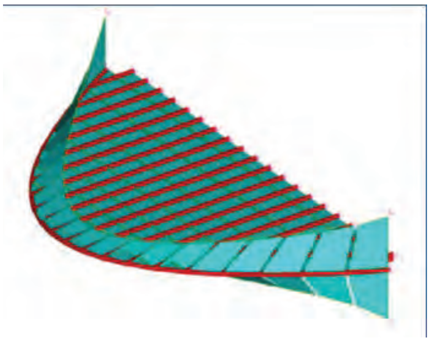

Figure 9. 3D View of Finite Element Model for 21m Cantilever Span Canopy-CTFTJ (Source: Skidmore, Owings & Merrill LLP)
图9天津周大福金融中心21米悬挑雨篷的有限元三维效果图 (来源: SOM)

Taking advantage of the aerodynamic building form and porous crown design, wind load effect was largely reduced, leaving seismic loading as the controlling case. The 10-year return period wind induced acceleration at uppermost occupied hotel floor is 7cm/s^2, which is much lower than Code limit of 25cm/ s^2.

As per requirement from EPR, a 1:40 model shaking table test was successfully conducted under frequent, moderate and rare earthquakes and proved the adequacy of design.

Building Services Design Challenges

Zoning of Building Services (BS) Systems

All the BS water systems are designed with multiple vertical zones to fulfill both of the functional requirements and the technical requirements of different system water pressures. Likewise, the electrical power distribution system which is also vertically subdivided with HV transformers located in the mechanical floors of mid and high zones, to keep a practical service radius.

Challenge of Super-High Speed Elevators

Super-high speed shuttle elevators of 20m/s are provided in the Hotel at the top zone of CTFGZ tower, offering an extraordinary arrival experience for our guests. Such high speed elevators require extra elevators shaft specifications of much deeper elevators pits and overrun, and larger elevator shafts. Intermediate vents are provided to connect between elevators shafts with the designated space on mechanical floors in the tower zone against the piston effects from high speed car running.

Also, super-high speed elevators adversely affect guest riding comfort. Self-induced lateral vibration, aerodynamic noises and air pressure change in the elevators cab are a few of them. Measures against these effects include adopting:

1. Advanced active roller guide mechanism with electromagnetic actuators to suppress car vibration;
2. Aerodynamic of the elevators cab;
3. Sound insulation shields to the door system;
4. Double-wall cab enclosure separating the inner walls from outer to reduce the noise caused by the vibration of car walls;
5. Sound-absorbing double flooring and acoustic floor and ceiling tiles to suppress the reverberation of noise inside the car;

八根斜柱巧妙地依附在轻微弯曲的玻璃幕墙旁，连接了四个立面的中心和角落，并结合成为竖向和侧向的结构体系，从而大大增加了塔楼的刚度。

天津周大福中心按照LEED®金奖标准设计。除了节能系统和节水系统，可持续发展策略还包括一个高性能的幕墙，为办公楼创建3.7米高的开窗，为服务式公寓和酒店提供了3.15米的开窗以达至最佳的采光和景观。

建筑外墙采用了参数化建模设计，以优化面板尺寸和幕墙的弧度。在超过24,910块面板当中，只有339块是非标准的，因而面板尺寸得到了高效的重复使用。建筑师与厂商密切合作，提供位移平板玻璃块或冷弯玻璃幕墙系统两种选择，以供成本、安装及质量评测。幕墙被设计成"U"形双竖框，减少玻璃可视范围至70%，以满足规范要求的窗/墙面积比率，并创建一个在白天光线闪耀，在夜间轻轻点亮的弯曲实墙面 (见图7) 。

结构设计

530米高的塔楼采用核心筒+周边流线型斜向柱体系 (见图8) ，塔楼的高宽比为7.26，基本周期为8.53秒。组合核心筒墙厚度由底层的1.8米逐步减少到顶层的0.8米，墙内的钢板厚度在B4~L23层为30毫米，而在 L45~L54层为25毫米。

塔楼坐落在5.5米厚的底板上，底板由434支直径1米从地面计约100米长的后注浆钻孔灌注桩支撑。

三道环带桁架和一道帽桁架设置在机械层及避难层，86米高的钢结构雕空塔冠位于帽桁架上面直达屋顶530米。为了施工便捷，没有设置伸臂桁架。

C80和C60混凝土分别用于低层的钢管混凝土柱和高层的钢骨混凝土柱。外侧框架由钢梁和周边柱固结。

塔楼南北两侧主要入口处设有悬挑跨度约为21米的雨篷，分别由固定在外围柱上面的预应力钢绞线支撑 (见图9) 。

外立面独特的流线型及雕空塔冠最大限度的减小了风荷载，使得本项目中地震荷载成为控制因素。 在10年回归期的风荷载作用下，最高居住楼层酒店的风振加速度为7cm/s^2，远小于规范限值25cm/s^2 。

应超限专家会要求，成功完成1: 40模型在小、中、大地震作用下的振动台试验，验证了设计的合理性。

楼宇机电设计面临的挑战

楼宇机电系统分区

楼宇内的各类供水系统设计，根据其各自系统工作水压要求，并按建筑划分的不同功能区，做出竖向分区设计，以同时满足技术及建筑功能两方面的要求。同样，配电系统也采用了竖向分区设计，将服务中、高区的变压器放置于塔楼相应的分区设备层，以维持合理有效的配电系统供电半径。

超高速电梯设计面临的挑战

广州周大福中心为位于塔楼顶高区的酒店选用了20m/s的超高速穿梭电梯，为乘搭这电梯的酒店宾客带来绝非一般的乘梯体验。超高速电梯对电梯井的要求较一般为高，设计需考虑较深的电梯底坑、较大的冲程距离、以及较大尺寸的电梯井。设计针对活塞效应，在电梯井之间设置了通风管道，以降低电梯行走时带来的活塞效应。

同时，超高速电梯也会对电梯乘客的舒适度产生一定的影响，其中包括运行时轿厢自身的横向振动、空气动力导致的噪音、以及

6. The downward elevators speed preset at 10m/s instead of the upward maximum 20m/s, and the elevators speed made adjustable where necessary to cope with the special requirements; and
7. Active pressure control system using an air-pressure adjustment unit to control the pressure change inside elevators cab. (see Figures 10 &11)

Supertall buildings suffer unavoidably from the building sway phenomenon, particularly in strong wind conditions. To safeguard the elevators operation, automatic safety control under the dictation of vibration sensors for the elevators shaft movement was tailor-designed. Such control will function in 2 stages in response to the magnitude of the building sway. At Stage 1, the elevators speed will be reduced; at Stage 2, when the building sway exceeds the elevators safe operation criteria, the elevators car will be stopped at the nearest landing and the passengers discharged.

Fire Fighting / Safety

An overhead FS water tank on tower roof is adopted for both CTFGZ and CTFTJ to offer increased fire-fighting system reliability. With the main storage of fire-fighting water located at the topmost level, it enables all the fire-fighting water systems to be fed by gravity and to function even when the fire pumps may breakdown.

Fire Evacuation for Top Zone Occupants – According to China GB Code, a helipad shall be provided on building roof as Means of Escape (MOE) for buildings exceeding 100m. In CTFTJ, the tower design has its highest occupant floor located at 80m below the roof crown. This makes it impractical for the occupants in the top zone to climb up such height for evacuation. Also the building crown does not allow provision of a helipad by virtue of its form. Therefore, designated evacuation elevators, backed-up by emergency generators, are provided for the evacuation of the top zone occupants.

Stack Effect

Stack effect due to outdoor and indoor air pressure differential, is one of the critical factors adversely affecting building performance for supertall buildings. The effect becomes critical in extremely cold, hot and windy climate. A stack effect study was carried out, which showed that the CTFTJ ambient temperature varies from -10 to 34ºC and CTFGZ from 5 to 34ºC. The differential air pressure across the external façade during winter time could be as high as 600Pa in CTFTJ, and 240Pa in CTFGZ; CTFTJ tower is more vulnerable to the stack effect compared with CTFGZ. Such high differential pressure may elevate the infiltration level; induce uncontrolled air movement within the building leading to thermal discomfort; impede the proper operation of entrance, stairwell, vestibule doors, elevators doors, and mechanical ventilation system.

Engineering measures adopted to mitigate the unavoidable adverse impacts of the stack effect include :

1. Radiant floor heating system for the double volume building entrance lobby in CTFTJ for achieving more effective space heating to the occupied zone;
2. Upgraded motor specification for elevators door open/close mechanism for proper closing of doors under the predicted high differential air pressure;
3. Exhaust fans in series (with bypass) designed in CTFTJ, with the 2nd fan to operate in case of the extra high wind pressure suffered from stack effect be encountered;

轿厢内空气压力变化等。针对以上技术难题的应对措施包括:

1. 采用先进的配备电磁制动器的滚轮导向机械装置，以抑制轿厢的振动;
2. 符合空气动力学的轿厢厢体的流线形设计;
3. 轿厢门增设隔音措施;
4. 轿厢采用双壳设计，内、外壳分隔，以减少由于轿厢壁振动而产生的噪音;
5. 轿厢地板采用双层台板设计，配以消音板材应用于地板及轿顶天花，以抑制轿厢内的回音;
6. 相对设定的电梯上行速度可高达20米/秒，针对人体的适应能力，下行的电梯速度默认值为不高于10米/秒，且电梯运行速度也可实地调整以迎合特殊需要;
7. 采用自动控制系统，透过空气—压力调节器，控制轿厢内的空气压力变化。(参见图10 & 11)

超高层建筑难免会产生建筑晃动的现象，尤其在强风天气情况下。为确保电梯安全运行，项目设计上为此量身定制了一套自动安全控制程序，当电梯井发生振动时，电梯井壁上振动传感器将发出讯号，启动自动安全控制程序。控制程序将根据建筑晃动程度，分成两个阶段的进行控制: 第一阶段，减低电梯运行速度; 如果建筑晃动超过设定的电梯安全运行标准值，控制程序进入第二阶段，指令电梯停泊最近的楼层，并疏散乘客。

消防与安全措施

广州周大福中心及天津周大福中心两个项目的设计都是将消防水池放置于塔楼顶部，以提升消防系统的可靠性。由于所有消防灭火系统用水的蓄水放置于建筑屋顶，在火灾情况下当消防水泵出现故障时，仍可保障消防灭火系统可通过重力供水而正常运作。

塔楼高区的人员火灾逃生措施——根据国家规范，超过100米的建筑物屋顶层需设置直升机停机坪，作人员紧急疏散用途。天津周大福中心在最高使用层以上设置了超过80米高的特色构筑物，令高区人员在紧急情况下向屋顶逃生变得并不现实; 而且特色构筑物的外型设计未能容纳直升机停机坪的设置，因此，设计上指定了一组高区直达地面的电梯，为高区人员提供紧急疏散逃生工具，该电梯配以应急发电机电源作后备供电以确保安全逃生。

烟囱效应

对于超高层建筑来说，由室内外空气压力存在压差而产生的烟囱效应，是影响其建筑性能的关键不良因素之一。烟囱效应在极端寒冷、炎热和强风气候下的影响显得越发严重。针对这两座超高层建筑进行的烟囱效应分析结果显示，天津地区的气温变化为 -10至34ºC，而广州为5至34ºC; 天津周大福中心冬季建筑维护结构的室内外的空气压差可高达600Pa，而广州则为240Pa。可见天津周大福中心需承受较广州周大福中心更严重的的烟囱效应的影响。如此过高的空气压差引致的负面影响包括: 室外空气渗入室内的渗透量升高; 不受控制的室内空气串流; 人体热舒适度的降低; 影响大厦大门入口、楼梯井、门厅门、电梯门、机械通风系统的正常运作。

针对难以避免的烟囱效应的负面影响，设计所采用的用来减低该负面影响的工程措施包括:

1. 针对天津周大福中心内空间开敞的建筑入口大堂，采用地板辐射供暖系统，为人员使用高度的空间提供有效的供暖;
2. 提高电梯门开/关控制的机械马达的技术规格要求，以使其在预设的较高空气压差情况下，能够正常关门;
3. 天津周大福中心的排风系统设计采用了两台排风机串联 (带旁通设施) 的安排，后备的一台排风机将在产生严重烟

4. Outdoor air intake fans equipped with automatic volume control dampers at their suction side to balance the extra wind pressure suffered from stack effect on the intake louvers on building façade.

Summary

The sharing of the above information will hopefully help facilitate a continual pursuit of improvement for the design professions and building industry on supertall buildings. It should not only be the aesthetic excellence that is aimed for. The city that the tower anchors and its residents are the focus of design. Projects that respond and contribute to the people, city, and environment would be a valuable and sustainable investment for developers.

囱效应的强风天气下投入运行;

4. 设计为新风主机配置了自动风量控制调节阀，调节阀位于外墙的进风百叶背后，以平衡由于烟囱效应所产生的额外风压。

总结

最后，分享以上资料数据是希望能为促进设计专业和建筑行业在超高层建筑的发展需求出一分力。不仅以追求美观为目的，塔楼所处的城市和居民才是整个设计的重点所在。只有积极为市民、城市和环境做出积极贡献的发展项目，对发展商来说才是一项有价值和可持续发展的投资。

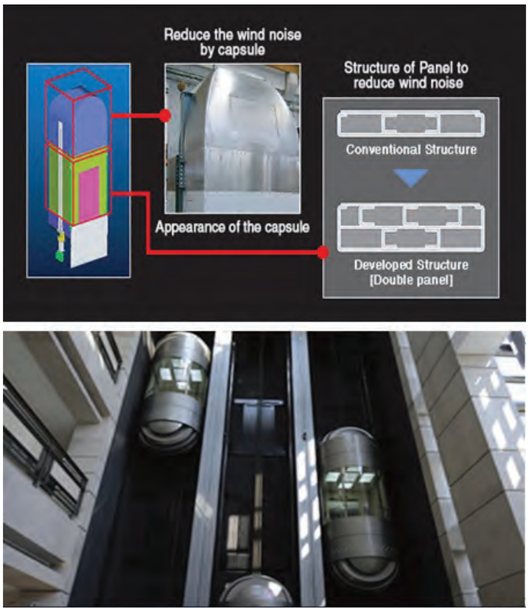

Figure 10. Lift Cab Vibration and Noise Control (Source: Hitachi)
图10.电梯轿厢振动及噪音控制 (图片来源: 日立)

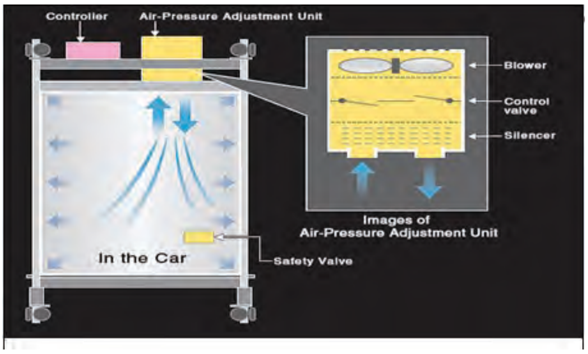

Figure 11. Lift Cab Pressure Control Diagram (Source: Hitachi)
图11.电梯轿厢压力控制示意图 (数据源: 日立)