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Design to Fabrication: Fifth Hotel City of Dreams, Macau

从设计到建造：澳门新濠天地第五酒店

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Viviana Muscettola joined Zaha Hadid Architects in 2004, having worked for a number of different practices in China, the Netherlands, and Italy. Viviana has worked on a wide range of projects and competitions in Malaysia, China, Egypt, Singapore, France, and the UK.

As Project Director, she has led a number of major projects for the practice, including the d'Leedon 7 residential towers in Singapore, which was completed in 2015 and a master plan for the Cairo Expo City's exhibition and conference centre in Egypt. Currently, she is the project director for a 780-key hotel and casino project in Macau.

维薇安娜(Viviana)于2004年加入扎哈•哈迪德建筑师事务所。此前，她曾经在位于中国、荷兰和意大利的多家不同事务所工作。她所从事的多类工程和设计竞赛项目遍及马来西亚、中国、埃及、新加坡、法国和英国。

作为项目总监，维薇安娜参与领导了我司的众多大型项目，其中包括2015年建成的新加坡“丽敦豪邸”（D’Leedon）7座住宅塔楼，以及埃及“开罗博览城”展览与会议中心的总体规划。目前，她负责一个位于澳门拥有780间客房的酒店与赌场项目。

Abstract | 摘要

This paper presents the unique collaboration among architects, engineers and contractors for the 5th Hotel at the City of Dreams in Macau. Our methodology centers around a comprehensive 3D model that was iteratively optimized to refine the architectural shape, to analyze the structural integrity, and to fabricate the building. Parametric tools were used throughout the life of this project from initial design stages to final fabrication.

The final three-dimensional model is not an aggregation of parts manually and separately designed, but is a live set of adaptable inputs coded to simultaneously generate the final design and fabrication data. The power of such a tool lies in the high level of flexibility: each new input into the parametric model is interacting with and informing the data output for further recalibration and adaptation.

Keywords: BIM, Construction, Façade, Parametric Design, skybridges, Steel

本文讲述了建筑师、工程师与承包商们倾力打造澳门“新濠天地第五酒店”的独特的合作历程。我们通过建立一个综合系统3D模型，并在此基础上不断予以优化，从而完善建筑形体设计、分析结构完整性，以备施工建造。从初始设计的各个阶段到最后的施工建造，参数化工具的使用贯穿整个项目周期。

最终生成的三维模型并非手动单独设计部件的机械合成，而是一套动态可调整的编码信息，用以同步生成最终的设计与和建造数据。这种参数化工具的优势体现为其高度的灵活性：每次输入参数化模型的新信息，都会与数据输出端互动，并且通知输出端口与之校准和完成调整。

关键词：BIM、施工、幕墙、参数化设计、空中天桥、钢结构

The Fifth Hotel, City of Dreams:

Macau, a former Portuguese colony, is a special administrative region of China, renowned for its tourism and gaming industries. According to the latest census, the population of Macau is around 636,200 inhabitants living on a mere 30 square kilometers of land, making it one of the most densely populated regions in the world. Today Macau is one of the richest cities in the world, serving as Asia's premier gaming and entertainment hub.

City of Dreams (CoD) is a comprehensive resort in the Cotai Strip reclamation area of Macau. It is built, owned and managed by Melco Crown Entertainment, and is part of Melco Crown's first mega-sized property in Macau. CoD comprises a three-floor podium with a mega-casino, two theaters, 200+ retail shops, and four hotel towers offering 1,400 rooms.

In 2012, Zaha Hadid Architects was appointed by Melco Crown Entertainment's Co-Chairman and CEO, Lawrence Ho, to design a new flagship facility – the Fifth Hotel. The brief

新濠天地第五酒店

澳门曾经是葡萄牙的殖民地，回归后成为中国的特别行政区，因其旅游和博彩业而享誉盛名。根据最新统计数据，澳门约有636,200人口，居住在这座面积仅为30平方公里的岛屿上，因此成为全球居住人口最密集的地区之一。如今的澳门作为亚洲最顶尖的博彩和娱乐中心，是全球最富有的城市之一。

“新濠天地”（CoD）是澳门填海区路凼金光大道上的一个综合度假圣地，由新濠博亚娱乐有限公司兴建、持有和经营，也是新濠博亚在澳门首个巨型地产项目的一部分。新濠天地包括一座3层裙楼（其间设有1个巨型赌场、2个剧场和200多个零售商铺）以及4座酒店塔楼，可提供1,400间客房。

2012年，新濠博亚娱乐有限公司联席主席兼执行总裁何猷龙先生委任扎哈•哈迪德建筑师事务所为该公司设计新旗舰设施—“第五酒店”。设计任务包括一个五星级豪华赌场酒店与商场，使得整体开发形象焕然一新，并且将酒店客房总数扩大至2,150间。

includes a five-star luxury casino, hotel and mall, which would renew the image of the entire development and bring the combined hospitality capacity to over 2,150 rooms.

The sculptural form and composition of the Fifth Hotel is as undeniably intriguing as it is equally mysterious because it is non-referential to traditional architectural typologies. A simple volume is carved by a series of voids into a complex form, which implies an abstract figure-eight or double loop. The aesthetic effect of the voids is unique and it offers exciting internal spaces. The underlying diagram is of two towers connected at the podium levels and the roof, with two additional bridges from which the external voids can be observed and experienced up close.

Zaha Hadid Architects is building the first high-rise hotel complex supported by a free-form exoskeleton steel structure to accommodate a mixture of programs. Within one coherent building envelope, the building features three sky bridges, five different glazing systems, and a non-repetitive doubly curved aluminum cladding on the exoskeleton. The challenges from these formal and structural complexities as well as stringent performance criteria for users' comfort are unprecedented (Figure 1).

The building occupies over 40 levels. The lower three levels connect directly with the surrounding CoD podium and house public functions and a casino floor. The higher floors house the hotel, which will cater for up to 780 keys, with adequate back of house areas and ancillary guest facilities exceeding five-star hotel standards. Several top floors will house VIP gaming facilities, villas, specialty F&B venues, a premier lounge, and a roof top exterior pool semi-enclosed within the building form (Figure 2).

The porte cochère is neatly integrated within the external fabric to keep a monolithic appearance without the insertion of external elements alien to the design language. The entrance brings the hotel guests directly within the grandiose atrium, a 40-meter-high space that looks up into the voids (Figure 3). The atrium is finished with elegant and simple materials, to give a sense of confidence and refinement. The hotel lobby gives direct access to the retail strip and the main gaming area at ground level. The atrium itself houses the main reception area, a lobby bar, and a flexible installation space. The vertical circulation is split between two cores to the east and west sides of the atrium, which connect to the hotel accommodation floors and the additional VIP gaming areas. Panoramic lifts within the atrium enable views of the atrium and to the outside

Figure 1. Fifth Hotel at City of Dreams in context (Source: Zaha Hadid Architects)
图1. 新濠天地第五酒店（来源：扎哈·哈迪德建筑师事务所）

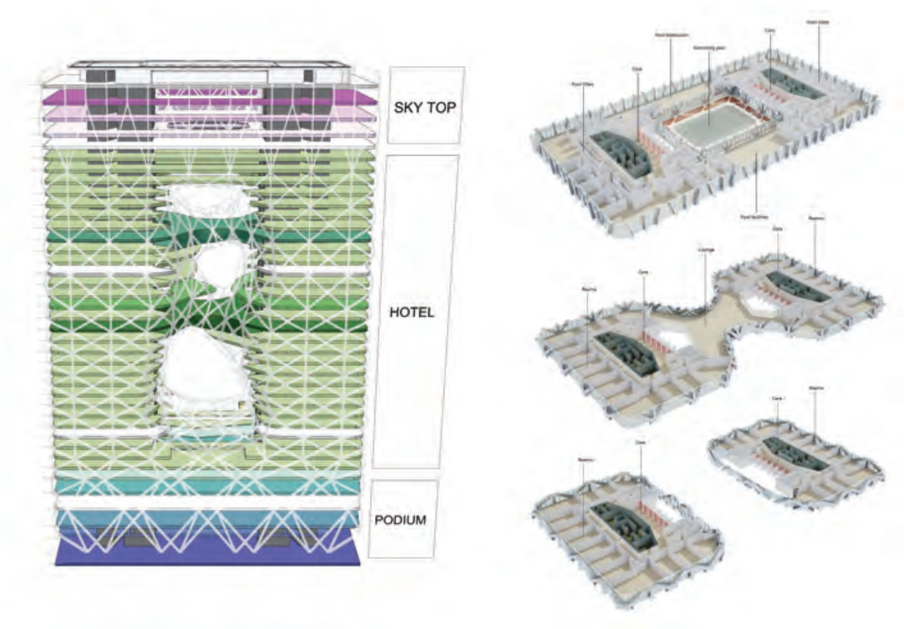

Figure 2. Diagram of the program distribution and typical axonometric plans (Source: Zaha Hadid Architects)
图2. 功能分区图与典型轴测图（来源：扎哈·哈迪德建筑师事务所）

“第五酒店”雕塑般的建筑形态和构造引人入胜；与之同样不可思议的是，它较之传统建筑类型而言是史无前例的。一系列中庭空间将一个简单的建筑体量雕刻打造成为一个复杂的形态，仿佛八或双的抽象数字。中庭空间的美学效果无与伦比，带来精彩盎然的内部空间感受。该项目的基本构造包括两座塔楼，与低处裙楼及其屋面连接交汇；另设两座天桥，从天桥上可以观看并近距离感受外部空间。

扎哈·哈迪德建筑师事务所正在打造的是首例高层酒店综合体设施，一座由自由造型的外部框架钢结构支撑的混合功能建筑。在统一的建筑外表皮之下，该建筑特色在于其设有三座天桥，采用了五种不同的玻璃幕墙系统和一个附在外骨架之上的非典型双曲铝材盖板系统。建筑形体和结构的复杂程度以及对用户舒适度的严格性能标准无不带来史无前例的挑战（图1）。

该建筑共有40多层。较低三层直接连接环绕 “新濠天地”的裙楼，并且设有各类公共设施和一个赌场大厅。较高楼层设有酒店，提供多达780个客房，辅以面积充足的后勤空间和超五星级酒店标准的配套设施。建筑顶部多层设有贵宾级博彩设施、别墅、特色餐饮场地、贵宾室、以及与建筑造型相协调的半封闭式屋顶户外泳池（图2）。

车辆通行入口与外部建筑风格浑然一体，保持了建筑外观和建筑语言的统一。酒店宾客经过入口后直接可以进入宏伟的中庭空间，这个空间高达40米，仰头即可观望天穹（图3）。中庭使用了优雅而简约的

Figure 3. Axonometric section of the 40-meter-high atrium and hotel lobby (Source: Zaha Hadid Architects)
图3. 40米高中庭空间与酒店大堂的轴测剖面图（来源：扎哈•哈迪德建筑师事务所）

Figure 4. View of the atrium from the panoramic lifts (Source: Zaha Hadid Architects)
图4. 全景电梯内俯瞰中庭视图（来源：扎哈•哈迪德建筑师事务所）

as they travel between the mass and the voids of the building (Figure 4).

Parametric Design to Construction

The challenge of designing a multi-programmed tower and its subsequent construction in a very tight time frame confronts the limitations of human production of information. Zaha Hadid Architects therefore looked at implementing the traditional BIM models not only to retain different layers of inputs from the different consultants, but to also transform it into a system that communicates exchanges and recalibrates the output every time the parameters are modified.

The essence is to allow the different parties (client, designer, engineers and contractors) to implement, change and recombine the data to create an always up-to-date set of outputs (drawing, measurements, etc.) that can at any time reflect the current status of the project.

For the façade of the main iconic area of the CoD, the main contractor appointed four different façade contractors. Zaha Hadid Architects has since set up a rigorous platform for collaboration amongst the designer teams. Performance input, geometric input, aesthetical input, and their regulated interactions formed the instructions that guarantee the integrity of the design solution (Figure 5).

Inputs:

- Structural stability
- Fabrication limitations
- Budget
- Program

材质，给人以自信与典雅之感。酒店大堂直通位于首层的零售商群和中心博彩区。中庭内设有主接待处、大堂吧和一个可供灵活配置的空间。垂直交通动线由中庭空间东西两侧的核心筒区分开来，通向酒店住宅楼和增设的贵宾博彩区。使用中庭区内的全景电梯上上下下，既可欣赏到中庭内的景观，可也以眺望到建筑外部的景色（图4）。

参数化设计到兴建

在异常紧迫的时间内设计一座多功能塔楼并进行后续施工，挑战者人工信息制作的局限。因此，扎哈•哈迪德建筑师事务所研究在传统建筑信息模型的基础上，不仅录入各类专业设计顾问的多层设计数据，同时将之转化为一个系统，用以信息交流和设计输出端与每次的参数变化的实时校对。

此举旨在协助包括客户、设计师、工程师和承包商等在内的各有关方面对数据实施、修改和整合，从而保证实时生成的设计方案（包括图纸和尺寸等细节），都能够反映项目进展阶段的最新信息。

主承包商委任了四家幕墙分包商负责“新濠天地”标志性区域的幕墙设计。与此同时，扎哈•哈迪德建筑师事务所建立了一套严谨的数据平台以便设计团队之间开展设计协调工作。兼顾性能、几何形体与美学设计，在控制性专业互动下所形成的设计指令，保证了设计方案的协调完整性（图5）。

设计录入：

- 结构稳定性
- 建造局限性
- 预算
- 功能

设计输出：

- 几何形体优化
- 参数化工具

全球团队

第五酒店从设计到落成，离不开一支由专业人士所组成的国际团队契而不舍的敬业精神。

从甄选负责本项目的结构与幕墙工程团队（标赫伦敦和香港分部担任），乃至负责后期的主承包商（ 香港宝嘉– 布依格联营公司担任），新濠博亚娱乐管理层和其执行团队自始至终对扎哈•哈迪德建筑师事务所的工作提供了大力支持。

Output:

- Geometrical rationalization
- Parametric tools

Global Team

The Design of the 5th hotel has come to reality due to the perseverance and dedication of a truly global team of professionals.

The great support from Melco Crown Senior management and their execution team to develop the iconic design from Zaha Hadid Architects was clear since the selection of the engineering team for structure and façade (Buro Happold, London/ Hong Kong) and at later stages of the main contractor (Bouygues / Dragages, Hong Kong).

The fabrication and final details of the façade of the 5th Hotel was done by five different contractors. Working in different time zones allowed a 24-hours effort that was a real bonus for the project. With workshops alternating between Macau, London, Belgium (Kyotec), Shenzhen (Hachley, Front and Jhango), the almost daily video conferences allowed the team to work at a great speed and in constant communication despite the physical distance.

Tools

The design of the building was made possible by the use of bespoke scripts and tailor-made codes in Rhinoceros and Grasshopper, created by the design team. These bespoke scripts and coding were enhanced by the incredible speed at which this software analyzes a vast amount of parameters and outputs solutions at high precision.

The process is based on the following steps:

- Formalize the parameters in response to programmatic necessities, structural constraints or limitations in the fabrication process.
- Sorting the parameters by priorities.
- Define the functions that regulate the interactions between parameters.

The algorithm that regulates the different parameters makes possible the visualization of the following items:

- Correlation of key elements.
- Possible incongruences in the system.
- Set of possible outcomes to the same problem.

第五酒店的建造和幕墙细部由五家承包商共同完成。这几家幕墙承包商位于不同时区，可以全天候为本项目工作，这无疑是一个巨大的优势。工作研讨会轮流在澳门、伦敦、比利时（Kyotec公司）和深圳（Hachley, Front and Jhango公司）举行；与此同时，项目团队几乎每日都通过视频会议交流工作进展，从而得以加快工作进程，有效克服了所在地不同所带来的不便。

工具

使用设计团队所创建的Rhinoceros与Grasshopper模型软件中的定制函式和代码，使这座建筑的设计成为可能。这些定制函式和代码借助这些模型以惊人的速度高精度分析大量参数和输出方案。

这个过程基于以下步骤：

- 将参数正规化，以应对功能需求、结构限制、或建造过程中的其它限制条件；
- 按优先级整理参数；
- 定义调节参数之间互动的不同功能；

通过调节不同参数的算法实现了下述内容的可视化：

- 关键要素互相关联；
- 系统中潜在的不协调性；
- 同一问题的一系列潜在结果；

我事务所制作的线框模型可以识别幕墙的主要组成原则，例如容差限制及建筑外表皮最大化限制等。

这个线框模型汇集了工程师、业主和制造商各方的数据，从一套简单的初始设计原则逐步发展成为一个精密复杂且涉及多层次的系统。

用于准备各类参数和制定调节参数需要时间，然而如果直接从各类模型中逐一汲取信息制作施工所需文本将更加耗时。我们的工作方法有助于业主、设计师和制造商在短时间内建立起一套最佳设计解决方案。

建立这一系统的是一支由多学科专业人士所组成的团队，他们为设计不同阶段的参数和系统结构性逻辑的定义作出了重要贡献。

与传统3D模型相比，重要的改进在于该系统既能够保留最初约定的参数，又能够最终调节以适应该系统的精确性。之前的设计经过系统综合处理，形成一套新的完整的设计输出成果，清晰地显示对系统其它部分的正面或负面的影响。这不仅可以检测录入数据之间的冲突，而是逐步演化为一个解决问题的智能化系统（图6）。

建筑外骨架

第五酒店大楼的的初始设计首先需要应对两套限制条件：新濠天地目前开发所剩公共区域有限；业主方设计任务中要求高密度功能配置。

为了既能满足上述初始设计条件，同时坚持采用独栋塔楼这一设计理念，我事务所开始探索内部中空、另设两个核心筒以服

Figure 5. Iconic doubly-curved façade at the voids (Source: Zaha Hadid Architects)
图5：中空体量标志性双曲幕墙（来源：扎哈·哈迪德建筑师事务所）

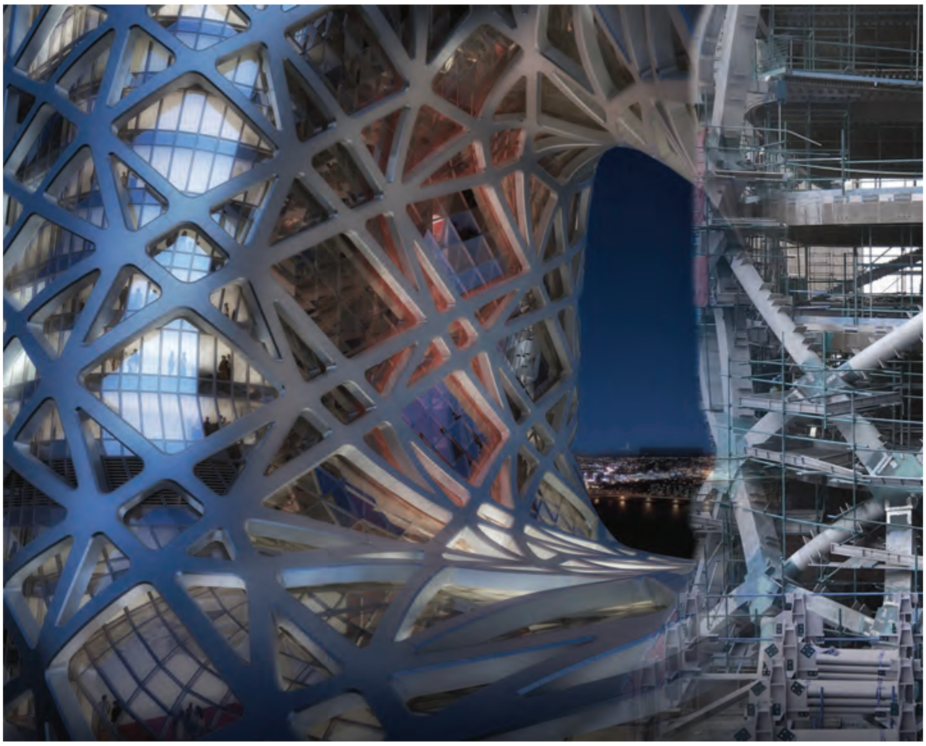

Figure 6. Photomontage of the process design to fabrication supported by parametric tools (Source: Zaha Hadid Architects)
图6. 由参数化工具支持的工艺设计到制备流程合成图（来源：扎哈•哈迪德建筑师事务所）

ZHA produced a wireframe model that identified the principle components of the façade, such as the limits of deviations and the maximum envelope. This wireframe is the sum of the inputs from engineers, client, and fabricators, and it has evolved from a simple set of initial rules to a very sophisticated and multilayered system at the end of the process.

The time spent in the preparation of both the parameters and the functions that regulate them is fully recovered by the time saved in producing the necessary documentation for the project execution directly from the models. This process is augmenting the possibility for the client/designer/fabricators to establish the optimum solution in a very short time.

The multidisciplinary team that worked on creating this system has contributed at different design stages in the definition of the parameters and the structural logic of the system.

The fundamental improvement in comparison with traditional 3D models is the capability of the system to retain the initial set of agreed parameters, and to subsequently absorb and adapt to the articulation of the subsystems. The history of the design is processed into a new complete set of outputs showing the positive or negative effect on other parts of the system. This is not limited to clash detection between different inputs but is increasingly an intelligent problem solving system (Figure 6).

Exoskeleton

The initial design for the 5th Hotel responded to two sets of constraints: the limited footprint left over from the existing City of Dreams development and the client's brief for a high-density of different programming.

To comply with those initial inputs without compromising the idea of a single tower, ZHA started to explore the option of an extruded box with voids in the middle and two cores for vertical circulation. The requirement for a large podium and roof area was the reason for connecting the volumes at the top and bottom. The initial three-dimensional volume would therefore maximize the number of rooms with an external view. It also creates a series of special areas in the bridges for communal programs, and, finally, it guarantees a standard room distribution on both tower sides. More mass is carved out from the 40-meter-high atrium and at the swimming pool to emphasize the constant game of solid and void both inside and outside the building.

The mixed-use requirements for the tower make a strong case for freeing the internal layout from vertical support to allow for maximum flexibility in the programming – a structural exoskeleton attached to the façade was therefore the perfect solution. The exoskeleton strengthens the image of the building and at the same time contributes to its stability. The design of the enveloping grid

务竖向交通这一挤压型框架模型方案。此外，鉴于对大型裙楼和屋顶区域的要求，我们在设计中提出在这座建筑中庭空间的顶部和底部实现联通。立体空间将有助于提供最多的景观房数量。同时在连接桥内可以打造一些列特殊区域作为公共空间。不仅如此，我们的设计还保证了塔楼内两侧的标准房间布局。在这座40米高的中庭空间和泳池区延伸出更多空间，使整座建筑内外虚实交错，趣味横生。

鉴于塔楼的混合功能要求，我们决定取消竖向支撑，采用开放式室内布局，从而实现建筑空间的最大灵活性。结构外骨架落与建筑幕墙的契合无疑成为最佳设计解决方案。外骨架可以增强建筑外观效果，同时有助于实现建筑结构的稳定性。建筑外表皮网格的设计体现着我们与分包专业顾问团队的成功协作（图7）。

受台风和地震荷载挑战的横向荷载的稳定性由外钢骨架和两个内部混凝土核心筒提供。复合钢梁与楼板的的设计方案保证了外钢骨架与竖向核心筒之间的受力转移。

外钢骨架组件连接平面区域的螺栓节点，现场焊接在自由造型区域和填角内。这座建筑共有2,500个接点需要优化，使之融入其各组设计之中。

我们所提出的初始设计方案，根据业主方的设计任务定义和外骨架结构的优化过程，经过多重迭代设计而完成优化。

从设计伊始，我司即与结构工程设计方标赫公司紧密合作，制定一个可共享且轻便的设计平台，它作为"母"模型的一部分以供各自设计探究。就一系列设计参数达成共识的重要性在于这种做法使得双方以及后续的承包商们得以测试和尝试不同的解决方案，同时节约了时间和精力。

结构参数：

- 所有节点均与楼板边梁水平对齐；
- 所有管桩均与装配玻璃基准面保持水平和垂直；
- 所有组件须为平面和单曲面；

设计参数的目的在于使荷载路径更为直接也因此更为有效。共享轴线模型为探索设计可能性创建了最佳工具：它可以迅速地进行设计操作，并且更快地生成量化数据输出，例如钢铁吨位和整体结构稳定性分析等。最终的设计可以显示受力如何从建筑顶部转移到底部，其中底部受力更密集更复杂，顶部受力更轻更直接。

我们所提议采用的每个新线框格栅致力于逐步实现结构要求：从回接底板钢梁的节点位置，到改善框架布局使内部钢梁与房

was the first successful collaboration with the team of consultants (Figure 7).

The lateral load stability, challenged by typhoon winds and seismic loads, is provided by the steel exoskeleton and the two internal concrete cores. A composite beam and slab solution guarantees the transfer of forces between the external exoskeleton and the vertical cores.

The exoskeleton steel members are connected to the nodes with bolted connections in the flat areas and site welded in the freeform areas and building fillet. The building has 2,500 nodes that had to be optimized into families.

The proposed initial design solution has been optimized following a sequence of reiterations due to various inputs including the client's brief final definition and the optimization of the exoskeleton structure.

From the initial stages ZHA worked closely with the structural engineers, BuroHappold, to set up a shared lightweight platform that constitutes the "mother" model for the respective speculations. The importance in agreeing to the set of parameters has allowed the two parties and subsequently the contractors to test and try different solutions with minimum effort and time.

Structural Parameters:

- All nodes need to be horizontally aligned to floor edge beam
- All stubs horizontal and perpendicular to the glazing reference surface
- All members need to be planar and single curved

The set of parameters was based on making the load path more direct and therefore more efficient. The shared axis model created the optimum tool for the exploration of possibilities: quick to manipulate and even faster in the production of quantifiable outputs such as steel tonnage and overall structural stability analysis. The final design shows how the forces travel from top to bottom, denser and more intricate at the bottom and lighter and straighter at the top.

Each new wireframe grid proposed by ZHA would progressively implement the structural requirements: from the node's position connecting back into the steel beam at the floor plate, to the improved framing arrangement with internal beams and room partition aligned.

Special attention has been given to the void area where the exoskeleton directly supports the free-form façade. This area required many inputs from the contractor to establish the construction methods and sequencing.

For the fabrication of the steel nodes, Grasshopper scripts made possible the visualization in a 3D model of the complex areas of the belly by combining geometrical, structural and fabrication limitations. Moreover, this processing tool enabled the fabricators to process the information without the laborious task of producing millions of 2D drawings. The 3D visualization and the related Excel chart provide the complete set of fabrication information

间隔墙对齐等。

中庭区内由外骨架直接支撑自由造型幕墙的设计无疑是我们所重点关注的。该处设计需要承包商的大力以确立施工方法和次序。

关于铸钢节点的制备，Grasshopper建模函式通过汇集几何造型、结构与建造等多重限制条件，实现了建筑腹部复杂区域的3D模型的可视化。与此同时，这种处理工具使制造商能够更为便捷地处理信息，避免了手绘数百万2D图纸的繁重任务。3D可视化和相关Excel图表可以提供一套完整的建造信息，最大限度地减少了人为出错的可能性和施工周期（图8）。

不得不说，这套 共享平台是我们用开展设计和优化工作的首要和终级设计工具。

外骨架装饰面板

本文为了清晰起见，将建筑外骨架装饰面板的设计和制造与结构外骨架设计分不同章节介绍。实际上，设计和建造所采取的工具与方法始终是相互作用的。在设计进展过程中我们进行了许多测试和尝试；通过不断学习和反复实践，我们在最初设计原则的基础上补充了许多设计参数，与此同时，对组件的所规定的功能也在不断地转变。

建筑主体结构的几何造型与业主方所设定的预算及功能限制严格相关，从而保证了设计团队能够打造出一座可以适应不同建造方法和工艺的灵活的设计方案，同时注重采用合理的设计原则以表达设计初衷

装饰面板参数包括：

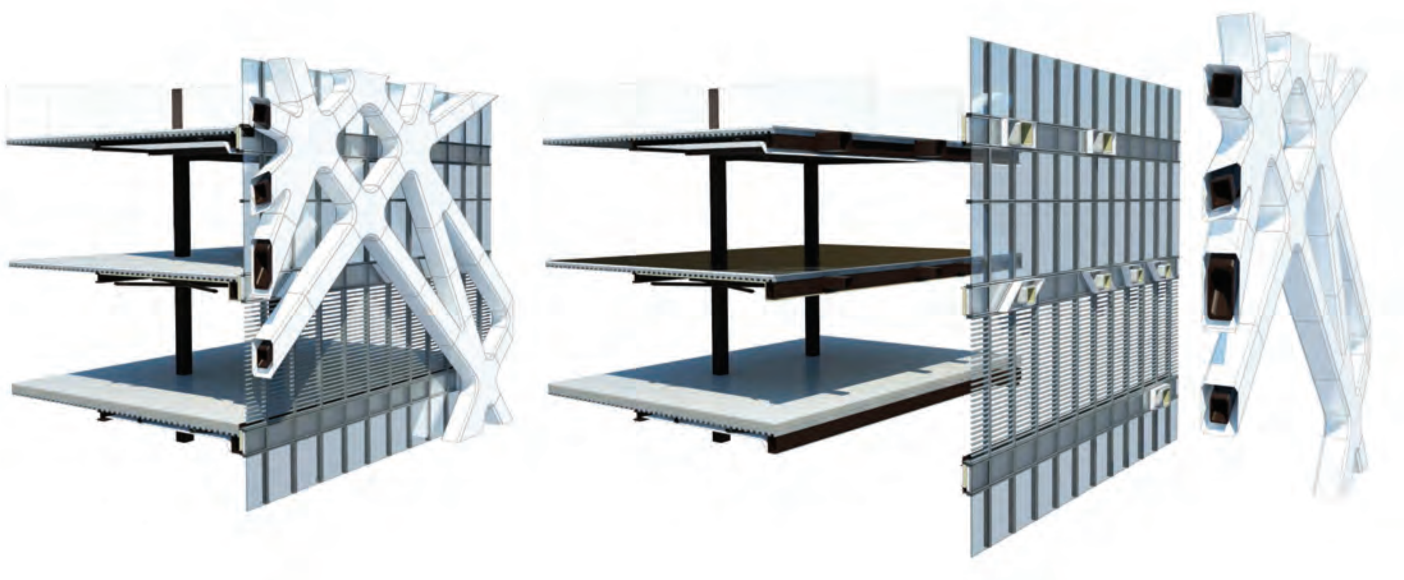

Figure 7. Exploded axonometric view of flat façade system (Source: Zaha Hadid Architects)
图7. 平面幕墙系统的分解轴测图（来源：扎哈•哈迪德建筑师事务所）

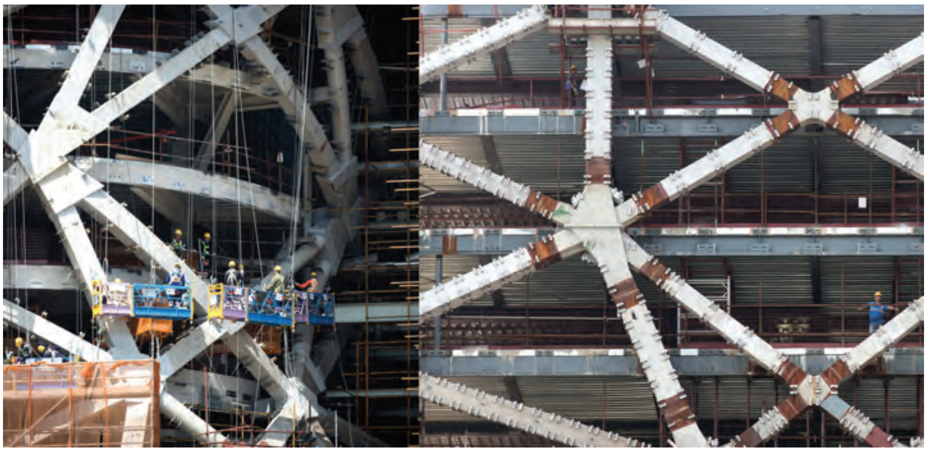

Figure 8. Exoskeleton steel structure at flat and doubly-curved areas (Source: Zaha Hadid Architects)
图8. 位于平面和双曲面区域的外钢骨架结构（来源：扎哈•哈迪德建筑师事务所）

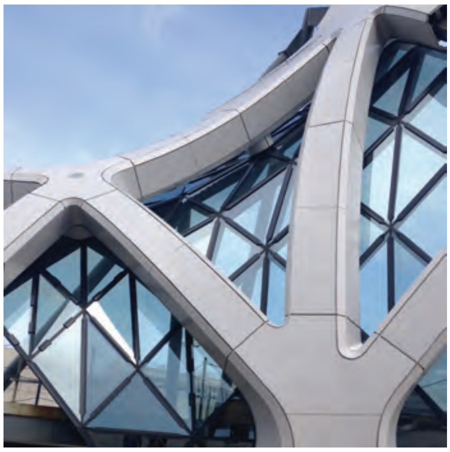

Figure 9. Visual Mock-up of free-form façade (Source: Zaha Hadid Architects)
图9. 自由造型幕墙视觉样板图（来源：扎哈•哈迪德建筑师事务所）

minimizing the possibility of human error and construction time (Figure 8).

Once again the shared platform constitutes the initial and final tool for the design and optimization.

Exoskeleton Cladding

For clarity within this paper, the design and fabrication of the exoskeleton cladding and the structural exoskeleton are presented in separate chapters. In reality the tools and the methodology behind the design and fabrication have been in constant interaction. Many tests and trials were performed during the design process; the learning curve was steep on adding parameters to the initial set of rules, and the regulating functions on the parts were also in constant transformation.

The strict geometrical correlation with the main structure and the budgetary and programmatic constraints set by the client left the designers with the task of creating not only a flexible design that was adaptable to different fabrication methods and skills, but also one that contained the correct set of rules to demonstrate the design intent.

Cladding Parameters:

- Cladding to follow structural sizing
- Minimum double curves
- Limit ruled surface
- 200 year return
- Typhoon area

The large numbers of the non-repetitive panels that constitute the cladding for the structural exoskeleton have been given special attention from the design team. The first step was to find a simple geometrical relation between the cladding and the structure needed for easy erection during site construction. The cladding geometry has been rationalized by forcing all exoskeleton structural members' axis to lie on a plane. As a consequence, all side panels are completely flat and the amount of curved panels is drastically reduced (Figure 9).

As the exoskeleton structure tapers toward the top part of the building, so does the cladding.

The 3D models and scripts that regulated the relations between components were then passed to the façade engineers and fabricators for the next iteration of design. This data automatically produced a 3D model and all the relevant sets of information that clearly visualized every single detail. Every last bolt is numbered, positioned in space and associated to tables of specifications (Figure 10).

Glazed Façade in Freeform Area

The glazed façade of the 5th Hotel is divided into three main categories: flat façade, trapezoidal façade (in the area around the void) and triangulated façade (in the free form area).

The optimization of each façade has followed different rules due to the different contractors

- 装饰面板符合结构尺寸
- 双曲面数量最小化
- 限制直纹面
- 200年重现期
- 台风区

设计团队格外重视组成结构外骨架装饰层的大量非典型面板的设计。首先需要找出盖板与结构之间的简单几何关系，使之便于施工安装。接着优化装饰面板的几何造型，确保所有的外骨架结构组件的轴线布置在一个平面上。由此所有侧边面板均为平板，大幅减少了曲面板的数量（图9）。

所有外骨架结构朝着建筑顶端方向逐渐变细，盖板的布置与此相同。

随后我们将3D模型和用以规定组件关系的参数指令交给幕墙工程师和建造方进行迭代设计。这些数据将自动生成一个3D模型和所有相关信息群，清晰地展示每个设计细部。每类螺栓的最后一个都被编号、安装、并且与规格表相对应（图10）。

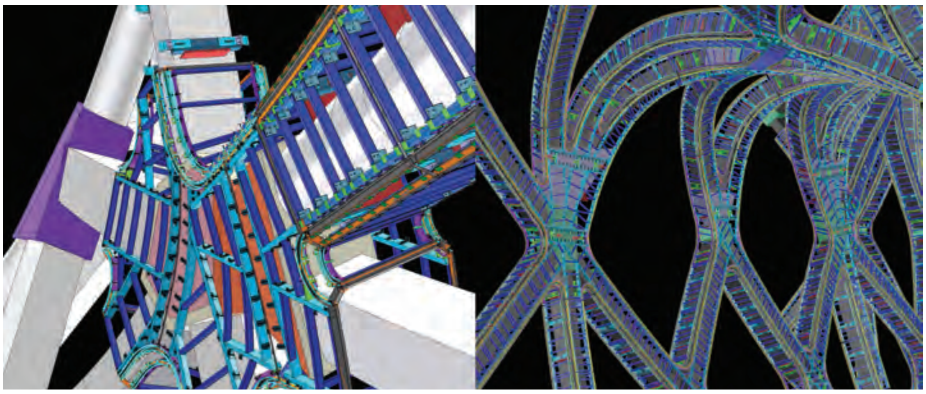

Figure 10. A visualization of free-form cladding substructure in a 3D model is generated with parametric tools (Source: Zaha Hadid Architects)
图10. 借助参数化工具而生成的自由造型装饰面板底层结构的可视化3D模型（来源：扎哈•哈迪德建筑师事务所）

Figure 11. Rendering of the freeform façade components, freeform macro panels subdivision and 3D model visual mock-up of free- and form glazing is supported by exoskeleton (Source: Zaha Hadid Architects)
图11. 自由造型幕墙组件和自由造型大型面板效果图（来源：扎哈•哈迪德建筑师事务所）

involved, but special attention has been given to the optimization of the central free form space. The process of transforming the initial 3D model, a smooth poly surface, to a faceted triangulated surface has been done following many performance requirements: from structural to environmental, to maintenance and cleaning, to drainage. During the processes of optimization it was also very important to maintain the new triangulated surface as close as possible to the original smooth surface so as not to lose the required proximity with the exoskeleton and the overall appearance of a soft, continuous and elastic surface.

In the free form areas, the steel exoskeleton is the main support for the triangulated façade. The grid of the exoskeleton is projected back into the glazed façade surface generating a series of macro divisions called macro panels. This steel macro window sits in at the back of glazed façade and the steel exoskeleton and transfers only the dead load back onto the steel exoskeleton. The macro panel also transfers the wind load back to the exoskeleton, though the connections between the two systems is detailed in a way to ensure the panel does not stiffen the exoskeleton – so they don't interact with each other in the in-plane direction of the macro panel. The macro panel and the exoskeleton interact with each other in the out-of-plane (of the macro panel) direction. All macro panels are connected at the node with perpendicular stubs (Figure 11).

The starting point for the triangulated glazed façade that envelops the voids was once again ZHA's wire frame model. The macro panel main frame is set from the four points and axis of the wireframe model of the exoskeleton. The next step was to find an optimum subdivision: wind load, limitation in glazing sizes, installation and replacement and cleaning strategy were all factors that contribute to the set of parameters.

At the end of the process a more detailed 3D wireframe model was created where the macro panel families' subdivisions (multiples of two) responded to the overall size and level of curvature of the initial surface.

自由造型区域的玻璃幕墙

第五酒店的玻璃幕墙分为三大主要类型：平直幕墙、梯形幕墙（环绕中庭区而设）和三角形幕墙（位于自由型造型区域）。

由于不同承包商的参与，每种幕墙的优化采取了各专业幕墙特有的设计原则，然而，我们尤其注重中央自由造型区域的幕墙优化工作。将初始3D模型中平滑的聚合面转变为多个三角状曲面的过程需要满足多重性能要求：从结构到环境、从幕墙保养到清洁排水。在这一优化过程中，同样至关重要的是，尽可能使新产生的三角化曲面接近原始光滑表面以免失去其与建筑外骨架之间应有的相邻性以及建筑整体外观所应具有的柔软度、连续性和灵活性。

在自由造型区域内，建筑外部钢骨架是三角形曲面幕墙的主要支撑。外骨架的格栅同时又反射到玻璃幕墙表面形成了一系列更大区域的分割，简称大型板块。这种钢制大窗位于玻璃幕墙后部和外钢骨架之上，仅将恒载转移回外钢骨架。尽管这两个系统之间的连接设计十分细致确保了大型面板不会使外骨架结构僵化，除此之外，通过在设计中使大型面板板也可以将风载转移至外钢骨架，从而保证大型板块在面内水平方向上不会相互作用。大型面板与外钢骨架之间在离面方向上产生相互作用。所有大型面板均与垂直管桩节点相连接（图11）。

围绕中庭空间的三角形曲面玻璃幕墙的设计出发点基于我建筑师事务所的线框模型。首先，大型面板的主要框架沿着外骨架线框模型的四个点和轴线设置。接着需要找到一个最佳分区方案，板块分割的参数化设计需要综合考虑风荷载、玻璃幕墙尺寸的限定、安装、更换和清洁策略。

经过上述一系列过程，我们得以创建出一个设计详尽的3D线框模型，其中大型面板组的细化分割（两倍于之前）和原表面的整体尺寸和曲度相互呼应。

有关大型面板的布置方向，承包商和设计团队提出了包括同向压制面板和紫外线数值分析等许多相关设计方案。 在每种方案下，通过可视化3D模型在整个区域的应用，辅以参数化软件支持，使得每种方案的利弊一目了然，帮助包括客户、设计团队、承包商在内的项目团队达成最终决定。

结论：

扎哈•哈迪德建筑师事务所正在打造的是首例高层酒店综合体设施，一座由自由造型的外部框架钢结构支撑。

的混合功能建筑。在统一的建筑外表皮之下，该建筑特色在于其设有三座天桥，采