

CTBUH "In Detail" Series
CTBUH "深入解读"系列

Shanghai Tower: In Detail

上海中心: 深入解读

Editors (编者): Antony Wood, Jianping Gu (顾建平) & Daniel Safarik





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Editors: Antony Wood, Jianping Gu & Daniel Safarik
Layout, Coordination & Design: Steven Henry, Kristen Dobbins & Marty Carver

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Council on Tall Buildings and Urban Habitat
世界高层建筑与都市人居学会(CTBUH)

S.R. Crown Hall
Illinois Institute of Technology
3360 South State Street
Chicago, IL 60616
Phone (电话): +1 (312) 567-3487
Fax (传真): +1 (312) 567-3820
Email (电子邮箱): info@ctbuh.org
<http://www.ctbuh.org>

Front Cover: Shanghai Tower, Shanghai, China. © Gensler
封面: 上海中心大厦, 中国上海 © Gensler

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Introduction

概述

Shanghai Tower 上海中心

Shanghai, China 中国上海

The Shanghai Tower is one of the most ambitious skyscraper projects ever undertaken on the planet, let alone in China. While the distant silhouette and the proximate detail of the tower will be immediately distinctive, the purpose of the building is not simply to be seen as an iconic landmark; it is much more than that. Because it incorporates many advanced techniques, it will be a learning laboratory for the next generation of skyscraper designers. Shanghai Tower provides a vision of vertically-integrated space through a double façade that contains numerous sky gardens, filled with vegetation and the potential for socializing. It provides relief from the isolative nature of tall buildings without requiring descent to the ground.

The statistics around the tower are formidable. Upon opening in 2015, at 632 meters it will be the tallest building in China, the second-tallest in the world, and one of only three “megatall” buildings of 600 meters or greater height in the world. Its sinuous double-skin façade and 14-story atria set into nine zones will redefine the experience of being in a tall building. To support its mass, contractors poured 61,000 cubic meters of concrete in 60 hours – and that was just the foundation.

From the outset, the ambition behind the project was to make it one of the world’s greenest and best-performing tall buildings, including a stringent requirement that the building support an energy saving rate of 54 percent over the Chinese Efficiency Standard, and that investments in green technology pay back in seven to 10 years. Passive solutions included the glass curtain wall’s curvature, which reduced wind load by 24%, offered low reflectivity and, with louvers, a high shading coefficient. Active solutions include a combined cooling and heating power (CHP) system, and grey- and rainwater recycling.

To ensure that these investments continued to pay off, a Central Energy Management Control System was deployed, to perform air conditioning load forecasting and management, regulate the operation of the CHP system, heat pump and ice storage systems.

Further, the use of advanced digital technology continues into the operations phase, as data collection for optimization is vital. The BIM system developed for design and construction will continue to be used as part of a Property Asset Operations Platform (PAOP), comprising BIM, Facilities Management (FM) and Intelligent Building Management System (IBMS) technologies.

上海中心是中国乃至全世界最有雄心的超高层建筑项目之一。虽然这座摩天大楼的剪影远眺显得与众不同，近处的细节设计也独具匠心，但上海中心的目标绝不仅仅止步于被看作一座地标性建筑，还有更多超前的理念。由于应用了很多先进的技术，上海中心将成为下一代高层建筑设计师学习的范例。上海中心为我们提供了一个实现垂直一体化空间的愿景，并通过独具匠心的双层幕墙设计来实现，两层幕墙之间设置了数个空中大堂，种植了绿色植物，提供了可能的社交场所，将人们从脱离地面的高层建筑中解放出来，无需到达地面层就能回归自然。

关于这座大厦的数据是令人惊叹的。到2015年投入使用时，632米高的上海中心将成为中国第一高、全球第二高的建筑，也是世界上仅有的三座600米以上的“巨型高层建筑”之一。其扭曲的双层幕墙和设置在九大分区中的14层高中庭将重新定义在高层建筑中的体验。为了支撑如此大的体量，承包商在60小时内浇筑了61,000立方米混凝土——这还仅仅是地基部分。

从设计伊始，上海中心就立志打造成世界上最绿色、性能最高的摩天大楼之一，这

Right: Overall view of the nearly completed Shanghai Tower (Source: Gensler)

右图: 接近完工的上海中心全景图 (出自: Gensler)



The Parametric Design of Shanghai Tower's Form and Façade

上海中心大厦造型与外立面参数化设计

Jun Xia (夏军) & Michael Peng (彭武), Gensler

The Shanghai Tower was only made possible by using innovative design ideas, integrated technology, and advanced tools. This paper is centered around the project as a case study on the parametric design platform utilized by the design team to bring this iconic tower to construction. The design process revolved around the use of a series of parametric software programs. These programs allowed the design team to manipulate and refine the project's complex geometry iteratively. The parametric platform played a pivotal role in assisting the team to define the tower's unique and environmentally responsive high-performance form, façade, and supporting structure.

世界级最可持续的超高层塔楼只有通过革新的设计理念、一体化的技术和先进工具的运用才能实现。本文围绕上海中心大厦作为范例，分析设计团队使这一标志性塔楼得以实现施工所采用的参数化设计平台。设计过程围绕采用一系列参数化设计软件。这些软件允许设计团队可以迭代式操作和改进项目的复杂几何。参数化设计平台在协助团队定义塔楼的独特及环保的高性能造型、外立面和支撑结构的过程中发挥了关键作用。

Introduction

Shanghai Tower is currently in advanced construction, en route to becoming the largest and tallest double-skin façade structure in the world, and one of the most sustainably advanced. As the last of three supertall towers, and the only megatall tower, of Shanghai's Lujiazui central business district, adjacent to SOM's Jin Mao Tower and KPF's Shanghai World Financial Center (see Figure 2.1), Shanghai Tower will redefine the identity of the city and the world's perceptions of China. Its originative architectural, structural, and MEP design, as well as its innovative design process, exemplify the future of high-rise construction.

The form of the 128-story building is a triangular column that twists and tapers as it rises 2,073 feet (632 meters). The curved corners of the triangle act to minimize wind loads and create 21 atria between the inner and outer curtain walls. A notch running up one corner adds to the aesthetics and sustainability of the design. Nine zones, 12 to 15 floors each, are stacked to create smaller neighborhoods within the supertall tower. The resulting unique, complex, and environmentally-responsive form helped win the international competition for its design in 2008. It also called for an inventive approach to bring it from paper to reality—it called for innovative use of parametric design.

The team for Shanghai Tower chose to use a parametric design process for several reasons. Constructing a complex building shape that had never before been conceived required the most innovative tools. Parametric design platforms allow for highly accurate results and good correlation between a model and its built form. They are very flexible and adaptive, offering instant feedback to changing variables. These nonlinear adjustment tools give architects the ability to effect multiple changes simultaneously. This allows designers to better understand iterative massing studies while observing the relative impact to the overall performance of the systems involved.

Another important reason for the use of parametric design was its assistance in creating Shanghai Tower as a sustainable building. This can be seen in the example of parametrically incorporating wind load data on the building. The location of Shanghai Tower and its proximity to two other supertall buildings means that these loads can have substantial impact. To address

引言

上海中心大厦目前正处于施工阶段，竣工后将成为世界上最大及最高的双层外墙建筑，同时其可持续技术也是最先进之一。作为上海市陆家嘴中央商务区三座超高层塔楼当中的后起之秀，而且是唯一的一座巨型高层建筑，与SOM公司的金茂大厦和KPF的上海环球金融中心比肩而立（见图2.1），上海中心大厦将重新定义城市形象，改写全世界对中国的看法。其原创性的建筑、结构和机电设计，以及其创新性的设计流程，均昭示了高层建造的未来。

这栋128层建筑的造型为一个沿2,073英尺（632米）的高度螺旋上升的三角尖锥形柱体。三角形的弧形转角有效地将风荷载降到最小，在内外幕墙之间形成21座中庭。一条切口沿着其中一个转角蜿蜒而上，增加了设计的美感和可持续性。九个分区层层叠加，每个分区设置12-15个楼层，在巨型高层塔楼内形成规模较小的邻里关系。独特、复杂而又环保的造型在2008年的上海中心大厦国际设计方案竞赛中一举中标。同时也需要一个创新性的设计手法——参数化设计的创新性使用使构变为现实。

上海中心大厦设计团队选择采用参数化设计有几大原因。构筑一栋前所未有的复杂形体建筑需要最富有创新性的工具。参数

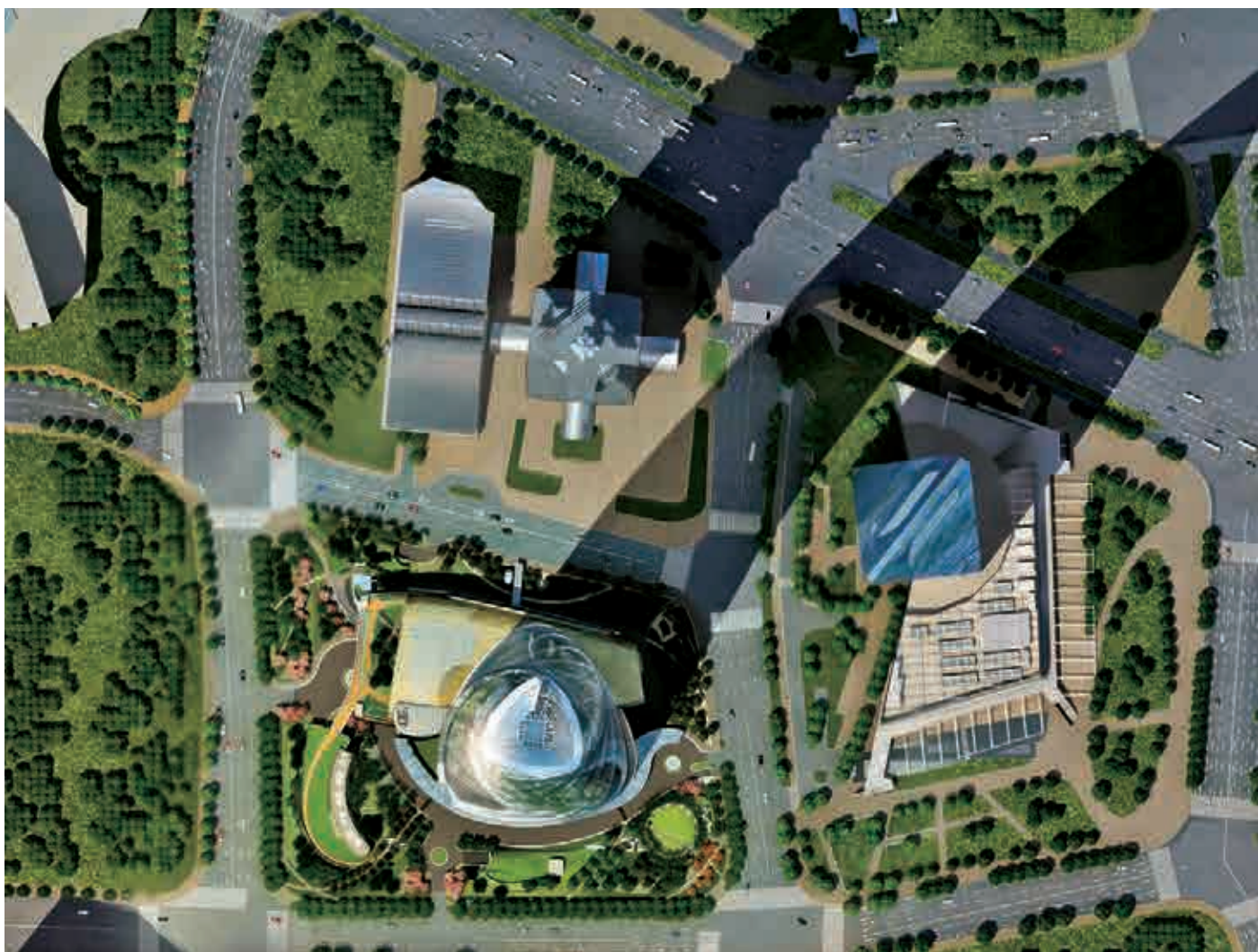


Figure 2.1. Site Plan. (Source: Gensler)
图2.1. 总平面图 (来源: Gensler)

these loads, the design team developed a series of models in a parametric program. Rotation in the models ranged from 90° to 180°. They sent these to Rowan, Williams, Davies & Irwin (RWDI), a wind engineering consultant firm, which tested the series in a wind tunnel with 1/500 physical models. The researchers found that increasing the rotation reduced the wind load on the façade and superstructure, and suggested an option that manifested a reduction of 24% compared to a rectangular form of the same height; this in turn reduced the amount of material of the structural system. Then, the design team generated a detailed model incorporating wind-tunnel data back into a parametric program. The result was made into a 1:85 scale physical model that was then tested in a large-scale wind tunnel. The model was set within the context of its supertall neighbors as wind loads on buildings in realistic environments surrounded by neighboring buildings may

化设计平台顾及到高度精确的结果和模型与其建成形式之间的默契关联。这些平台非常灵活且适应性强，能够对不断变化的变量即时做出反馈。这些非线性调整工具让建筑师有能力同时影响多项变更。这允许设计师能够更好地了解迭代体量研究，同时观测对所研究涉及系统的整体性能的相对影响。

采用参数化设计还有一个重要的原因，那就是其有助于将上海中心大厦打造成一栋可持续建筑物。这可在参数化合并风荷载数据的建筑物示例中看出。上海中心大厦的高度及其与另外两栋超高层建筑的接近程度意味着这些荷载会产生实质性的影响。为了解决上述荷载，设计团队在参数化程式中发展了一系列参数化方案模型。模型中的旋转角度从90°到180°不等。他们将这些模型发送给风工程顾问公司RWDI。RWDI以1/500比例的实体模型进行了一系列的风洞试验。研究者发现更大的扭转可以降低外立面和上部结构上的风荷载，RWDI同时建议采用一个能比相同高度下的矩形造型降低24%风荷载的方案；这反过来也减少结构系统的材料用量。接下来，设计团队制作了一个详细的模型，并将风洞试验的数据合并到参数化程式中。结果整合到在大型风洞中测试的1:85比例实体模型中。将模型置入相邻高层建筑的整体大环境中，“在现实环境中被相邻建筑包围的建筑与单独建筑的风荷载实测可以有明显的区别”。这项高雷诺数试验显示了额外8%的效益，导致风荷载整体下降32%。这一迭代过程容许上海中心大厦在所需的结构钢材上节省5800万美元。此外，在确定玻璃厚度规格、幕墙单元框架构件和幕墙支撑结构的设计荷载上使项目节约资金。

上海中心大厦举不胜数的参数化研究全部遵循一套严谨的流程。设计团队首先将数据、参数和条件输入到程序中，然后将由公式、数据和脚本驱动的信息包括在内。通过这一过程，他们会同时得到以数据表和3D模型形式存在的输出结果。为进一步的深化和优化设计，他们与业主和顾问分享并分析输出结果。下一步，建筑师会再建立一个模型，

The Shanghai Tower is one of the most ambitious skyscraper projects ever undertaken on the planet, let alone in China. While the distant silhouette and the proximate detail of the tower will be immediately distinctive, the purpose of the building is not simply to be seen as an iconic landmark; it is much more than that. Because it incorporates many advanced techniques, it will be a learning laboratory for the next generation of skyscraper designers. Shanghai Tower provides a vision of vertically-integrated space through a double façade that contains numerous sky gardens, filled with vegetation and the potential for socializing. It provides relief from the isolative nature of tall buildings without requiring descent to the ground.

The CTBUH "In Detail" series provides an in-depth, full-color exploration of some of the most important tall buildings in the world, drawing from the multi-disciplinary expertise of the practitioners directly involved in bringing these buildings to life.

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