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Utilization of BIM and Façade Optimization via Computer Technology in a Super High-Rise | 电脑科技在超高层建筑中的应用—BIM使用及幕墙优化



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陈观伟先生，毕业于皇后大学土木工程系，获得荣誉学士学位，并获得香港大学硕士学位。在GT任职十年，现就职于锆利科技（北京）有限公司董事。实际负责的大型BIM执行项目主要集中在澳大利亚、中国、香港、日本、韩国、马来西亚和新加坡等地。他的经验包括项目交付系统、项目管理、合约管理和制定。他将BIM可执行流程实际运用在设计、制造和建设，广泛用于基础设施、多功能综合体、商用和民用项目，如：北京银河SOHO、香港太古广场、上海浦江双辉大厦、上海尚嘉中心和上海迪士尼乐园等。并积极的在中国、印度、日本、韩国、马来西亚、新加坡和台湾进行广泛的BIM介绍和客座演讲活动。



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Abstract | 摘要

Tianjin Chow Tai Fook Finance Centre (TJCTF) is a mixed-use development with a total gross floor area (GFA) of 389,980 square meters. This 530-meter-tall building is expected to be opened in 2019. This article will provide an overview of the utilization of state-of-the-art computer technology, including BIM application in façade optimization and construction, based on the practices under TJCTF project management. With functional-based BIM strategy, the rationalization process of the building envelope is practical and can be utilized as a form of conscientious practice to manage the building costs. For construction coordination, optimal decisions are created by using visualizations, simulation, and other techniques. BIM and the development of handheld devices have enhanced the build-ability of TJCTF, while fulfilling the desired iconic shape within an economical target, as should be the aim for any commercial project. The team seeks to rationalize the intentions and processes, from design to construction, in building this iconic super high-rise.

Keywords: BIM, Construction coordination, Façade system, Geometry, Optimization

天津周大福金融中心(TJCTF)为总建筑面积达389,980平方米的综合性发展项目，建筑高度 530 米，预计于2019年开幕。本文将会根据天津周大福金融中心项目管理的实践，概述如何使用最先进的电脑技术，包括BIM于幕墙优化及现场施工中。由于采用功能化的BIM策略，幕墙表面的合理化是可行的，且应作为一种严谨的方法实践于管理幕墙的建造费用。在BIM技术用于施工协调方面，可通过可视化及施工模拟等手段，从而提供最佳的决策。BIM及手持式设备的发展，增强了天津周大福项目的建筑可行性，同时又在预算内实现了标志性造型，此为所有商业项目的目标。在标志性超高层建筑项目的建设过程中，从设计阶段到施工阶段，项目团队都应尽量保证原设计意图和复杂流程的合理化。

关键词：建筑信息模型(BIM)、施工协调、幕墙系统、几何学、最优化

Phenomenon – Tall Buildings From “Boxed-Form” To “Non-Boxed Form”

Traditionally, most high-rise buildings were designed and built in the rectangular “boxed form” to maintain architectural and engineering simplicity in order to save on building costs and construction time; however, with the improvement of the computational power of personal computers in recent decades, architects and engineers are now empowered and equipped to effectively design and analyze complex building forms. The time and cost spent in design and construction of the “non-boxed formed” buildings has become more manageable. Accordingly, the trend of super high-rise building has drifted from a “boxed form” to a “non-boxed form,” exhibiting various distinctive and iconic building shapes.

Challenges of Super High-Rise Building

Drawing upon the experience of the Tianjin Chow Tai Fook Finance Centre (TJCTF) project, four major challenges are identified:

现象——高层建筑从“方正外形”到“不方正外形”

一直以来，大多数的高层建筑都被设计及建造成为规则的“方正外形”，以简洁的建筑及结构，达到节省建筑成本及建造时间的目的。但随着近年来个人电脑的计算能力大幅提升，使建筑师和工程师能够高效的设计及分析复杂的建筑外形。设计、建造“不方正外形”建筑的时间与成本变得越来越可控。因此，超高层建筑的趋势已经从“方正外形”转移至“不方正外形”，并展现了各种独特及具有标志性的造型。

超高层建筑的挑战

根据天津周大福金融中心(天津周大福)项目的经验，主要面对四项挑战：

“F” – 功能性

在天津周大福，不同功能区竖向堆叠(餐饮，酒店，服务式公寓，办公楼及商场)。由于各主要功能区皆有不同功能及布局的要求，这样大大的增加了设计及施工协调的复杂性。

“F” – Functionality: In the case of TJCTF, different major functional zones stacked up vertically (food and beverage (F&B), hotel, serviced apartment, office, and retail). Due to the different functional and layout requirements of each major zone, this arrangement greatly increases the complexity in design and construction coordination.

“D” – Design Complexity: Due to the tower shape, the floor plates vary in size and form at every single floor level, imposing great challenges to the design and construction coordination for architectural, structural, E&M, and façade.

“C” – Construction Sequencing: The modern, super high-rise buildings inevitably require different functional areas to stack up and occupy the same floor zone. This poses particular challenges to effectively arrange construction sequences during the construction stage. These issues include:

(i) Vertically – Vertical transportation: The main challenge for vertical transportation is the moving of labor and materials to the floors above, while the upper part of a structure is still under construction. Since the number of tower cranes that could be erected is limited due to the available size of the working area, logistic planning for vertical transportation is most crucial to site progress.

(ii) Horizontally – Trade coordination: After the façade and certain major E&M installation works are completed, coordination works between wet trades (such as painting or flooring) and dry trades (such as wall coverings or carpentry) become another critical issue which will have a direct impact on the quality and target completion time of a project.

“S” – Site Logistics: Drawing from the example of the TJCTF project, vacant site area designated for site storage is quite limited (Figure 1).

Therefore, a detailed day-to-day logistics management plan is essential to ensure a smooth site operation is maintained by an efficient material delivery schedule.

Opportunity as “Tool for Construction”

Building construction technology advances with the sophistication of the construction methods in which we employ. In the past, people used stone/brick/timber for building



Figure 1. SiteSite plan of TianJin Chow Tai Fook Finance Centre Plan of TianJin Chow Tai Fook Finance Centre (Source: Christopher King)

图1：天津周大福金融中心工地平面图（来源：金润宾）

houses; in the recent past, people introduced steel columns, I-beams, reinforced concrete, and glass panes; today, the popular use of elevators and cranes, and the introduction of prefabrication and computer-aided design, all empowers the industry to build taller, and more complex buildings.

Although the age of the personal computer came into fruition in the 20th century, its use was limited in building industry because the size of the hardware was too bulky to carry into the site, making it difficult to become a practical “tool for construction.” In the 21st century, the invention of tablet computers and smart phones, and the popularity they have gained, has changed the way we use computers. These state-of-the-art computer technological products have large screen sizes and are lightly built, allowing for true portability. Additionally, these products now come with large and powerful memory sizes, which make them fully compatible with the application of BIM software, which has high-demands on hardware performance. In other words, the BIM models are no longer limited to office desktop computers, but have become handy and easy to bring directly onto the construction site.

“D” – 设计复杂性

归因于塔楼外形，楼板的尺寸及形状每一层均不同，这给建筑、结构、机电、幕墙的设计及施工协调增添了巨大的挑战。

“C” – 施工顺序

现代超高层建筑不可避免的需要把不同功能分区叠起及垂直占用同一楼层区域。这对施工阶段中施工顺序安排的高效性，构成了特别的挑战，其中包括：

(i) 竖向-垂直运输 – 垂直运输最大的挑战，是在上层保持施工状态的情况下，将工人及材料运送到不同楼层。由于工作面有限，可以装置的塔吊数量亦有限，垂直运输的物流规划将成为工地进度的最关键点。

(ii) 横向 – 工种协调 – 当幕墙及主要机电的安装工程完成之后，湿工种（例：油漆工程、地板铺设工程等）与干工种（例：贴墙纸、木工等工程）之间的协调就成为直接影响工程质量及项目竣工时间的重要因素。

“S” – 工地物流

以天津周大福项目为例，工地可以用于材料储存的地方非常有限（图1）。

BIM Application – Façade Optimization

This BIM-based approach to façade optimization shall combine a set of geometry processing frameworks, together with an in-depth study of façade system functions and performance.

The design intent of the Tianjin Chow Tai Fook (TJCTF) tower calls for a bold monolithic expression on the skyline. The façade uses undulating curved surfaces to subtly express three programmatic elements. With the original building envelope design intent from Skidmore, Owings & Merrill LLP (SOM), Gehry Technologies (GT) was commissioned by New World Development (NWD) to optimize the building envelope and to provide panelization strategies for its unique surface geometry with the aim to minimize panel typologies and ultimately improve the façade system performance as a whole.

The façade systems of TJCTF tower range from unitized, stick to point-fixed systems. For the tower envelope, a unitized curtain wall system is the preferred solution for the enclosure, as it one of the most sophisticated available systems. The benefits are that it allows building to be enclosed quickly, which helps to speed up the construction progress leading to earlier occupation. The stick system is an exterior wall and cladding system that is hung on the building structure from floor-to-floor. A few functions and performances of the façade system include the capability to allow the drainage of rain water, prevention of water penetration, facilitation of differential building movement under wind and/or

maintenance loads, air infiltration control, and pressure equalizers.

The challenges of the TJCTF tower project can be categorized into two sections – geometry and its curtain wall system.

(1) Geometry

The gently-undulating curves of the building envelope of TJCTF are originally designed with geometries described by ellipses and hyperbolas, which can be represented with associated mathematical equations. The wavelike building profile changes from concave-to-convex and vice versa throughout the building envelope. With the given geometry and model elements, the panel units are not in a symmetrical shape, which is ineffective from cost saving viewpoint (Figure 2).

(2) Curtain Wall System

The curtain wall system component of the tower includes V-shape mullions to adapt different geometrical profiles. They also act as structural members that transfer the dead load of the panels and above floor, including wind and maintenance loads, onto the structure. With further detail analysis and a breakdown of the façade panels through different zonings, irregular panel types with different end conditions exist on both ends of the V-joint profiles. The unique types of end panel increases as the V-joints incline in various degrees while extending upward.

Because of the convex and concave profiles of the building, the stack joints will not be aligned within each floor, and thus the work

因此，制定每天详细的物流安排计划是必要的，为了可以通过有效的材料运送安排，保障工地顺畅运作。

成为“建造工具”的机遇

建筑施工技术随着日渐成熟的施工方法也不断进步。过去，人们用石头/砖/木头建造房屋；到了现代，人们懂得于建筑上引用钢柱、工字梁、钢筋混凝土和玻璃，再加上电梯及塔吊的普及使用、引入预制件，及使用电脑辅助设计等等，都让建筑业能够建造更高更复杂的建筑。

虽然个人电脑时代在20世纪已结出硕果，且变得越来越流行。但其在建筑行业的应用仍然有限：笨重的硬件无法带进工地，使得其变为“建造工具”非常困难。在21世纪，平板电话及智能手机的发明和普及已经改变了我们使用电脑的模式。这些顶尖的电脑科技产品既轻巧、亦配有大尺寸荧幕，使其变得真正的可携。再加上这些产品的强大储存容量，使得他们完全可以配合BIM这种对硬件配备要求高的应用程序。换句话说，BIM模型不仅局限于办公室的台式电脑才可使用，而是可随身携带，很容易在工地使用。

幕墙优化

BIM应用——建筑幕墙优化

超高层建筑的幕墙BIM优化设计不仅需优化外表皮形状构造，而且要提高建筑幕墙系统性能。

天津周大福中心项目的设计旨在天际线中展示高大醒目的形象。外形设计运用起伏的曲线，巧妙的体现大厦三个功能空间组成元素。由SOM设计事务所提供反映设计意图的建筑外表皮，新世界发展有限公司委托铿利科技（以下简称“GT”）优化建筑外皮并提供板块分割策略，希望最大限度地减少板块类型，提高整体性能。

周大福中心幕墙体系包括单元式和点支撑式两种。应更优先考虑单元式幕墙外表皮构造，其好处是能更快围合建筑，提前入驻日期。点支撑式属于外墙铠装系统，逐层悬挂在建筑结构之上。幕墙的性能包括雨水排放、水密性、风荷载或维护荷载下的微分建筑活动、气密性和均压等。

周大福中心面临的挑战分为两部分——几何学和幕墙系统。

(1) 几何学

由于外表皮不断起伏变化，幕墙单元板块的形状不对称，成本偏高（图2）。

(2) 幕墙系统

幕墙系统包括能适应不同型材的V形竖挺。竖挺还可将风力和维护荷载传递到

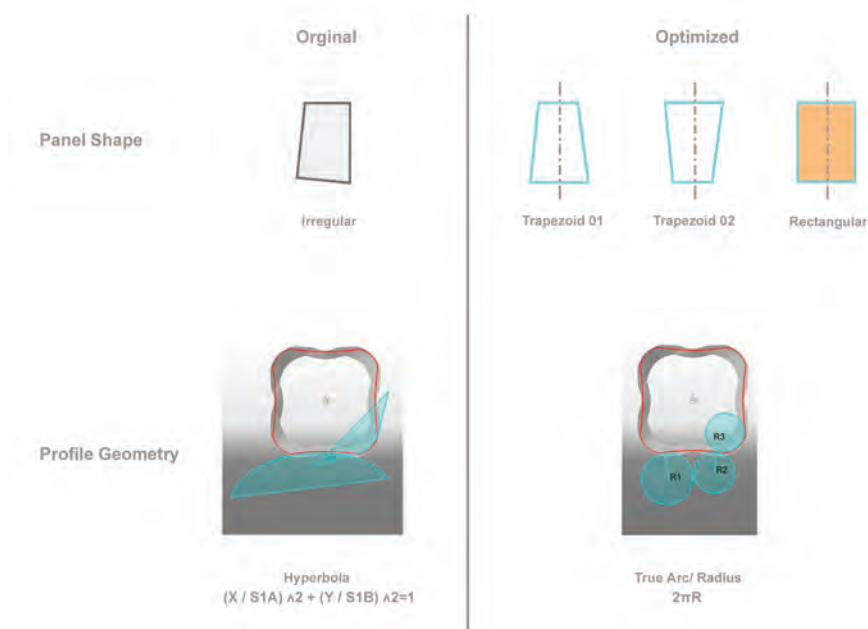
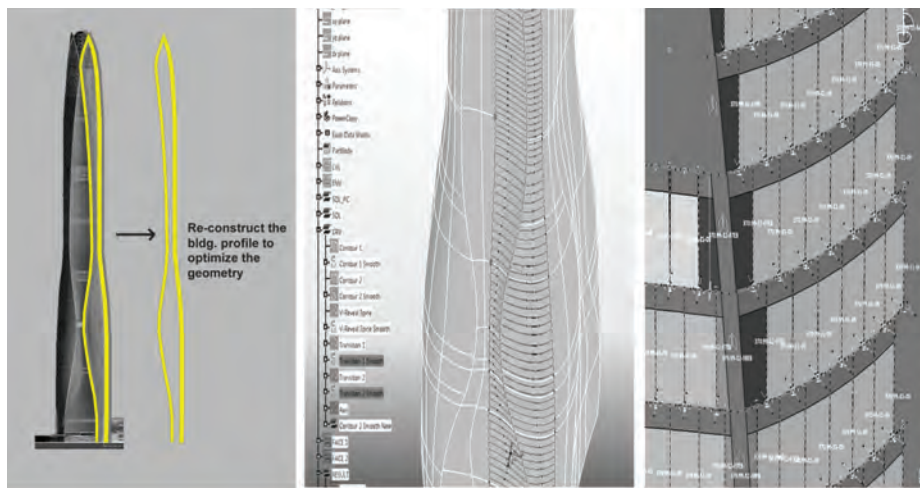


Figure 2. Optimized panel shape and surface profile (Source: Christopher King)

图2：优化板面形状与表面轮廓（来源：金润宾）



Re-construct building profile Rationalize Surface Geometry Panelization

Figure 3. General panelization process for building surface (Source: Christopher King)

图3 建筑表皮通用板块化流程（来源：金润宾）

points between the glazing surfaces of each curtain wall unit to the centerline of the gutter will be different. The sloping mullion tilting angles on plan and elevation requires analysis for the TJCTF tower project. From elevation, the sloping mullion is staggered due to the spiral effect of the envelope design; thus, the regular panels or end panels for upper and lower adjacent floors cannot be aligned due to the spiral effect of the envelope design intent.

Gehry Technologies' general approach to building surface optimization takes into account the following (Figure 3):

- Rationalization of building profiles and surface geometries;
- Panelization and identification of unique panel types;
- Panel typologies optimization;
- Patterning and further development of panel shapes;
- Improvement of building form efficiency; and
- BIM-based analysis and study of façade system.

Building Envelope Optimization – General Process

GT proposed and formulated a geometry process framework using Digital Project™ as the primary tool for the entire envelope optimization analysis. Digital Project™ is a computer-aided design (CAD) software application developed by Gehry Technologies. Digital Project™ is also used in several renowned architectural firms such as Zaha Hadid Architects, UNStudio, and

Coop Himmelb(l)au. The overall envelope surface geometry is first rationalized and reconstructed in Digital Project™.

There are two stages to deal with the panelization and optimization for the TJCTF building envelope:

Stage 1 – Regular Panels: The optimization algorithm was established in Digital Project™ to instantiate the regular panels with which the shapes are isosceles trapeziums.

Stage 2 – End Panels: The panelization shall continue for end panel conditions along the V-joints. This was reviewed in a 3-D environment for visual and constructability reasons. In certain conditions, end glazing panel will be fused with adjacent panel or isolated to cater for the ease of manufacturing and aesthetics. The final step includes grouping the developed panels into families to further investigate the reduction of panel typologies and eventually standardization (Figure 4).

Building Envelope Optimization – From Surface Geometry to Façade System

To deal with the geometrical complexity of the TJCTF tower, surface geometry optimization alone is insufficient to provide the optimum solution for the envelope. A holistic approach is to integrate both surface geometry and functional requirements into the optimization process.

With a unitized curtain wall system, stack joint is the major system component to provide a water drainage path within the curtain wall system; a continuous stack joint alignment is critical to ensure water tightness. Thus, the stack joints should be modeled and studied in

主结构，此项目V形槽两端均存在不规则板型。端板的独特类型随V形槽向上延伸倾斜而增加。

异形造成幕墙的层间接缝不对齐，每组单元的玻璃表面到天沟中线工作缝不相同；立面上，坡向竖框参差不齐。因此，要满足设计意图，相邻上下层的常规单板或端板就无法对齐。

GT考虑了以下因素（图3）：

1. 表面和外轮廓合理化
2. 独特板面类型的鉴别与重组
3. 板面类别优化
4. 板块划分与板块形状深化
5. 提高幕墙性能
6. 分析与研究建筑外立面系统；

幕墙表面优化——通用流程

GT采用自行开发的Digital Project作为主要工具，先对外表皮合理化论证，再重新构造。分为两步：

一、把规则等腰梯形板块进行实例化。

二、沿着V型接缝划分端板，在3D环境中进行建造可行性研究，镶玻璃端板分为混装与单独安装两种。最后将分好的单板进行分类，进行下一步板面类型优化和最终的标准化的（图4）。

幕墙结构优化——从表面到幕墙系统

周大福中心的幕墙优化将表面与功能要求两者都整合到优化流程中。

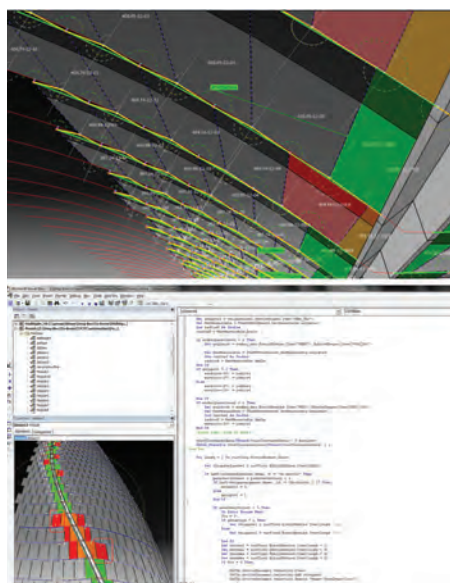


Figure 4. Scripting in Digital Project™ to deal with end panel matrix (Source: Christopher King)

图4 在Digital Project中进行编程处理端板矩阵（来源：金润宾）

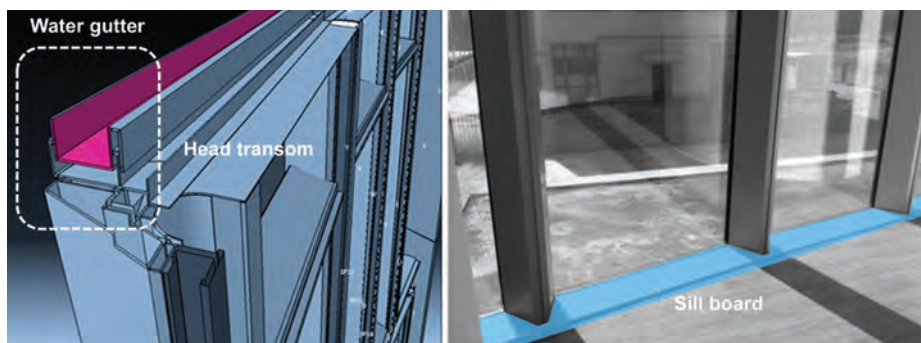


Figure 5. Improved water gutter and sill board relationship (Source: Christopher King)
图5. 改进后的天沟和窗板关系（来源：金润宾）

a 3-D environment to ensure that the upper and adjacent lower units of the unitized systems are connected in a water sealed condition. For this case, the development of stack joints should cater to different conditions, such as staggered mullions, glazing panels, and building profiles.

Another critical relationship is to consider the gutter minimum width to allow adequate flow of water in case of infiltration. At this stage, close collaboration with the façade consultant is necessary to acquire the necessary engineering inputs and parameters. Given the technical relationship between gutter and the sill board, the shift of gutter will have significant impact to the usability of the spaces/rooms behind the system. Throughout the optimization process, critical areas with potential risk of jeopardizing the Usable Floor Areas (UFA) were identified (Figure 5).

Building Envelope Optimization – Result

The utilization of the parametric façade BIM model enables faster iterations of analysis, which ultimately leads to the development of a better system performance and fabrication. The early introduction of BIM-based optimization workflow during the design phase will facilitate future onboard façade contractors in better understanding the design intent and fast-consuming the vast amount of design challenges within a shorter timeframe upon contract award. These optimization techniques will further enhance and optimize the system performance and their fabrication criteria.

With the above two stages of optimization, the variation of panel types has been reduced significantly. Gehry Technologies has improved the efficiency of the building envelope by approximately 60 percent with $\pm 2.5\text{mm}$ design tolerance applied. The optimization approach for the TJCTF tower is practical and can be utilized as a form of conscientious practice to manage the façade component of building cost. BIM has enhanced the practicality and the buildability of the TJCTF tower, all while

fulfilling the desired iconic shape within an economical target, as should be the aim for any commercial project. The project team seeks to rationalize the original intentions and complex processes from design to construction in building iconic super high rise.

Utilization of BIM in the Construction of TJCTF

Since BIM was always implemented before construction in various specialties such as architecture and structure modeling, MEP system, façade, and interior design (Figure 6), the whole modeling process was more like a full-cycle construction simulation process. BIM modeling was coordinated by the project team before construction so that all design clash issues between different specialties could be optimized to finally meet design and construction requirements.

Challenge & Opportunity

Because of the limitation of narrow corridors, high clearance requirements and more than

单元式幕墙中，层间接缝是保证幕墙内部排水畅通的主要组件，应在3D环境下建模研究，确保相邻的上下单元在水密条件下衔接。就本案而言，层间接缝深化应考虑到错位竖框、镶玻璃单板和建筑型材等工况。另需考虑天沟的最小宽度，在渗水的情况下保证水流畅通。本阶段需与幕墙顾问公司密切合作，获得专业意见。天沟移位将影响幕墙后面使用空间，故在优化过程中，确定了对可用建筑面积构成潜在风险的区域（图5）。

幕墙优化——成果

参数化模型加快了分析迭代的速度，并可使后期承包商更易理解设计和进行深化。经优化，板面类型已显著减少。GT使可建造率提高近60%并使设计误差控制在 $\pm 2.5\text{mm}$ 。BIM增强了天津周大福项目的实用性和建筑可行性，同时又在预算内实现了标志性造型，此为所有商业项目所追求。在标志性超高层建筑项目的建设过程中，从设计阶段到施工阶段，项目团队都应尽量保证原设计意图和复杂流程的合理化。

天津周大福施工BIM应用

中建八局著项目BIM实施在建筑结构建模、机电管线综合排布、幕墙方案调整、精装设计优化等过程始终走在了各专业施工之前（图6），整个建模过程，更像是一个全周期施工模拟的过程。在施工之前项目各参与方进行可视化设计协调，对碰撞问题进行设计优化调整，最终达到设计施工要求。

机遇及挑战

由于项目走廊狭窄，净空要求高，管线走廊密集区多达十余层，总包率先提出以机

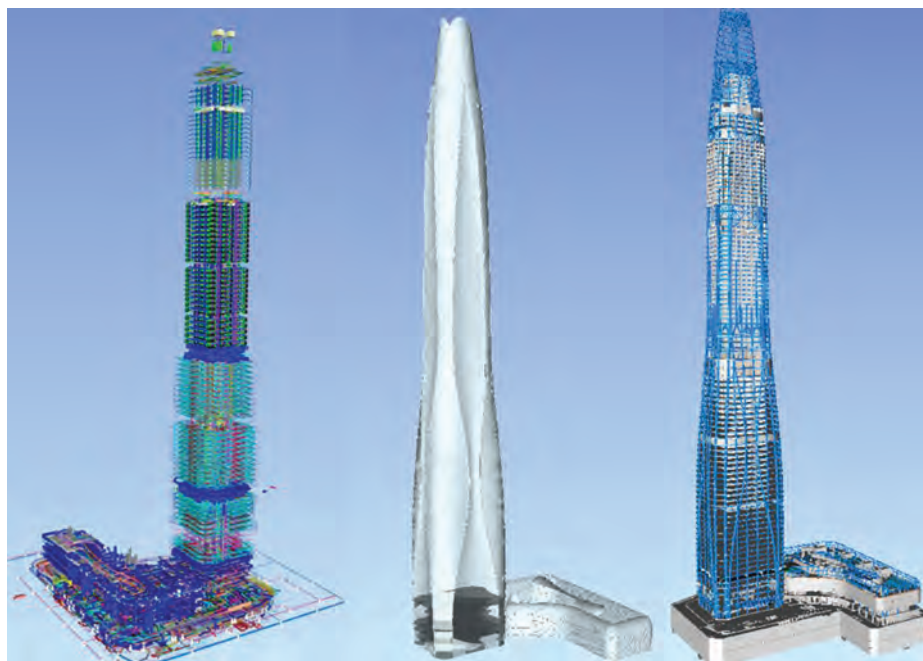


Figure 6. Comprehensive BIM model of Tianjin Chow Tai Fook Finance Center (Source: Christopher King)
图6. 天津周大福金融中心全专业BIM模型（来源：金润宾）

ten layers in pipeline overlap along the ceiling void of the corridor, time and quality cannot be achieved if a conventional construction method is applied. The main contractor proposed to build the MEP system as a bridge (Figure 7) that made a link between the building structure and the curtain wall. The design optimization adjustment process is shortened and design is improved through visualized coordination involving multiple specialties.

In order to accurately embed sleeves through walls and find the accurate relative setting for building walls and electromechanical pipeline, every wall, opening, and shaft will be sectioned in a BIM model before construction in order to reasonably consider the position of structural columns, ring beams, and the layout of block walls. It's truly achieved that every single wall, opening, and shaft has its own drawing to avoid a second opening and plugging.

BIM 4-D Utilization

The LOD definition and criteria, which were introduced from AIA G202-2013 and LOD Specification 2015, have been included in subcontracts to ensure an effective implementation by subcontractors. Comprehensive plans, such as master schedules, annual plans and quarterly plans, were simulated through the LOD300 model. Different scenarios were explored to improve the whole schedule and a step-by-step optimization ensures that the whole plan is reasonable.

After mobilization, specialist subcontractors will be briefed about the whole construction process of the project through 4-D plan video, the key milestones of the project and work contents of each phase, the layout of the construction site, the consumption of resources, and the preparation processes for construction.

Detailed weekly and daily programs are stimulated by using LOD400. Based on this schedule plan, the main contractor can strictly control everyday work contents and construction process of each specialty and review daily schedule of subcontractors.

In the Tianjin CTF Finance Center project, the BIM 4-D technology is employed for the visualization preparation and process control of the construction schedule, so that the construction schedule is reasonable, effective, and controllable (Figure 8).

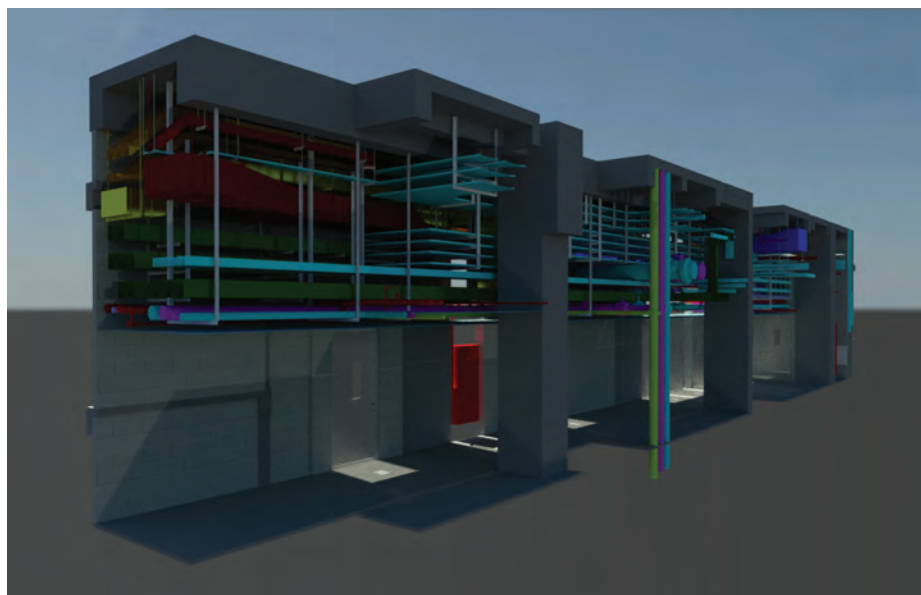


Figure 7. BIM model of basement (Source: Christopher King)
图7. 地下室BIM模型 (来源: 金润宾)

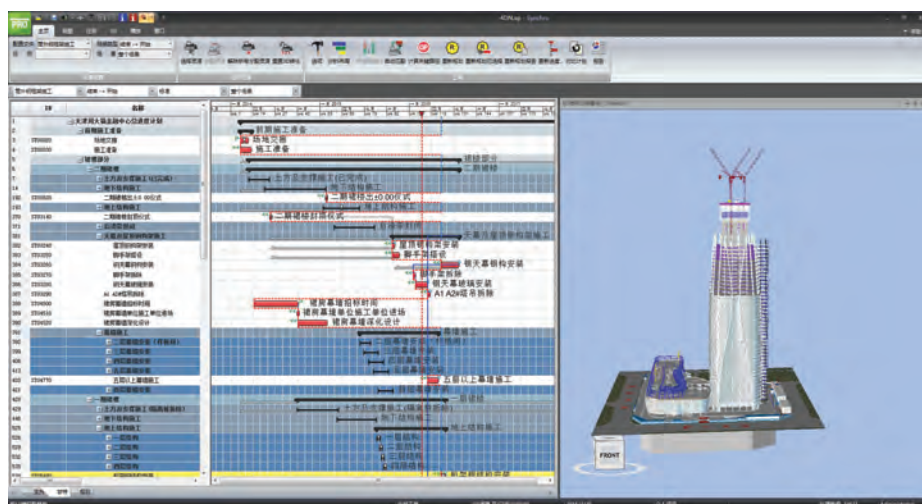


Figure 8. BIM 4-D schedule plan (Source: Christopher King)
图8. BIM 4D工期计划 (来源: 金润宾)

电为纽带 (图7), 承上衔接建筑结构, 启下协调精装修幕墙。通过多专业可视化协调, 极大的缩短了设计优化调整的过程, 推动了设计的完善。

为实现二次墙体在砌筑时提前精确预埋过墙套管, 准确定位建筑墙体与机电管线的相对位置, 施工前, 在BIM模型中对每一个墙体、洞口、井道进行剖切, 合理考虑墙体的构造柱、圈梁的位置和砌块的排布, 真正做到一墙一图, 一洞一图, 一井一图, 杜绝墙体二次开凿, 避免墙面的二次封堵。

BIM 4D 应用

天津周大福金融中心工程引用美国AIA G202-2013以及LOD Specification 2015中LOD的定义标准, 将其纳入分包合同内, 有效促进各分包积极执行。利用LOD300精度模型模拟总进度计划、年、季度计划等整体性计划。制定预案, 事前预判, 完善整个进度计划, 逐步推演, 不断优化, 保证整体计划编制的合理性。

在各专业分包进场后, 通过4D计划了解整体建造计划安排, 对关键节点及各阶段的施工内容、场地布置和资源消耗等提前做好准备。

利用LOD400精度模型模拟周、日计划等细部控制计划。总包依据此进度计划, 严格控制各专业分包每天的工作内容和施工工序, 对分包单位每天的施工进度进行考核。

使用BIM 4D技术进行建造计划的可视化编制和过程控制, 使项目的建造计划合理、有效、可控 (图8)。

BIM应用——质量管理与控制

在工程建造过程中, 对于钢结构、幕墙、机电系统等结构形式复杂或空间位置关系多变的节点, 采用BIM技术进行数字化预制加工, 已涉足多个专业领域, 通风系统采用BIM模型进行分节下料, 加工厂采用等离子切割、拼装; 幕墙采用CAM系统自动拾取单元体结构特征, 自动选择刀具加

BIM Utilization – Quality Management & Control

During construction, for interfacing details of complex structures or complex 3-D setting out of steel structures, curtain walls, and electrical and mechanical systems, digital prefabrication and processing are done by using the BIM technique that has been involved in multiple specialties: the ventilation system uses the BIM model for segmental cutting; factories use plasma cutting and assembly; curtain walls use the CAM system for automatically picking the structural characteristics of units and automatic selection of processing tools; field welds are corrected with compression and deformation compensation of inner and outer barrels; field installation is accurately positioned with a total station, etc. (Figure 9).

3-D laser scanning techniques are used to review the spatial position relation between the steel structure model and on-site installation, and monitor whether each module in embedded parts at the edges of floor slabs and the curtain wall model meets the installation requirements, so as to ensure installation precision and controllable errors (Figure 10).

With the support of BIM, the complex building structure from interior fit-out to exterior façade is easily be visualized and thus be evaluated, therefore, the quality of construction management for super high-rise project is enhanced and improved.

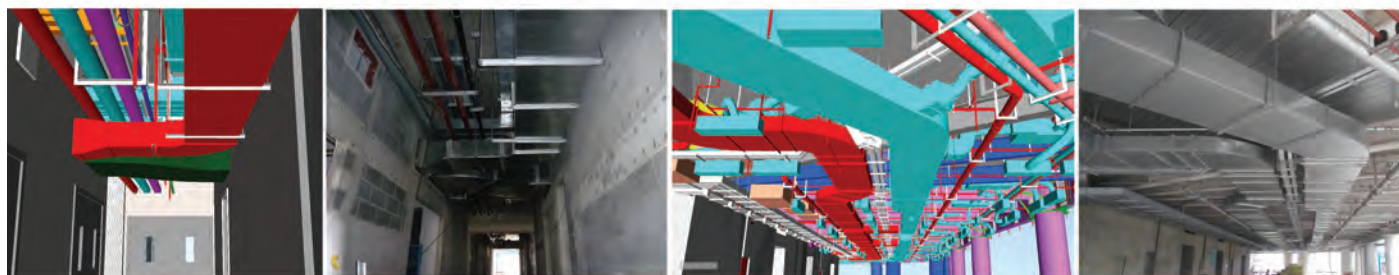
工等；现场焊缝修正实现内外筒压缩变形补偿，现场安装采用全站仪进行精确定位（图9）。

采用三维激光扫描技术复核钢结构模型与现场安装空间位置关系，监测混凝土结构楼板边预埋件实体与幕墙模型每一个板块是否满足安装条件，确保安装精度准确、误差可控（图10）。

建造过程中的质量管理在BIM的支撑下，使建筑从复杂的内部结构体系到高端的外观装修质量控制有了可视化的虚拟仿真预控评判技术，提升超高层建造过程的质量管理水平。



Comparison between actual works and the model (Basement)
地下室模型与实际对比



Comparison between actual works and the model (Office)
办公区模型与实际对比

Figure 9. Comparison between actual works and the model (Source: Christopher King)

图9. 工程实体与模型对比（来源：金润宾）

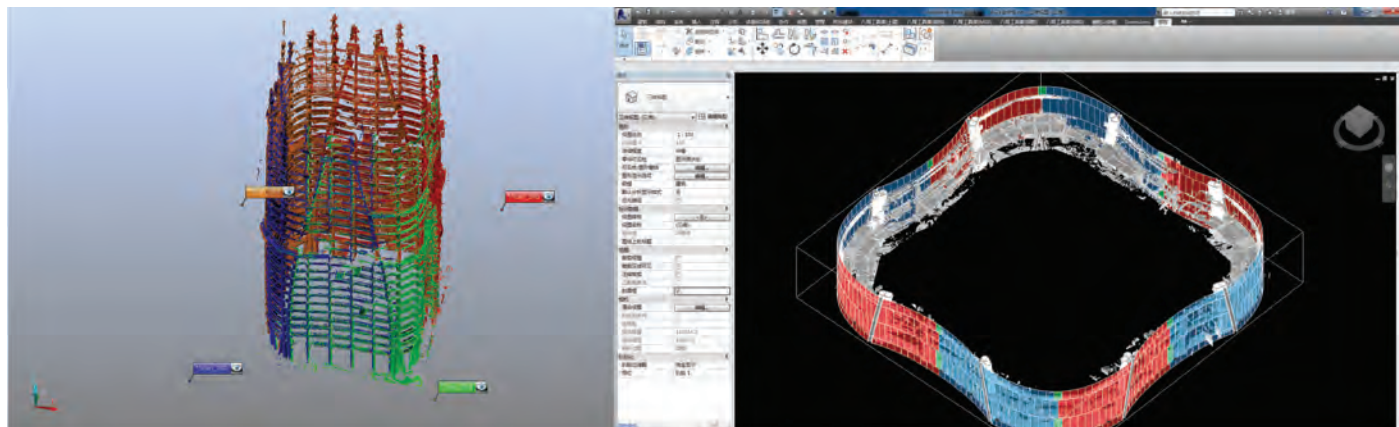


Figure 10. Cloud model of 3-D scanning points of the tower (Source: Christopher King)

图10. 塔楼三维扫描点云模型（来源：金润宾）



Figure 11. Tianjin Chow Tai Fook Finance Centre designed by SOM (Source: Christopher King)

图11. 天津周大福金融中心，由SOM设计（来源：金润宾）



Figure 12. Site photo of Tianjin Chow Tai Fook Finance Centre (Source: Christopher King)

图12. 天津周大福金融中心工地照片（来源：金润宾）

Conclusion

Future

The popularity and mature development of the above mentioned technologies greatly increases the practicality of BIM application in the building industry, from design to construction stages. BIM will help and tackle the previously mentioned “F,D,C,S.” It has also greatly improved the design coordination, façade and E&M optimization, and site planning and construction coordination. The entire construction process can thus be “rehearsed” within a computer. In order to make it commercially viable and to build an iconic building with anticipated high construction cost, computer technology must be fully utilized within this day and age. The bridging between project management and facility management can be optimized as well (Figures 11 & 12).

结论

未来

上述科技的流行及成熟发展将大大提高BIM在建筑行业由设计到施工的可应用性。BIM的应用能帮助处理之前提到的“F,D,C,S”。它对设计协调，幕墙、机电优化，工地规划及工地协调各方面亦有极大的帮助。整个建造过程可以于电脑中进行“预演”。标志性建筑预算的建造费一般较高昂，为使其具有商业可行性，如今必须全面应用电脑技术。项目管理和设施管理之间的桥梁也可以因此得到优化（图11、12）。

References:

Eastman, C. (2011). **BIM Handbook Second Edition.**