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Shanghai International Financial Center: Future City Vision

上海国际金融中心: 未来城市愿景

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Sergio Valentini studied at the Politecnico of Bari. After working in Italy since 2003 he joined Foster+Partners in 2007. In 2010, he moved to JAHN, where he is a Principal Architect. From 2011 to 2013 he was the Chair of the CTBUH Young Professional Committee and is Co-Chair of the BIM working group. In 2014 he lectured at the Universities of Florence, Bologna and Cesena. He assisted a Studio at the IIT, and has been part of several competitions' jury. His archeological research work was presented at major international congresses

Sergio Valentini毕业于巴里理工大学，2003年开始在意大利工作， 2007年加入福斯特事务所。2010年，Sergio Valentini进入JAHN (墨菲/扬) 建筑事务所，任职主任建筑师。2011至2013年间，他担任CTBUH的青年专业委员会主席兼BIM工作组联席主席。2014年，Sergio Valentini分别在佛罗伦萨大学、博洛尼亚大学及切塞纳大学发表演讲，并协助讲授了伊利诺斯理工大学的设计课。与此同时，他还担任了多个设计竞赛的评委。Sergio Valentini的古建研究成果曾在主要国际会议上发表。

Francisco Gonzalez-Pulido holds a degree in Architecture from Monterrey Tech and a Master's Degree from Harvard University. In 1992, he founded 2MX3, a design-build practice with base in Mexico City. In the fall of 1999 He began his collaboration with Helmut Jahn at JAHN in Chicago, where he is currently a Partner and the Firm's President. Francisco has created uncompromising Architecture under the principles of Integrated Design. He teaches and lectures regularly, his own work and in collaboration with JAHN has been widely published and exhibited around the world.

Francisco Gonzalez-Pulido拥有蒙特雷理工大学建筑学学位以及哈佛大学硕士学位。1992年他成立了2MX3设计实践工作室，专注于墨西哥城的本地项目。 1999年秋，Francisco加入位于芝加哥的JAHN (墨菲/扬) 建筑事务所，开始了与Helmut Jahn的合作，并在之后成为合伙人与现任总裁。Francisco遵循着综合设计的原则创作建筑。 Francisco定期担任教学工作和发表演讲，他的个人项目以及在JAHN (墨菲/扬) 的合作项目已在世界范围广泛出版和展览。

Abstract

JAHN's Archi-Neering –integrated design approach- is broadly displayed in the future Shanghai International Financial center, in Pudong, which consist of 3 towers physically connected by a 130 meter long bridge and by a sunken theater at the heart of the complex. The inclusion of public functions such as a museum, a theater and park; the project relationship to the urban-scape with a monumental open plaza ; are all attempts to gain back the urban linkages, still visible in the Bund, that have been intrinsic to the imagery of Shanghai but that have been neglected by current developments. The suspended museum, and the full high atriums, establish an ideology to integrate that 'public space' that once lived in the ground, back into the elevated spaces pushing through the idea of the vertical City as the 'city of the future'. The project addresses complex codes and integrates sustainable measures in the design, to deliver a LEED Gold pre-certificate complex.

Keywords: Chinese Code, Integrated Design, Energy Consumption, Vertical City, Public Space

摘要

JAHN (墨菲/扬) 的建筑-工程 (Archi-Neering) 综合式设计方法已在位于上海浦东的上海国际金融中心项目中广泛体现。该项目由3栋塔楼组成，塔楼之间由一长达130米的廊桥连接，并在中心位置共享一个下沉庭院。 本项目的公共空间包含了博物馆、剧院和公共绿地，并通过巨大的开放广场与城市景观连接; 这些都是与城市建立联系的方式。作为上海形象的特质，这些联系在外滩仍清晰可见，却在当今的发展中常被忽略。位于空中的博物馆以及通高的建筑中庭，建立了一种将通常位于地面的公共空间融入高层空间的方法、以体现垂直城市的未来城市理念。 项目在满足复杂规范的基础上将可持续发展的措施整合进了设计，创造出一个LEED金级品质的建筑群。

关键词: 中国规范，整体式设计，节能，竖向城市，公共空间

Introduction

Asia's fast economic growth over the past 20 years has led to a high demand of commercial spaces. These have often been developed with scarce regard to the urban space and the rich Chinese tradition. Large areas of Chinese cities, characterized by small fragmented urban scale, have been demolished to make room to the large infrastructure and viability necessary to support the development of tall buildings.

At the same time, the fast and strong technical progress that has happened in China has allowed the construction industry to build extremely tall and complex buildings. The aspiration to surpass the western world construction achievements, together with the great economic capability and large construction resources available in the Chinese market, resulted in a race to tall and Supertall that is exemplified in the city of Shanghai.

This has often not concurred with careful city planning and attention to local climates, resulting in unsustainable buildings, from an energetic point of view and on an urban and

简介

亚洲最近20年的经济高速增长带来了对商务空间的高需求。但在这些项目的开发中经常忽视了城市空间和中国丰富的文化传统。中国城市的很多小尺度街区被大量拆除，以腾出必要空间用作大型基础设施和高层建筑的开发。

与此同时，中国建筑技术已取得巨大的进步，能够建造超高复杂的建筑。受超越西方建筑成就之渴望的驱动，同时凭借强大的经济实力和丰富的工程资源，使中国一再出现了建筑高度的竞赛和攀比，这在上海尤为突出。

这些设计往往没有遵循精心的城市规划，也往往忽视当地的气候环境，因而出现了一些从节能角度、或是城市与社会角度均不符合可持续发展需要的建筑。粗劣的设计、过快的施工以及发展中国家常见的建筑试验冒险现象带来了规模失控的开发项目，已经严重损害到城市环境。

遗憾的是，当地规范和审批程序的发展没有跟上地产建设的快速变化，以前的项目往往在缺乏监管的情况下草率完成，之后

social scale. Poor design, fast construction and the experimentations of a rich developing country caused out-of-scale developments that have hurt the city environment.

Unfortunately, this sudden change in the local construction industry has not been accompanied by a similar development in the local codes and approval procedures that have been trying to address problems that emerged after the development of unregulated previous projects. The result of this is an extremely elaborated approval process and new stringent local codes that have opened a new era in which architects are challenged to design safer, more sustainable and site specific buildings.

Site and Climate

Shanghai, is the most populous Chinese city and also has historically been a city characterized by its developed commercial trading and an international population thank to its port, one of the busiest in the world. Today, Shanghai is considered the financial center of China and one the economic and commercial centers of the world. The Shanghai Stock exchange is the third in the world for number of transactions.

Shanghai has a humid subtropical climate with damp, cold winters and hot, humid summers. It is subject to thunderstorms and typhoons and has up to 54% percentage of sunshine. The spring and autumn are relatively mild allowing for usage of natural ventilation and outdoor activities during these seasons.

Project Description

Home to the Shanghai Stock Exchange (SSE), the China Financial Futures Exchange (CFFEX), and the China Securities Depository and Clearing Corporation (CSDCC), the complex of 516,808 m^2 of the, Shanghai International Financial Center forms a complement to the City Center plaza and frames the center of Pudong and the old City The Shanghai International Financial Center is a powerful, unified architectural complex of memorable image addressing the three corporations individual needs by providing each with an appropriate individual identity (see Figure 1).

The project brief for this complex proved to be very challenging beyond the architectural and urban agenda. Merely from a programmatic point of view the 3 clients had very specific requirements that varied for each tower. In addition to this a number of special functions associated with the owner offices had to be accommodated in the buildings while not compromising the efficiency and performance of the typical office floors.

The idea of not having a podium in order to preserve the public space of the plaza at grade but at the same time integrating public functions such as a theater and a museum, led to the development of an innovative typology. JAHN's approach to this problem was to re-gain the urban public space in the vertical development of the project.

The vertical stratification of the different functions is attempting to become a trend for the vertical cities of the future. The different areas and functions of a city that were traditionally articulated in the ground plane are in this project layered within the project's iconic image (see Figure 2).

才开始尝试解决其中的问题。这一情况促成了当前极其繁细的审批程序和更加严格的本地标准。当然，这开启了一个新的时期，而建筑师面对的挑战是设计更为安全、可持续发展和有基地特色的项目。

基地及气候

上海，是中国人口最多的城市，也是世界上最繁忙的港口之一，历来以其发达的商贸和国际化所著名。当今的上海被定位为中国的金融中心以及世界的经济商业中心之一，而上海证券交易所的交易量已位居世界第三。

上海处于湿润的亚热带气候区，有着寒冷的冬季和湿热的夏季，属于雷暴和台风的活动区，并有54%的日照。春秋两季相对较温和，可采用自然通风，户外活动在这些季节也可进行。

项目描述

约52万平方米的上海国际金融中心建筑综合体容纳了上海证券交易所 (SSE)，中国金融期货交易所 (CFFEX) 以及中国证券登记结算公司 (CSDCC)，围绕着浦东和旧城的中心，形成了城市中心广场的重要组成部分。金融中心具有有力、统一、鲜明的建筑综合体形象，并按三家业主的需求分别赋予了建筑适宜的识别特征 (图1)。

本项目的设计任务非常具有挑战性，超越了建筑和城市的议题。仅从功能方面来说，三家业主对建筑功能有非常具体的需求，且三个塔楼各异。除此之外，建筑必须具有与业主办公相关的一些特殊功能，同时要求标准办公楼层的效率和性能不能因此降低。

项目不设裙楼，目的是在地面留出公共广场的同时整合出多种公共功能，例如剧院和博物馆，实现建筑模式的创新发展。JAHN (墨菲/扬) 的解决问题的思路是在建筑的竖向发展中寻求城市公共空间。

Figure 1. The Complex, Rendering. (JAHN)
图1. 建筑整体效果图 (墨菲/扬)

At the ground, the Central Plaza ties the three buildings together and open the complex to the city through the landscape solutions at the site perimeter. The public space of the plaza continues in the lobbies of each tower (see Figure 3).

The SSE Tower measures 72 m by 72 m in plan and it is the tallest and largest building of the complex with 220 m of height and over 125.000 m^2. CFFEX footprint measures 54 m by 72 m and it reaches 198 m for an area of almost 94.000 m^2. CSDCC is the smallest building with a footprint of 42 m by 72 m, a height of 163 m and an area of 50.500 m^2. All the buildings have the same width (72m) facing the bridge since it is 21 m wide and it penetrates the towers at the 24 m wide atriums.

The unique architectural planning concept used for the towers is that of twin towers with split cores, connected only at certain levels, that divides the buildings into two slabs with column free lease spans between the façade and the cores (see Figure 4). This allows the integration of the special functions desired by the Clients such as multifunction halls, IPO and ceremony halls and exhibition space within the volume of the buildings. At the same time this allows the integration of spacious through-building atriums, which create both openness and connection between each building (see Figure 5). Standing in the Central Plaza one can see through each building to the landscaped outer portions of the site and to the river to the south.

The first part of the towers is the first stratification of the program with the data centers and technical floors occupying the first 6 levels of the buildings and giving the base a very solid and classic image. 40m in the air, a 130m long bridge, of over 10,000 m2 of area, connects the three towers and hosts the Listed Company Exhibition Center, Investor Training Center, International Media Center, the China Securities and Futures Expo Center and a roof garden.

Above the bridge level, the office floors are constructed in two twin towers for each building connected with bridges and slabs through a full height atrium. This solution allows maximizing daylight, using natural ventilation and giving all the office spaces great views to the city and the complex. This unique space in this very monumental composition responds to the important stature of the clients.

Each tower is connected again at its top where multiple stories high spaces host the public clubs of each building where ceremonies will take place with the city as a backdrop visible through the large transparent façades. Above these spaces vertical screens project past the building and protect the accessible roof garden that continue the plaza space from grade, through the atrium terraces, to the summit of the complex.

The 800 seats Sunken Financial Theatre is centrally located in the plaza thus forming a focus point with a sense of community between the users of the three buildings. The theater is accessed from the first level below grade where shopping areas and additional services for the towers and 3 floors of parking are located.

Structure

The structural concept for this building is relatively simple giving its complexity. Each tower acts as a mega structure composed by each of its halves. The semi-towers are braced by their concrete core and by the composite columns as required by the local seismic code (Code of Seismic Design of Buildings, GB 50011-2010).

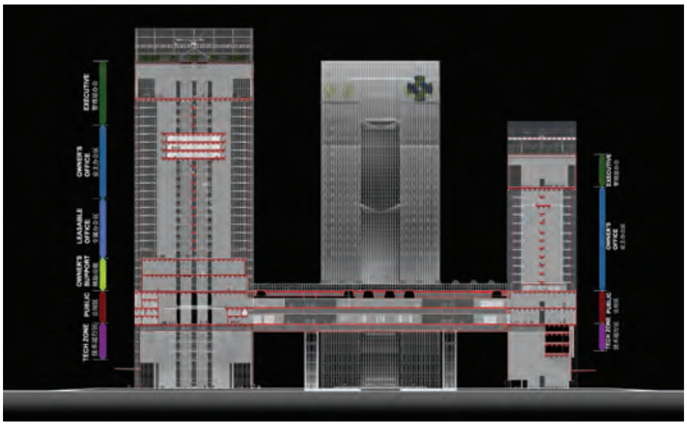
Figure 2. Building Section. (JAHN)
图2. 建筑剖面图 (墨菲/扬)


Figure 3. Site Plan. (JAHN)
图3. 总平面图 (墨菲/扬)

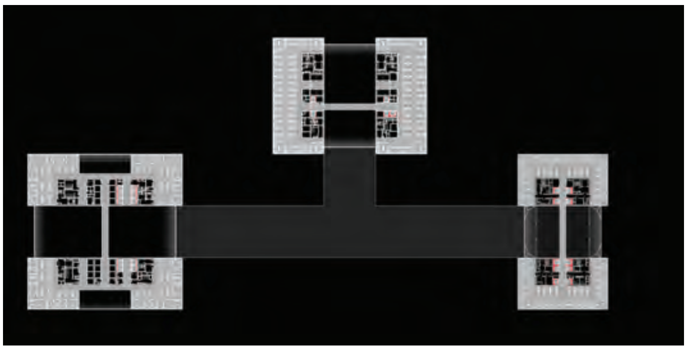
Figure 4. Typical Plan. (JAHN)
图4. 标准层平面图 (墨菲/扬)


Figure 5. Lobby Atrium Rendering. (JAHN)
图5. 大堂中庭效果图 (墨菲/扬)

The two halves of the towers are then braced together through the slabs and cross bracing where the floor plates are continuous, i.e. at the top of the buildings, at the bridge levels and in the "H" shaped office floors. The towers are also braced through the basement slabs. The bracing at the top of the tower was added following the instruction of the experts' panel, even though calculations showed it was not necessary (see Figure 6).

The structure consists of steel reinforced concrete cores and composite columns, steel floor beams, composite slabs and steel bracing beams. The bridge is built as an independent steel structure supported by the 2 concrete elevators cores and free to move at its extremities where it connects to the towers. In this way in case of a seismic event no loads are transferred from the bridge to the towers structures (see Figure 7).

The bridge steel structure consists of a deck system with hollow boxes supporting the concrete decks above, as used at regular street bridges. This allows avoiding bracing members and heavy vertical columns typical of construction in China that would have made the bridge very heavy and not transparent

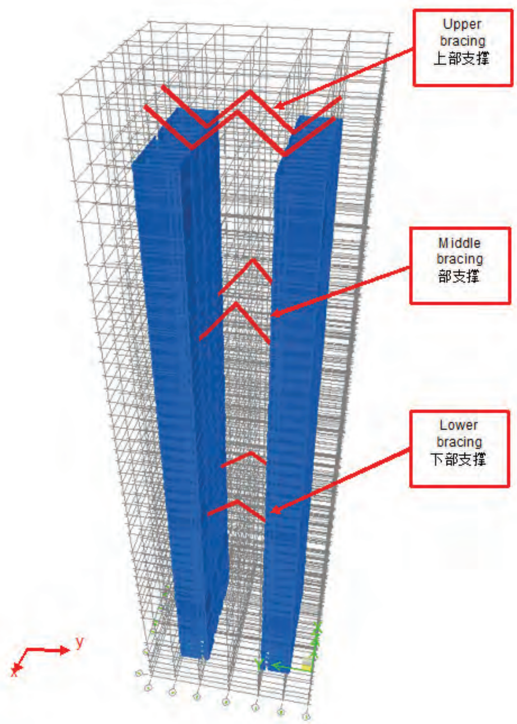

Figure 6. SSE Tower Structure. (Werner Sobek)
图6. 上交所结构图 (Werner Sobek)

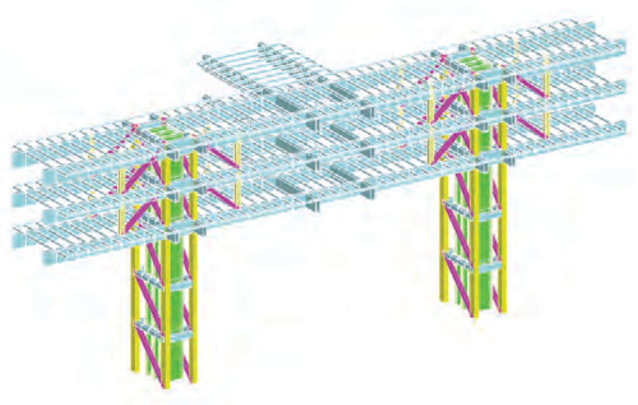

Figure 7. Bridge Structure Concept. (SIADR)
图7. 廊桥结构概念图 (上海院)

设计尝试实现了不同功能区的垂直交通分层，试图使其符合未来竖向城市的趋势。一个城市中的不同功能和区域通常在地面上横向定义，然而在此项目中则在建筑标志形象中对其进行了分层 (图2) 。

在地面首层，中央广场将三个建筑连为一体，并通过场地周围的景观设计使综合体向城市开放。广场的公共空间同时也延续到了每栋塔楼的大堂 (见图3) 。

上海证券交易所 (SSE) 塔楼平面为72乘72米，在综合体中是最高和最大的建筑，高度为220米，总建筑面积超过12.5万平方米。中国金融期货交易所 (CFFEX) 的平面为54乘72米，高度达198米，总建筑面积为9.4万平方米。中国证券登记结算公司 (CSDCC) 是体量最小的建筑，平面为42乘72米，高度163米，总建筑面积约5万平方米。所有建筑朝向廊桥的方向具有相同宽度 (72米) ，廊桥自身的宽度为21米，接入建筑24米宽的中庭。

项目采用了独特的建筑平面设计思路，将塔楼和核心筒一分为二形成内部双塔，在部分楼层有所连接。建筑分成了两组楼板，幕墙和核心筒之间的区域成为无柱空间 (图4) 。这种做法使得建筑体量内可以方便地整合出业主要求的各种特殊空间，例如多功能厅、上市空间和仪式大厅。同时，如此布局也使得宽敞通高的中庭空间融入建筑，每栋塔楼的空间均具有开放性，并易与其它塔楼相连 (图5) 。站在中央广场，人们的视线可以穿越每栋建筑，看到外围的景观设计以及周边的公共公园。

塔楼的第一部分为功能的第一分层: 数据中心及技术楼层占据了建筑底部6层，赋予了塔楼底部扎实和传统的形象。40米高度处，一座130米长面积超过1万平方米的廊桥连接了三座塔楼，包含了上市公司展览中心，投资者培训中心，国际媒体中心，中国证券和期货展示中心以及屋顶花园。

在廊桥层上方，每个塔楼的内部双塔设置了办公楼层，它们的楼板通过通高中庭的廊桥相连。这种处理方式使日照面积最大化，利于自然通风，同时创造了从所有办公空间到城市环境和整个综合体的良好视线。如此巨大组合所营造的独特空间，体现了业主的重要地位。

各塔楼内部在顶部再次连接，形成数层通高的空间，设置了各楼的公共活动场所。在那里城市环境将透过庞大的透明幕墙成为各仪式活动的背景。在这些空间的上方，竖向的玻璃幕越过建筑屋顶继续升高，围护着可上人的屋顶花园，将广场空间通过中庭平台延伸至了综合体顶部。

800个座位的下沉式金融剧场位于地面广场中心，成为了三栋建筑使用者最具归属感的焦点。剧院可由地下一层进入，该层还带有配套商业空间、三层停车库及其他辅助空间。

结构

相对项目本身的复杂性，该建筑的结构概念相对简单。每座塔楼是由两个核心筒部分构成的巨型结构。每一个核心筒部分则由核心筒自身和组合柱支撑，符合中国抗震规范要求 (GB 50011-2010 建筑抗震设计规范) 。

塔楼的两个核心筒部分在局部楼层 (塔楼顶部、廊桥层以及H型办公平面处) 通过楼板和斜撑连为一体。另外，各塔楼同时也通过地下层楼板连为一体。根据专家组的建议，塔楼在顶部额外增加了支撑结构，尽管结构计算证明这是不必要的 (图6) 。

建筑结构由钢筋混凝土核心筒、组合柱、钢梁、组合楼板和钢斜撑梁组成。廊桥为独立的钢结构，由两个带电梯的混凝土核心筒

Continuous vertical supports are available at every building; additionally the free-standing cores are available in-between the long span. The reinforced concrete walls located in each core and the outer steel tube of the cores provide lateral stiffness to the structure.

For an analysis with the time history analysis method, the Chinese Code suggests the use of 2 natural records and 1 artificial time-acceleration record (s. chapter 5.1.2.3). However, in accordance to the expert's panel directive seven graphs were calculated for this project. Wind tunnel analysis was also carried out as required for the project.

Since it seemed not possible to source locally concrete of the same resistance as specified (according to international standards) it was necessary during the calculations to lower the resistance of the concrete type selected.

Façade

The building façade had to be designed to respond to the latest code requirements as indicated in DGJ08-56-2012. This code is particularly demanding on the façade design both from a performance point of view and from a structural design point of view. It also puts some serious limitations to the design establishing the maximum size of the glass panels and the proportion between glass and solid wall.

In order to achieve the necessary façade approvals it was necessary to produce a full set of construction documents, analysis and calculations and to present them to the experts' panel. This represented a serious time and effort burden on the design team and differs greatly from the approval process necessary in Europe and the US. Furthermore, the requirement to perform a reflection analysis given the sensitivity of the area led to a reduction of the maximum reflectance to the outside of 3% from the 15% allowed in the code, that turned out to be very demanding on the performance of the glass panels. Low-E coated low iron IGUs are to be used with a reflectance of less than 12%, a shading coefficient of less than 0.38 and a light transmission higher than 55%.

The new façade code requires the buildings to have a glass surface of less than 70% of the total building envelope in commercial areas and 40% in residential ones to limit light reflection. The code applies these requirements to each elevation and also bans the use of curtain wall in areas next to sensible buildings. Furthermore the code limits the glazed areas of a curtain wall to 0.7 of the total surface with the remaining part having to be solid with a U-value of less than $1.0W/^{2} \cdot K$. Tables prescribe ranges for acceptable average u-values and shading coefficient with the first one been limited in our case to a value less of 2.5 and the latter less than 0.4.

Therefore, the building uses 4 different façade types. More transparent in the spaces that need it and solid where no daylight is necessary. In fact, the base façade is composed of stone and stainless steel clad insulated panels to maximize the building solid surface in those floors that host the data center. The lobby façade alternates glass panels to stone insulated panels to continue the base façade to the ground. Similarly, the museum floors where less light is necessary, alternates stainless steel insulated panels to glass panels.

The office floors have continuous glass panels that are split horizontally by a transom (the floor to floor heights are generous at 5 m minimum) to limit the glass area to $4.5\ m^2$, provide a fall restrain (guardrail) device as requested by the code and support the secondary frames of the operable windows. To assist in achieving the necessary solid façade

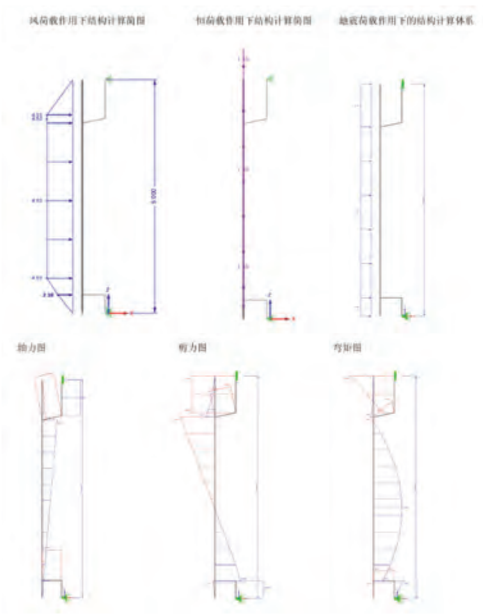

Figure 8. Typical Façade Analysis. (Werner Sobek)
图8. 标准幕墙分析图 (Werner Sobek)

Figure 9. Façade Mock-up Picture. (JAHN)
图9. 幕墙实样照片 (墨菲/扬)

支撑，廊桥边缘以活动式支座与塔楼连接。这种做法的好处是在地震时廊桥承受的地震作用不会影响到塔楼主结构 (图7) 。

廊桥钢结构由中空钢箱梁上覆混凝土板的梁板系统，如同常规的过道桥梁。这样避免了中国一般采用的斜撑加竖向粗柱的方法，使得廊桥变得轻盈通透。

每栋建筑都有连续的竖向支撑; 另外在大跨度空间中有独立的核心筒结构。各核心筒内的钢筋混凝土墙，以及核心筒的外部钢管为结构提供了抗侧力刚度。

关于罕遇地震时程分析，中国规范建议使用两组天然地震波和一组人工地震波 (章节5.1.2.3) 。然而根据专家会议的建议，本项目进行了七组地震波的验算分析，同时进行了风洞试验。

鉴于按国际标准强度设计的混凝土材料在当地难以采购，因此在计算中根据所选混凝土类型对混凝土强度进行了降低调整。

幕墙

建筑幕墙必须根据最新规范 (DGJ08-56-2012) 的要求设计。此规范对幕墙的性能和结构设计有严苛要求，并且通过玻璃面板最大尺寸和玻墙比对设计进行了严格控制。

ratio, the spandrels were exposed with recessed corrugated steel panels and their height increased from the 800 mm minimum required to meet the GB 50045-95 2005 Code for Fire Protection Design of Tall Building. This also helped articulating the volumes of the large buildings. To reinforce this, glass shingles were introduced in front of the spandrels. These are supported mechanically (silicon fixing only is not acceptable according to the code) by a steel channel at the base and by the vertical mullions (see Figure 8).

Since it was necessary to fix the glass mechanically and the buildings façades needed to reinforce the vertical direction to increase the verticality of the towers, it was decided to use exterior mullions that also assist in achieving the necessary opaque area and provide shading to the façade, supplementing the interior blinds. The façades of each tower utilize projecting 'V' mullions (see Figure 9).

In order to meet the thermal performance requirements without oversizing the insulation in the solid areas, particular attention has been paid to eliminate thermal bridges in the split mullions sections and argon in-filled IGU's have been used.

The maximum transparency of the building envelope was reserved for the atriums where double laminated insulated glass units are used in a tensioned steel cables façade with minimal fixings. This exceptional installation had to be studied with extreme attention with analysis, calculations and wind testing to prove its feasibility, deformation and safety to the façade expert panels. The lack of installations of this type, local knowledge of these advanced systems and dedicated regulation led to an extended study of the performance.

Fire Approval

Given the large floor plate of the special floors, and the contiguity of fire zones through the central atriums, multiple fire zones on the same level had to be used and the separation of these carefully coordinated with the Fire Department. In order to maintain the transparency of glass walls fire curtains have been introduced along the atrium façades and in the exterior façades in limited areas where two fire zones are adjacent. Special measures had to be implemented to protect the atrium spaces where fire suppression water cannons were implemented instead of regular sprinklers.

Another critical approach to the approval of the building was the implementation of limited occupancies in the special floors (e.g. conference and dining areas) of the towers. These spaces if calculated according to the code would show occupancy far above the real one and require an amount of vertical exiting that would be unsustainable for the buildings. Working closely with the Fire Department, RJA and the Clients the architects demonstrated intent to limit the occupancy of these floors to a realistic number that allowed to size the staircases reasonably.

The most complicated element in the Fire Department approval was the theater that is recessed below the plaza level. The insertion of a sunken garden and dedicated exits, sized with an extensive performance analysis were necessary to meet the code requirements that assembly spaces should not be located below grade (see Figure 10).

为了通过幕墙设计审批，设计方必须提供全套施工图纸、分析计算结果供专家组审阅。这对设计团队来说需要巨大的时间和工作量，与欧美的审批程序大为不同。另外由于场地周边的条件，对幕墙反射率的要求比规范允许的最大值15%还要降低3%，使得对玻璃面板的性能要求极为苛刻。采用的低辐射镀膜超白中空玻璃单元反射率必须低于12%，遮光系数须小于0.38，而且光透射比必须高于55%。

新的幕墙规范要求在商业区玻璃面积的比例必须小于总建筑表皮的70%，在居住区则须小于40%以控制光反射。规范的这些要求适用于每一立面，并禁止在敏感建筑物附近的区域设置幕墙。另外，规范在限制玻璃区域占幕墙总表面积0.7的同时，剩余的部分必须为U值小于1.0W/m2 • K的实心外墙。图表规定的平均U值和遮阳系数取值范围在本项目中被分别限制要求小于2.5和0.4。

为此，建筑采用了四种不同的幕墙类型。在需要日照的空间设置更透明的幕墙，而在不需要日照的部分设置实心幕墙。底部数据中心所在楼层的幕墙由石材和不锈钢覆面保温板组成，以便楼层建筑表皮实心部分最大化。大堂幕墙交替使用了玻璃面板和石材保温板，将底部幕墙延续至地面。类似的，在不需要太多光线的博物馆楼层采用了不锈钢保温板和玻璃面板交替的幕墙方案。

办公楼层采用了连续的玻璃面板，由横梁分割 (层高充足、最小为5米) 将玻璃面积限制在4.5平方米内，并且提供了规范规定的防跌落设施 (护栏)，同时作为可开启窗的框架。为了达到幕墙玻墙比的要求，层间板做成了凹进的波纹不锈钢面板，高度大于最小要求的800mm以满足高层民用建筑设计防火规范 (GB 50045-95，2005年版)的要求。这也有助于明晰整个建筑的庞大体量。为了加强这一点，层间板的前方设置了玻璃悬板。它们由底部的槽钢和竖框直接支撑于结构上 (规范不允许仅作硅胶固定) (图8) 。

因为玻璃幕墙的直接固定、以及建筑幕墙需要加强塔楼竖向感等原因，决定使用外部竖框。这种做法不仅帮助建筑增加了必要的实心区域，并成为室内遮阳的补充。每座塔楼最终采用了截面形状为V型的竖框 (图9) 。

为了满足热工性能又不致使实心区域的保温材料面积过大，我们特别注意减少了这些分割的竖框区域存在的热桥，并采用了氩气填充中空玻璃单元。

建筑表皮透明度最高的部分留给了中庭区域，此处采用了预应力钢索幕墙和双层夹胶中空玻璃单元，并使用了最少的固定构件。这种特殊的组装方式经过了严格的分析计算和风荷载测试，以向专家组证明其可行性、变形及安全性。由于这种安装方式以及相关特殊系统在当地缺乏实践，项目进行了专项的性能研究。

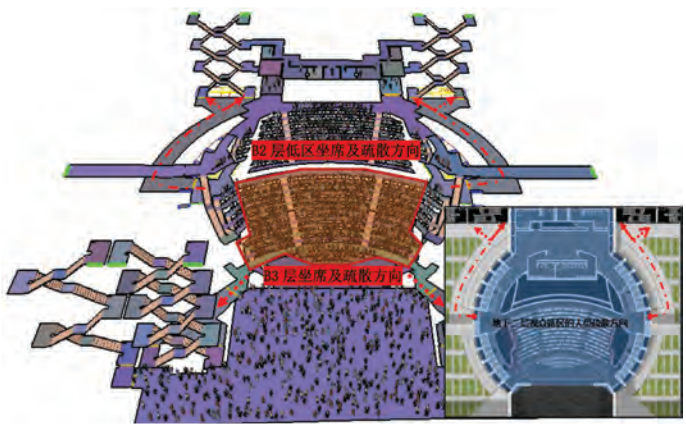

Figure 10. Theater Exiting Analysis. (RJA)
图10. 剧院疏散分析图 (RJA)

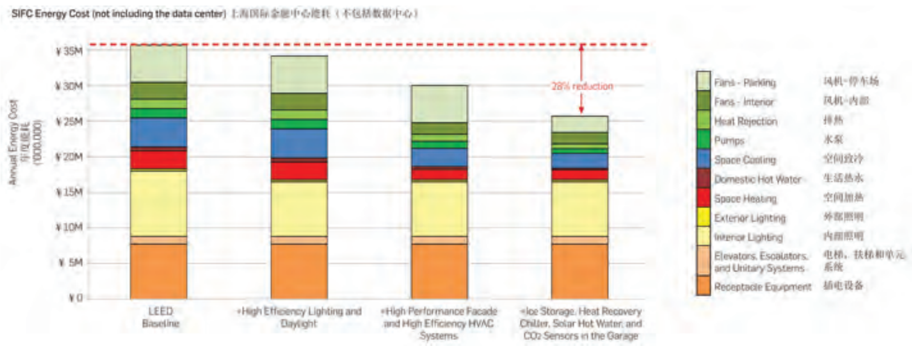

Figure 11. Energy Savings Chart. (WSP Group)
图11. 节能图表 (WSP集团)

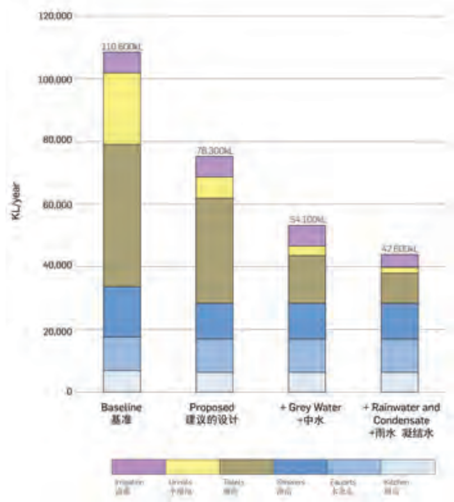

Figure 12. Water Usage Reduction Chart. (WSP Group)
图12. 节水图表 (WSP集团)

Sustainable Concept

The design team aspirations to realize high performance buildings and the client's desire to obtain a LEED gold certification pushed the design team to develop an energy concept to offset the high loads of the data centers through the buildings performances.

The design achieved a 25.3% energy use reduction compared to an ASHRAE 90.1 2007 baseline (see Figure 11). The integrated design of a high performance façade and relatively small floor plates allowed to implement natural ventilation, maximize day lighting (on average possible for 70% of the office hours) and support a highly customizable under floor air distribution system.

The atrium spaces are treated as semi-conditioned spaces, where radiant floors are used to adjust the temperature of the occupied areas while spill air from the offices is used to maintain the base temperature. Complex analysis of the air movements and temperature through the year were conducted by WSP to determine the operation of the windows integrated in the cable walls to ventilate the atriums in the summer and resulting in IGUs being used in the cable façade to minimize the drop of cold air along the façade in the winter.

The special floors with high ceilings, such as the lobbies and the conference floors, utilize a combination of displacement and radiant floors to limit the conditioned spaces to the lower, occupied part of the floor.

The combination of high efficiency plant equipment, heat recovery chillers, the integration of phase changing materials, the use of high performance cooling systems for the data centers and the use of thermal solar, drastically decrease the energy loads for HVAC reducing the yearly cost from 3.10 millions RMB/year to 2.66 millions RMB/year. The use of day lighting and use of energy efficient fixtures and motion sensors contribute to reduce the energy consumption of 1.53 millions RMB/year.

Rain water capitation throughout the large site, reuse of grey water, capitation of condensation in the cooling towers, and installation of efficient water fixtures in the buildings allow to reduce the fresh water utilization of 61.5 % from a 110,600kL/year LEED baseline to 42,600kL/year (see Figure 12).

消防审批

针对特殊层庞大的楼层面积和中庭防火区域所需连续性，同一层必须设置多个防火区，且防火分隔经过了与消防部门的认真讨论。为了维持玻璃墙的通透，中庭幕墙周围设置了防火卷帘，在室外幕墙的部分区域 (两个防火分区分界处) 也设置了防火卷帘。此外中庭采用了特殊的保护措施，以灭火高压水枪取代了常规的喷淋装置。

另外一个审批过程中解决的重要问题是塔楼特殊层 (如会议和用餐区) 人员数量的限制。如果按照规范计算，这些区域的使用人员数量将远远高于实际情况，为此将需要增加一定数量的竖向交通疏散措施，但这与建筑的可持续发展需求相悖。通过与消防部门、专业顾问和业主的紧密协作，这些楼层的使用人数将被限制在一定的范围，从而使楼梯间的尺寸和数量控制在合理范围。

消防部门审批中最复杂的部分是公共广场下方的下沉式剧院。为了满足规范集散空间不得设于地下的规定，设计了下沉庭院和专用疏散出口，其尺寸、位置的确定都经过了大量的性能分析 (图10) 。

可持续发展概念

设计团队对高性能建筑的追求，以及业主对LEED金牌品质的渴求，使设计者在建筑性能方面发展出了优秀的节能理念，尤其是消除了高负荷数据中心带来的不利影响。

设计在ASHRAE 90.1 2007的基准上额外减少了25.3%的能耗 (图11) 。整体化设计的高性能幕墙和相对较小的楼板可实现自然通风以及最大限度的采光 (平均70%的办公时间有效) ，并支持可灵活定制的地板送风系统。

中庭空间被视为半空调空间，这些空间在采用辐射地板以调节温度的同时，利用了办公空间溢出的冷空气以维持基本温度。机电顾问进行了复杂的全年空气流动和温度分析，确定了控制窗扇结合拉索幕墙进行中庭夏季通风的方案，同时在拉索幕墙中采用中空玻璃单元以减少冷空气在冬季沿着幕墙下沉。

在层高较大的特殊楼层，比如大堂和会议层，综合采用送风和辐射地板结合的方式，并将调节区域限制在较低的使用空间范围内。

Conclusions

This project shows the results that can be achieved in environmental sustainability and urban design, with the use of integrated design that JAHN has pioneered through the principles of 'Archineering'.

The project's approach to the city, with the inclusion of public functions and its relationship to the urban-scape are attempts to gain back the urban scale, in a vertical stratification of the city and its public and private spaces.

The Financial Centers' main features such as, the suspended museum, the gardens and the full high atriums, establish an ideology to integrate that 'public space' that once lived in the ground back into the elevated spaces of the 'city of the future'.

The Financial Center's ability of addressing complex codes issue and integrating sustainable measures in the design, to deliver a LEED Gold pre-certificate high-energy-demand complex, shows how it is possible to design high-rises in urban contexts and defines a better, more sustainable way forward for vertical cities.

总体上，组合高效率的装置设备、采用热回收冷水机组、结合使用相变材料、并在数据中心引入高性能冷却系统以及太阳能热利用等综合措施，大幅降低了空调暖通系统的负荷，将花费由310万元/年减少至266万元/年。自然光利用、节能装置以及移动传感器的使用也使所节省的能源花费达到了153万元/年。

在整个场地范围进行雨水收集、中水再利用、冷却塔冷凝水收集，配合建筑高效用水装置的安装使用，使净水的使用比LEED基准110,600千升/年下降了61.5 %，控制在42,600千升/年 (图12) 。

总结

遵循JAHN (墨菲/扬) 开创的"建筑-工程 (Archineering) "整体式设计原则，通过综合设计，实现了环境可持续性以及预期城市设计效果。

本项目的设计理念是在竖向层化城市中协调公私空间，通过公共功能及其与城市空间的关系设置赢得城市的规模。

上海国际金融中心的主要特色，如空中博物馆、屋顶花园以及通高的中庭等，建立了一种将以往通常位于地面的公共空间融入高度方向的"未来城市"的设计方法。

上海国际金融中心在解决了复杂的技术标准问题的同时，将各种可持续发展的措施和手段融入设计之中，创造了一个LEED金牌品质的高效建筑综合体，展示了城市环境中高层建筑以更好、更可持续的方式向竖向城市方向发展的有效途径。

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