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Raffles City Chongqing Conservatory: Studies For a New Bridging Building Type | 水晶廊桥：横向塔楼新建筑类型的演变

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Jeff Huggins于2006年加入萨夫迪建筑事务所，并于2013年成为合伙人。他目前担任项目经理，负责重庆朝天门项目的建筑立面及商业大楼组件。他之前作为项目建筑师完成的作品包括斯里兰卡科伦坡的科伦坡住宅大楼、中国重庆的重庆鹅岭住宅区及新加坡的滨海湾金沙综合度假胜区。在波士顿的滨海湾金沙项目的设计开发之后，他前往公司的新加坡分部，在那里任职三年，担任酒店大楼的住宅设计建筑师。

Abstract | 摘要

One of the outgrowths of dense vertical urbanism is the challenge of interconnecting tall buildings at multiple levels in the sky. In order to have the super-connected urban whole, pathways between the vertical nodes must be equally advanced along with technological breakthroughs that allow towers to grow vertically. The "Conservatory" At Raffles City in Chongqing, China is a new invention of the horizontal tower. It provides a fully enclosed mixed-use program while linking vertical towers together, creating a new type of three-dimensional building matrix.

Keywords: Life Safety, Mixed-Use, Sky Garden, Structure, Vertical Urbanism

密集垂直都市生活的产物之一，就是在空中实现高层建筑多楼层互连的挑战。为实现完整的超级互连城市，垂直节点之间的路径必须与大楼垂直增长的技术突破同步发展。中国重庆来福士广场的"暖房"是卧式楼的一项新发明。它既是一个全封闭混合用途项目，又将垂直大楼连接了起来，创造了一种全新类型的三维建筑矩阵。

关键词：生命安全、混合用途、空中花园、结构、垂直城市化

Introduction

One of the outgrowths of dense vertical urbanism is the challenge of interconnecting the towers that have developed as the main response to higher density. In order to have a super-connected urban whole, the pathways between these vertical nodes must be equally advanced alongside the technological breakthroughs that allow for the ever increasing heights of the tower. In response, Safdie Architects has designed the "Conservatory" at Raffles City in Chongqing, China. A building unto itself, the Conservatory is a horizontal tower that links multiple buildings. The Conservatory is an evolution from the Marina Bay Sands SkyPark, in that it provides a fully enclosed mixed-use program while linking the project's vertical towers together, thus creating a new type of three-dimensional building matrix (Figures 1 & 2).

The 280m long structure houses four main programmatic uses: public observatory, residential clubhouse, hotel lobby, and F&B destination. The Conservatory provides the dual function of housing these programs, as well as acting as a horizontal conduit linking the many towers together. It provides much of the same type of connectivity one would find at podium level or below grade, but here with new meaning, and new opportunity, located 250m above ground level.

As an emerging building type spawned from dense urban environments, the Conservatory

项目简介

密集的垂直城市化发展所面临的挑战之一是，如何将所开发的主体建筑相互连接起来从而提高建筑密度。为了将城市建筑的上层部分连接起来形成整体，这些垂直节点均必须采取具有技术性突破的方法，以便应对建筑高度不断增加的城市化环境。鉴此，萨夫迪建筑公司设计了位于中国重庆莱佛士广场的"水晶廊桥"。就建筑本身形态而言，它是一个连接多个建筑的横向塔楼。水晶廊桥项目，是我们在滨海湾金沙酒店空中花园基础上的进一步发展。作为封闭的室内空间，它不仅提供了多项综合性功能，同时连接了数个垂直塔楼。水晶廊桥创造了一种新型三维建筑形态（图1、2）。

水晶廊桥总长280米，主要提供四种功能：公共观景台、住宅会所、酒店大堂和餐饮设施。水晶廊桥兼具双重作用，既可以容纳上述业态功能，又可以作为横向媒介将众多塔楼连接起来。相似的综合连接体，人们在裙楼楼层或地下楼层已经司空见惯；但水晶廊桥的设计，让我们有能力在距离地面250米的空中实现相同功能，因此它意义深远，令人耳目一新。

作为一种新兴建筑类型，诞生于高密度城市环境的水晶廊桥面临着巨大的技术性挑战，比寻常的摩天大楼要复杂得多。接下来会具体介绍针对此项目的创造性解决方案，包括结构、立面挂板、环境舒适性、消防疏散和生命安全、垂直交通和业态布局等方面。

Figure 1. View of Raffles City Chongqing looking toward the city (Source: Safdie Architects)
图1. 重庆来福士广场面向城区的景观（来源：萨夫迪建筑师事务所）

Figure 2. View of Raffles City Chongqing from podium (Source: Safdie Architects)
图2. 自裙楼看到的重庆来福士广场风光（来源：萨夫迪建筑师事务所）

faces more technical challenges than a typical skyscraper. Presented here are the inventions that were crafted to tackle the requirements of structure, cladding, environmental comfort, egress and life-safety, vertical transportation, and programmatic distribution.

Program

The Raffles City Chongqing project is located at the confluence of the Yangtze and Jialing Rivers in the Yuzhong central district of the city. Overlooking the Chaotianmen public plaza and historical heart of the city, the site is truly one of a kind. Filling the site is a podium building of six above-grade stories, which houses some 200,000sm of retail space, as well as subway, bus, and ferry terminals. A public park and private residential gardens are created over the podium, with direct access from the city on the southern end of the site. Emanating from the podium are eight towers: six southern towers reaching 250m and two northern towers topping out at 350m. The towers are a mix of uses, comprised of residences (T1256), luxury residences (T3N),

项目业态

莱佛士城重庆项目坐落于城市核心部位渝中区，直面长江与嘉陵江交汇口。项目基地可以俯瞰朝天门广场和具有历史意义的城市核心区域，得天独厚的地理优势，独一无二。建筑底部为地上六层的裙楼，可以容纳200,000平米的商业设施，同时集地铁站、公交换乘站、渡轮码头等多种公共交通方式于一体。与此同时，裙楼顶部设置了公共公园和私人住宅花园，可以从项目南侧直接前往。裙楼向上坐落着八座塔楼：南侧六座塔楼高达250米，北侧两座塔楼高达350米。塔楼为综合体设

offices (T4N, T4S, T3S), service apartments (T4S), and hotel (T4N) programs. The Conservatory spans across four southern towers, and links six of the eight towers (Figures 3 & 4).

The Conservatory is a building that was born out of programmatic needs to fit with tight site constraints; the project is more than 800,000sm of GFA on a site of only 9 hectares. The need for creating a public observatory, amenity rich residential clubhouse, hotel lobby, and destination F&B anchor, all contributed to the formation of the Conservatory, as these functions could either not be located in any single tower, or needed to be accessible from multiple towers.

The prime example of how the Conservatory works to take a single program and integrate it across multiple buildings is the hotel. The hotel guestroom floors are located on the top half of Tower 4N, yet due to the efficiency and vertical circulation restraints at the office floors below, the main express lifts to serve the hotel are located in Tower 4S (one of the four towers supporting the Conservatory). This places the hotel's main entry lobby, reception and lounge within the Conservatory. A large and spacious bridge links the Conservatory back to the north tower at this level, providing access to the guestroom floors. One programmatic requirement for the hotel is multiple destination F&B venues, and these outlets are located within the Conservatory spreading to the east and the west from the hotel lobby area. At the western end, these F&B outlets are served by express lifts coming up from tower 5. Thus, the hotel program and access is spread across three towers, with the Conservatory providing program space and providing the main connectivity to unify this single program.

The residential clubhouse is another example of a program requirement that could not be housed in any one tower, and thus required a space that linked multiple buildings. The residential program is spread across five separate buildings, so the creation of a unifying space for the clubhouse was essential. Two access and arrival points serve the clubhouse, with express lifts in the centrally located T3S providing access for residents from T1256, and a bridge linking to the luxury residences of T3N. Thus, the Conservatory links the five residential towers bringing them together at the clubhouse. Once in the clubhouse, residents have access to the hotel F&B outlets, further providing horizontal connectivity and mixed program use in the Conservatory.

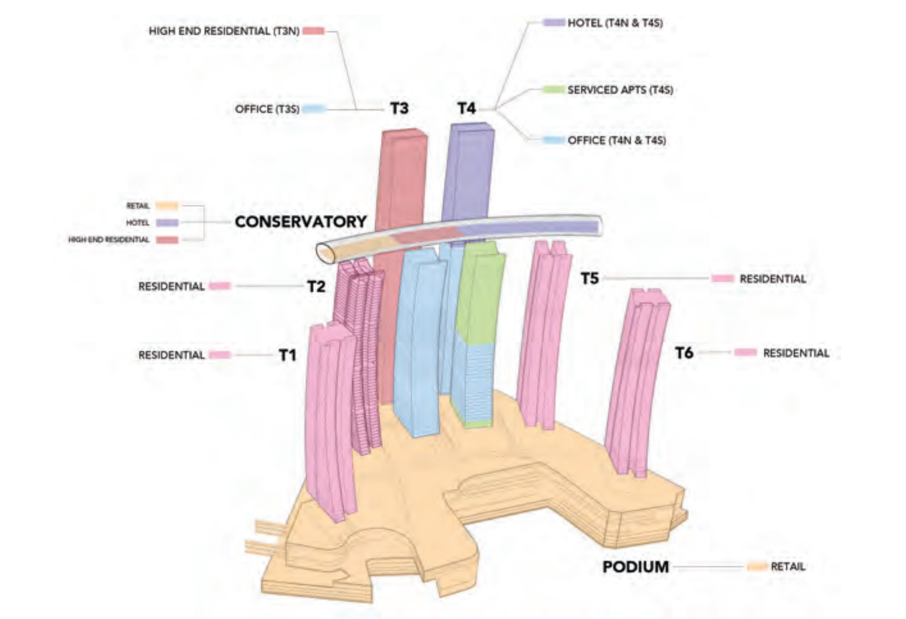

Figure 3. Raffles City Chongqing overall (Source: Safdie Architects)
图3. 重庆来福士广场总体项目图解（来源：萨夫迪建筑师事务所）

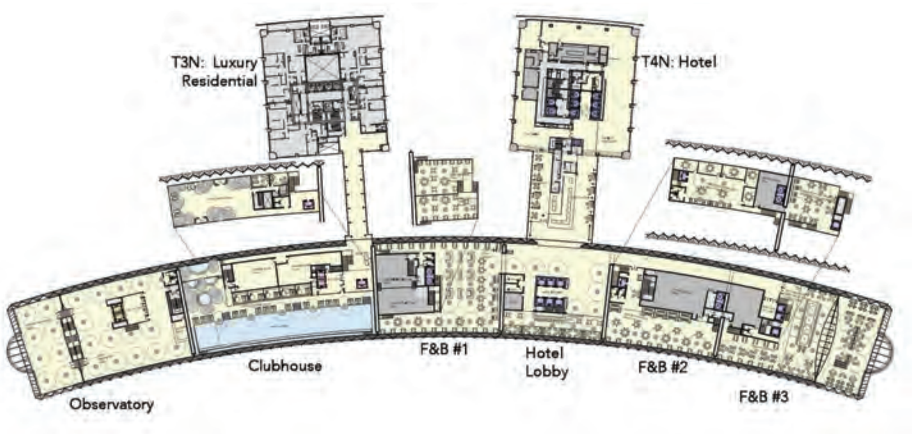

Figure 4. Tower and Conservatory program distribution diagram (Source: Safdie Architects)
图4. 大楼及暖房项目分布图解（来源：萨夫迪建筑师事务所）

施，业态包括住宅（T1256）、豪华住宅（T3N）、办公（T4N，T4S，T3S）、酒店式公寓（T4S）和酒店（T4N）。水晶廊桥横跨南侧四座塔楼，同时连接了八座塔楼中的六座（图3、4）。

项目占地面积仅为9公顷，但建筑总面积超过800,000平米，在场地各种限制条件下，为了满足业态需求，水晶廊桥应运而生。项目需要提供公共观景台、配套设施齐备的住宅会所、酒店大堂和餐饮设施，但是这些功能或无法仅仅设置于某一个单体塔楼，或需要横跨多个塔楼，这些因素最终促成了水晶廊桥的设计。

水晶廊桥可以把分散在多个建筑内的相同业态整合在一起，最好的例子就是酒店。比如，酒店客房楼层位于塔楼4N的上半部分，但由于下半部分办公楼层的实效要求和垂直流线限制，酒店的主要直达电梯不得不设置在塔楼4S（支撑水晶廊桥的四座塔楼之一）。因此，我们把酒店主入口大堂、前台和休息区设置在水晶廊桥内，同时用宏大宽敞的连桥联通了水晶廊桥和后面北侧塔楼（塔楼4N）的对应楼层，从而让人们可以直接前往客房楼层。再比如，根据功能要求，我们在水晶廊桥内设置了多个餐饮场所，分布在酒店大堂的东西两侧。西侧的餐饮设施可通过塔楼5直达电梯前往。因此，由于水晶廊桥既可容纳业态空间，又可作为主要连通渠道串联相同业态，酒店功能和到达方式便可以分置于三座不同塔楼内。

同时，有些业态无法仅仅设置于某一个单体塔楼，住宅会所便是一个很好的例子。我们需要将它设置在可以贯通多个建筑的空间内。住宅业态分布于五座独立塔楼，因此设置统一的会所空间非常必要。会所配置了两个连接和抵达点，直达电梯位于中间的T3S塔楼，成为T1256业主通往会所的主要搭乘方式；同时，T3N豪华住宅的业主可以通过连桥抵达。也就是说，水晶廊桥连接了五座住宅塔楼，并通过会所将它们串联在一起。进入会所后，住户可以直达酒店餐饮区用餐，也可以进一步前往水晶廊桥内的其他业态设施。

水晶廊桥是容纳各种业态的空间，也是连接不同功能的塔楼的桥梁，更是横向铺展

的空中城市。其自身的业态功能彼此交融，相辅相成。当明确了水晶廊桥作为关键业态设施，对项目起到举足轻重的作用后，接下来便需要解决一系列空中横向塔楼的技术和运作难题。

结构

第一个问题是，如何建造连接六座塔楼的280米长水晶廊桥？相应的支承体系和框架概念必须精心筹划，以确保设计成果切实可行，并且不会对支撑它的建筑造成过大负担。关键的制约因素是六座塔楼之间巨大的差异性位移，尤其要考虑到发生地震的情况。重庆市处于活跃的地震带，因而此项目面临着比新加坡空中花园项目更大的挑战。在工程合作伙伴奥雅纳工程顾问公司的协助下，项目团队殚精竭虑希望通过创新的结构方法来解决这个关键制约因素（图5、6）。

项目的突破点在于将水晶廊桥视为一个独立的结构。新加坡空中花园项目，我们用两座结构桥梁连接三座塔楼，并在一端设置了巨大悬挑结构；而这次不同的是，水晶廊桥将作为一个刚性元素，仅由四座塔楼支撑。这样一来，可以避免在水晶廊桥上设置巨大的变形缝。而如果采用与空中花园类似的概念，巨大的变形缝不可避免。根据三级地震设计要求，塔楼之间的差异性位移主要集中在X和Y方向上的+− 3米，因此在塔楼之间设置连接桥梁的概念似乎完全不可行。然而，要建造由四座塔楼支撑的刚性整体结构，支撑构件必须满足塔楼巨大的差异性位移要求。奥雅纳建议，在塔楼屋顶设置庞大的摩擦摆支承，以便水晶廊桥接纳来自主体结构的支撑。当四座塔楼朝不同的方向摇摆时，好像置于滚珠轴承上那样，支撑构件允许水晶廊桥作为刚性结构在塔楼上方移动。与此同时，这些支承构件以及支撑结构内

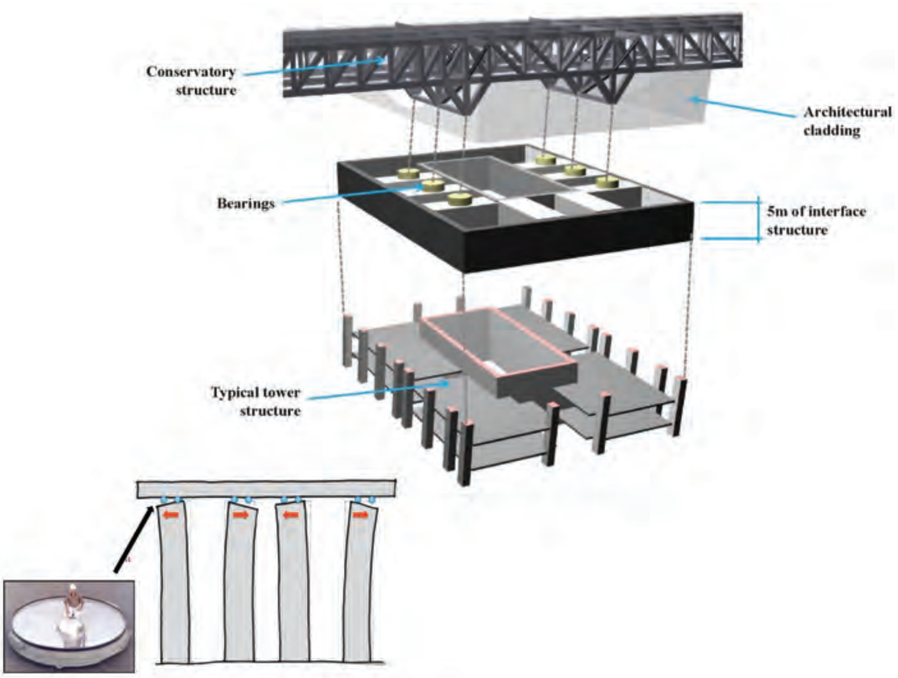

Figure 5. Conservatory structure diagram (Source: Safdie Architects)
图5. 暖房结构图解（来源：萨夫迪建筑师事务所）

The Conservatory functions as a container for individual programs, as a bridge that connects the various mixed uses of the towers, as well as a horizontal city in the sky allowing for its own programs to intermingle and mix. Once established as a vital programmatic requirement and fundamental linchpin for the project, the technological and logistical hurdles for creating a horizontal tower in the sky need to be addressed.

Structure

The first issue was how to structure the 280m long Conservatory as it links the six towers. The support system and framing concept had to be carefully analyzed to ensure that it was efficient in its design, and was not too onerous on the buildings supporting it. The key constraint was the vast differential movements between the six towers, particularly under seismic events. The city of Chongqing is in an active seismic zone, which posed a far greater challenge than the SkyPark in Singapore. Turning to our engineering partners at Arup, the team endeavored to create an innovative structural concept to solve this key constraint (Figures 5 & 6).

The breakthrough occurred in conceiving the Conservatory as an individual structure. Unlike the SkyPark that constituted two structural bridges linking three towers, with a large cantilevered structure at one end, the Conservatory would be one rigid element, simply supported by four of the towers. This allows the Conservatory to avoid having the massive movement joints that would have been required had a similar concept as SkyPark been pursued. Under the design requirement for a Level 3 seismic event, the differential movement between the towers was upwards of +/- 3m in the X and Y dimensions, thus the concept of bridging between towers became untenable. However, by creating a rigid whole supported by the four towers, the support members were required to cater for the huge differential movements of the towers. Arup proposed massive friction pendulum bearings that sit on top of the tower roofs to receive the main structural supports from the Conservatory. The bearings allow for the rigid Conservatory to move atop of the towers as if on ball bearings, while the four towers sway in various directions. At the same time, these

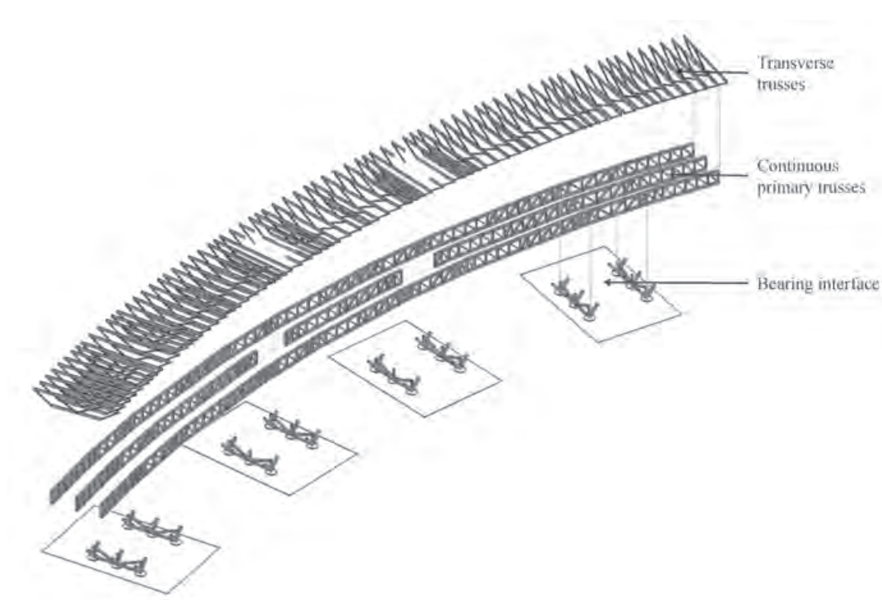

Figure 6. Conservatory truss arrangement diagram (Source: Safdie Architects)
图6. 暖房桁架安排图解（来源：萨夫迪建筑师事务所）

bearings, as well as dampers within the support structure, help to restrict the towers' differential movements. The bearings sit on huge steel reinforced concrete beams that span from the towers' structural core out to a deep perimeter beam at the top of the four towers. This distributes the load of the Conservatory, transferring and sharing it equally into the perimeter columns and core, thus keeping the tower's structure to reasonable member sizes.

Although the differential movement between tower and Conservatory support members can be catered by the friction pendulum bearings, the issue of where the tower itself interacts with the Conservatory still remained. The four lift shafts serving the Conservatory are part of the towers' structure. As such, around each of the lift shafts, there is a movement joint of reasonable size that caters for the day-to-day differential movements of approximately +/- 100mm. In addition, the slab edge surrounding the shafts is conceived as a "crumple" zone, designed to be sacrificial in case of a catastrophic seismic event. A similar concept is used for the link bridges that connect to T3N and T4N. The bridge structures are designed as cantilevered members from the Conservatory and thus move with the Conservatory. A reasonably sized movement joint of +/-300mm is located at the interface between the bridge and tower, with a 1.5m sacrificial crumple zone designed into the end of the bridge to cater for a Level 3 seismic event.

The design for this 280m long structure has three 5m deep longitudinal trusses spanning the full length, which are supported on the friction pendulum bearings atop the four towers. Bracing these three trusses together are transverse trusses spaced every 3–5m, which are shaped per the elliptical profile of the Conservatory. This arrangement allows for the utilization of the structural zone of the Conservatory, with two zones of space to be occupied between the three longitudinal trusses. The northern side comprises MEP rooms and a service corridor that links the towers' service lifts and provides a support conduit at the level below the main deck. On the south side, there are more MEP rooms as well as a long refuge corridor that is the main life safety link between the Conservatory and towers. The main deck of the Conservatory is located 2m above the top of the trusses on a raised floor, which provides depth for swimming pools, landscape planters, and MEP distribution runs.

In all, the structural design for the Conservatory was one of invention and ingenuity. Unlike the soaring skyscrapers that have evolved over the past century and have well established structural means, methods, and metrics to work from, the Conservatory required new thinking at the basic concept level. The structural solutions developed will serve as a meaningful precedent for future horizontal towers, as it provides an efficient and flexible construct from which to work.

Super-Structure and Enclosure

As innovative and exciting as the structural design is, it only comprises the bottom half of the elliptically shaped Conservatory. For the top of half the Conservatory, the design team needed to consider the most compelling structural and architectural method to span 32m across the Conservatory and provide a conditioned, comfortable, and soaring space. A key distinction of the Conservatory as an evolution from SkyPark is that the majority of this horizontal tower needed to be fully enclosed. Where the SkyPark in Singapore is truly a park in the sky, the Conservatory is required to be a conditioned and enclosed space due to the less than ideal climate of Chongqing. However, just because the space needed to be enclosed, as its name suggested, the concept for the Conservatory was to create a rich landscaped space, with clear views across the city, river valleys, and nighttime sky. The driving design factor became the best way to create an enclosure that maintained maximum visual clarity with an expressive architectural character.

The first design concept was to investigate the use of a space frame structure. The rationale for the space frame concept was twofold: it allows for for the lightest weight structure and glazing concept to preserve the garden in the sky interior, while providing the needed conditioned space enclosure. Additionally, the elliptical shaped profile of the Conservatory creates an outward thrust force, which made an arch structural concept highly inefficient. As a starting point the geodesic dome designs of Buckminster Fuller were studied extensively and one concept was zeroed in on, to use two layers of hexagonal shapes with tension ties coalescing at the center, creating the lightest and clearest structural construct. As the spans across the hexagon were far too great for cladding, a secondary aluminum structure of six triangular canted planes was created to complete the enclosure. The canted structure was efficient, and created a tessellated triangulate surface that allowed for alternating

的减震设施有助于缓解塔楼的差异性位移程度。支承构件位于巨大的钢筋混凝土梁上，这些梁跨越塔楼的结构核心，并一直延伸到四个塔楼顶部一个大幅度的圈梁。这样水晶廊桥的荷载可以均匀地转移到周边的柱子和结构核心并由其分摊，从而确保塔楼结构可以采用规模合理的构件。

虽然塔楼和水晶廊桥支撑构件之间的差异性位移问题可以通过摩擦摆支承系统解决，但下一个问题是，塔楼具体在什么部位与水晶廊桥相互作用？服务于水晶廊桥的四个电梯竖井是塔楼结构的一部分。正因为如此，每个电梯竖井周边都设置了规模合理的变形缝，以适应每天大约+− 100厘米的差异性位移。此外，竖井周边的楼板边缘被视为“撞击缓冲”区，在灾难性地震事件发生的情况下将被牺牲掉。类似的概念也被应用于连接T3N和T4N的连桥。连桥结构设计成水晶廊桥的悬挑构件，因此将与水晶廊桥一起移动。我们在桥梁和塔楼之间的接合处设置了+−300厘米大小合适的变形缝，并在桥梁末端设计了应对三级地震时将被牺牲掉的1.5米撞击缓冲区。

项目还为280米长的结构设计了三个5米深横跨全长的纵向桁架，由四座塔楼顶部的摩擦摆支承予以支撑。每隔3−5米设置的横向桁架将这三个纵桁架固定起来，并采用与水晶廊桥轮廓一致的椭圆形结构。这样的布局可以充分利用水晶廊桥的结构层，即位于三个纵向桁架之间的两块区域。北侧布置了机房和连通塔楼服务电梯的服务走廊，同时提供了位于主体平台下方楼层的配套设施。南侧布置了更多机房，以及一条很长的避难通道，作为水晶廊桥和塔楼之间的主要生命安全设施。水晶廊桥主体平台位设置于架空层桁架顶部上方2米处，架空层满足泳池深度要求、可以种植景观植被和布置机房。

总之，水晶廊桥的结构设计极具创造力和创新性。发展了近百年的高耸的摩天大楼，已经具备了完善的结构方式、方法和标准予以遵从；水晶廊桥与它们不同，需要在基本概念的基础上进行全新的思考。此项目所采用的结构方案将成为未来横向塔楼开发的先例，意义深远，因为它提供的结构方案，高效灵活，切实可行。

上层结构和建筑围护

上文所述的新颖且令人振奋的结构设计，仅针对了椭圆形水晶廊桥的下半部分。对于水晶廊桥的上半部分，设计团队需要构思出最引人注目的结构和建筑方法，跨越32米水晶廊桥，营造出舒适惬意、耸入云霄的室内空间。水晶廊桥从空中花园项目进一步改进完善的关键标志在于，大部分横向塔楼需要完全封闭。新加坡的空中花园项目是真正的空中“花园”；由于重

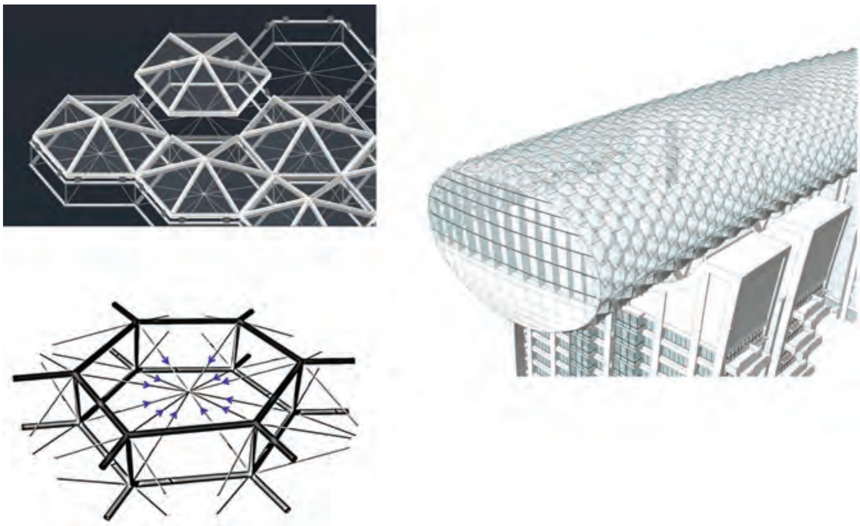

Figure 7. Detail of hexagonal structure of conservatory (Source: Safdie Architects)
图7. 暖房的六角形结构细节（来源：萨夫迪建筑师事务所）

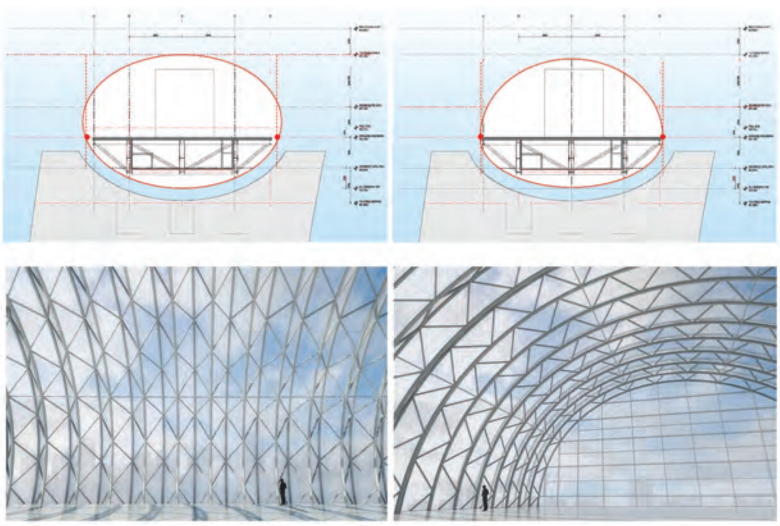

Figure 8. Conservatory section and elevations (Source: Safdie Architects)
图8. 暖房部分与立面（来源：萨夫迪建筑师事务所）

planes of glass and aluminum to create a high performing enclosure (Figure 7).

A key design fundamental at Safdie Architects is inherent buildability. It is at the forefront of our design process, with the building design evolving per many influences such as structure, construction methods, program, environmental comfort, and user experience. As the design team investigated further, there were a few key issues with the space frame concept that prompted its re-thinking. A lack of local building expertise with space frame designs and concerns of stitching together many members at 250m were the key issues that that led to reevaluation of the basic premise. As the cross-sectional shape of the Conservatory was not structurally ideal, we responded by re-shaping the top half of the Conservatory to be a simple arc, thus alleviating the structural penalty. To span the revised arc shape, a series of concertina shaped trusses march along and are collected at a perimeter beam member that transfers the loads into the main structure below. Thus a simple, elegant and consistent grid can be set out, independent of the main structural grid below. Once again, through exploration of the optimal structure and buildability methods, it was determined that by opening up the angle of the concertina truss from 90 to 110 degrees, the savings of the number of trusses and the reduced enclosure area outweighed the structural penalty of a less efficient truss. Additionally, as the trusses themselves could be lifted in three segments and welded together on site, the steel cords could be rolled at the proper radius without undue cost or complexity. This proved important, as the optimal glazing system was a segmented and rectilinear design. The result is that from the interior, the curved structural trusses soar overhead, and from the exterior, the simple glazing modulations complement the form of the enclosure.

Through extensive investigation, invention, and exploration into the inherent optimal buildability of the Conservatory super-structure and enclosure, a design evolved that is appropriate for the use type and is an elegant expression of its ideals (Figure 8).

庆气候的不理想，水晶廊桥需要打造成封闭的空调空间。然而，正因为空间需要封闭，水晶廊桥英文Conservatory的本意是温室花园，顾名思义，水晶廊桥概念旨在营造出景观丰富、视野开阔的空间，让城市美景、河流航道和夜空一览无遗。这种强烈的设计因素最终促成了封闭的空间设计方案，最大限度地确保视野开阔，同时呈现出极具表现力的建筑特色。

设计首先研究的是使用空间框架结构的可行性。空间框架概念原理包括两个方面：采用重量最轻的玻璃结构围合出水晶廊桥的室内边界，同时打造出封闭的空调空间。此外，水晶廊桥的椭圆形轮廓产生一种向外的推力，导致拱形结构概念非常不适用。最初项目团队对巴克明斯特•富勒的网格穹顶设计进行了广泛的研究，最终得出的概念是，采用拉杆在中心交汇的双层六边形构造，从而打造出重量最轻和视野最清晰的结构构造。由于六边形跨度不便于履层处理，项目又采用了六个三角形倾斜铝质板材来封闭结构。倾斜构造非常有效，玻璃和铝材交替呈现，从而营造出高性能的封闭空间（图7）。

萨夫迪建筑师事务所的根本设计原则是确保设计成果本身具有可建造性。这是我们设计流程的核心原则，并且贯穿建筑设计的诸多因素并不断完善，其中包括结构、施工方法、业态、环境舒适性和用户体验。随着设计团队进一步分析，空间框架概念的一些关键问题促使我们重新斟酌项目方案。比如项目当地缺乏熟悉空间框架设计的相关人员，在250米高空连接多种构件存在潜在风险，这些因素成为我们重新评估项目的基本前提。由于水晶廊桥的横截面形状从结构角度而言并不理想，我们决定将重新设计水晶廊桥的上半部分，改成简洁的弧形，从而缓解结构方面的不利影响。重新设计成弧形后，一系列六边形桁架整齐排列，并在圈梁构件处汇集，此圈梁将荷载转移到下方的主要结构。由于独立于下方主体结构，桁架沿轴线而置，简洁、优雅而有序。再次说明，通过对最佳结构及可建造方法的探索，我们决定将六边形桁架以90至110角度打开，所节省的桁架数量和减少的封闭面积，远比低效桁架的不利结构影响要划算的多。此外，由于桁架本身可以分为三段搬运并在现场焊接在一起，因而可以相应地确定钢索合适的半径尺寸，同时不会增加成本或增加项目的复杂性。事实上这些措施非常重要，因为效果最佳的玻璃系统将采用分段式直线设计。其结果是，从内部可以仰望头上高高的弧形结构桁架，从外观来看，简洁的玻璃构造将与封闭结构相益得彰。

通过广泛分析、不断创新和探索水晶廊桥上部结构和建筑围护本身最佳的可建造性，设计方案不断完善，呈现了其使用类型的最合理的建筑形态，同时也是一种优雅的解决方式（图8）。

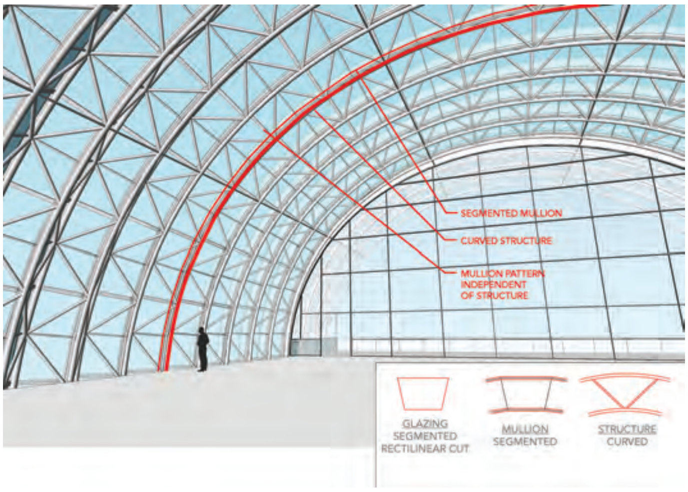

Figure 9. Conservatory mullion pattern diagram (Source: Safdie Architects)
图9. 暖房中梃模式图解（来源：萨夫迪建筑师事务所）

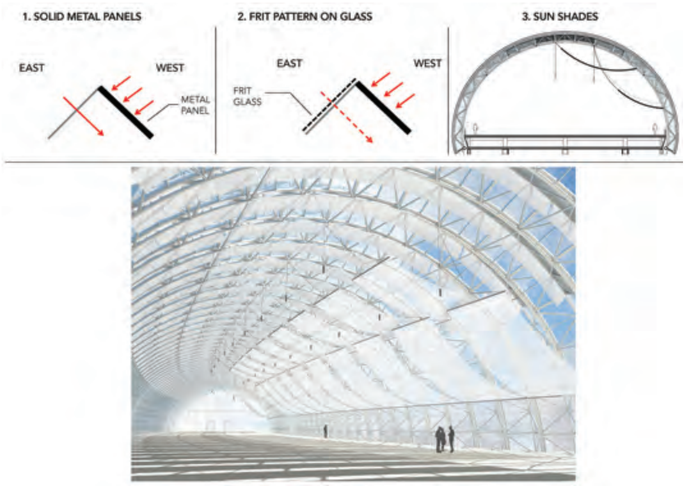

Figure 10. Sunshade and frit diagram (Source: Safdie Architects)
图10. 遮阳板与玻璃料图解（来源：萨夫迪建筑师事务所）

Life Safety and Planning

As the design for the main structural system and enclosure evolved, there were a series of logistical hurdles created by working on a new building typology (Figures 9 & 10). At the forefront of these challenges are issues of life safety, egress, and a building code not yet equipped to deal with this building type. Taken at face value, the fire and life safety codes would have meant that the Conservatory would have created an undue burden on the rest of the project.

The largest issue was the requirement that the Conservatory population be counted toward the egress requirement in the supporting towers. Since the Conservatory would constitute the largest floor plate and population size for each tower, every egress stair and fire-safety lift requirement would need to be sized off of it. When calculated, the impact on the tower egress stair sizes would have required that they be tripled. As the slender towers of the project were already less then optimally efficient, this impact could not be absorbed. Hence an alternative approach was needed.

Local code requires the use of refuge floors in high-rise buildings, such that all egress stairs must be interrupted at maximum increments of 15 floors. At the refuge floor, occupants must circulate through the floor and transfer back into an egress stair. This presented an opportunity, in that it was quite easy to establish the required number of egress stairs and width to safely bring the occupants down one level to a refuge zone in the Conservatory's structural zone. Thus, by creating a large continuous refuge zone, the occupants would be safe while transferring into the towers egress stairs to continue their exit. Through the use of egress simulation software, project engineers were able to model maximum allowable occupancy for the Conservatory that would not impact the size of the tower's egress stairs. It was determined that the total maximum occupancy for the Conservatory would be 1,800 people, which when analyzed for programmatic needs, was acceptable.

As egress simulation is not routinely accepted by fire and life safety code officials, and because the building typology was such a unique case, it was decided to request a formal national fire safety bureau review. The conclusion of that process was that the concept of bringing all occupants of multiple fire-compartments down to one refuge zone and transfer to the towers' egress cores was accepted.

As a whole, the major challenges of egress and life-safety became a fundamental driver of the planning for the spaces in the Conservatory. Through a mixture of invention and review process, the Conservatory was able to seamlessly integrate with the rest of the project.

Fire and life safety codes have evolved along with the development of the high-rise over many decades, and they will need to continue to evolve with the design inventions that are created as a response to dense urbanism. As these inventions and new building typologies are created, design teams will need to think creatively and work hand-in-hand with safety officials to ensure that the highest standards are maintained and applied appropriately.

Comfort and Placemaking

The design for the enclosure and interior spaces within the Conservatory presented a unique challenge of developing a blend of comfort and efficiency, while maintaining an open and light filled space. The main

生命安全和规划

随着主要结构体系和建筑围护设计工作的推进，新建筑类型带来了一系列运作难题（图9、10）。首要问题是生命安全和疏散事宜，建筑规范中没有针对这种建筑类型的相应规定。从表面上看，基于消防和生命安全规范，水晶廊桥将成为项目其他部分不必要的负担。

最大的问题是，水晶廊桥的人流将计入其支撑塔楼的疏散计算要求中。由于水晶廊桥的楼板最大，每座塔楼的人流、每个疏散楼梯和生命安全电梯的尺寸都需要根据它而制定。经计算，其影响是，塔楼疏散楼梯的尺寸将增大三倍。由于项目纤长的塔楼形态已经无法达到理想效果，这种影响不能被接纳。因此我们需要寻找另外一种替代方法。

当地规范要求高层建筑设置避难层，因此，所有的疏散楼梯都必须每隔15层被中断。在避难层，住户必须穿过此层再前往疏散楼梯。这种布局方式提供了一个契机，既在水晶廊桥主层设置疏散数量和宽度要求的疏散楼梯，将住户安全地引导到下一楼层，也就是设置在水晶廊桥结构区域的避难区。因此，通过营造大型连续的避难区，住户可以安全地转移到塔楼疏散楼梯进而继续疏散。通过使用疏散模拟软件，在不影响塔楼疏散楼梯大小的前提下，项目工程师们计算出水晶廊桥最大可容纳的人数。多种业态需求计算得出水晶廊桥最多同时容纳1800人，这一人数满足疏散要求。

由于消防和生命安全部门的官员通常不采用疏散模拟方式对项目进行审核，并且此项目的建筑类型非常独特，因此决定正式提请国家消防安全局对项目进行审核。审核结论是，将多个消防分区的住户引导到下面楼层统一的避难区，然后再转移到塔楼疏散核心的概念已被核准。

总之，疏散和生命安全方面的重大挑战，成为决定水晶廊桥空间规划的根本因素。

drivers are the occupants' comfort levels, the provisions required for a rich landscaped planting environment, and the efficiencies needed to maintain a sustainable design and operating cost.

The design responded through a multi-tiered concept, starting with the enclosure. The glazing of the enclosure is made up of insulated double glazed unit with low-e coating. Additionally, a 50% frit is applied to the glazing, starting at the apex of the enclosure and graduating down to 20%, 7m from the main floor. Lastly, an insulated metal panel replaces the glazing on the west facing side of the concertina truss. This allows for optimal views out, while blocking a great deal of solar gain from overhead. It also creates a unique character to the interior of the spaces. When looking to the west, the roof overhead appears as fully opaque, but when looking to the east, appears as a full skylight (Figures 11).

Inside the enclosure additional steps are taken to maintain the comfort and efficiency of the building. Large deployable sunshades are fixed on the concertina steel at two different levels within the space. The sunshade rollers span between the bottom cords of the trusses and are released with counterweights pulling down, which deploy the sunshade that takes on a beautiful parabolic shape. Using two levels of shades, the south facing side of the Conservatory can be covered during the day. These sunshades provide protection against solar glare during the afternoon, and when retracted during the morning and evening hours allow for enough solar radiation for the vegetation needs.

As per its namesake, the Conservatory's main interior features are trees and plantings. Unifying many different types of spaces and uses across the Conservatory, the landscape becomes a rich tapestry that blends with the interior design of the spaces. The types of the planting and trees respond to both the use type as well as the environment. Local species are used at the open air ends of the Conservatory, tropical species in the clubhouse pool and garden areas, and a few variations of plantings unify both the hotel lobby and F&B outlets. The landscape also provides shading and fresh air, aiding in providing a comfortable and stable interior environment.

The development of the interior design and architecture of the Conservatory has also created the ability to create smaller micro-climates. Common to many of the program spaces, small pavilion-like structures evolve under the larger roof enclosure. These interior spaces allow for their climate, lighting, and

Figure 11. View of conservatory F&B (Source: Safdie Architects)
图11：暖房餐饮区（来源：萨夫迪建筑师事务所）

经过创新设计与评估流程后，水晶廊桥可以与项目的其他部分无缝整合在一起。

消防和生命安全规范随着数十年高层建筑的开发得以完善。现今，高密度的城市化发展催生了创新的建筑设计，规范也会在这一过程中得到进一步完善。由于创新设计和新颖建筑类型的产生，设计团队需要采取创造性思维方式并与安全部门官员密切合作，以确保遵循最高标准并将其恰当地应用到项目实践中。

舒适性和场所感

水晶廊桥的围护和室内设计不仅需要满足舒适性和实效性要求，同时还要呈现光线充足的开放空间。项目设计的主要决定因素包括，确保住户的舒适性，营造景观植被丰富的氛围，以及兼顾可持续性设计和运行成本所需的实效性。

项目设计通过多种方式来满足这些要求，首先从建筑围护开始。建筑围护采用双层保温低辐射玻璃。此外，从建筑围护的顶部开始采用50%玻璃彩釉处理，然后逐渐降低到20%，距离主要楼面7米。最后，六边形桁架的西侧围护用保温金属板取代了玻璃。这样不仅可以提供最佳视野，还可以大量阻挡来自上方的太阳辐射。这种设计也使室内空间别具一格。从西侧向外望时，上方的屋顶完全不透明，而从东侧向外望时，透明天窗则让视野一览无遗（图11）。

为了确保建筑的舒适性和实效性，建筑围护内部采取了额外措施。空间内两层大型可开启遮阳板固定在六边形钢架上。遮阳板卷轴设置在桁架底部绳索之间，可以通过配重拉下来，从而呈现出美丽的抛物线形状。通过两层遮阳，在白天，水晶廊桥南侧可以被遮挡起来。这些遮阳板下午可以遮挡太阳眩光；清晨和傍晚时分则被收起来，为植被提供足够的阳光。

从温室花园本意顾名思义，水晶廊桥室内的主要特色就是树木和植被。水晶廊桥融合了许多不同空间类型和使用功能，绿色景观点缀着室内空间，营造出丰富多彩的氛围。植被和树木类型与空间用途和环境相呼应。当地物种将用于水晶廊桥的露天平台一端，会所泳池和花园区域将采用热带植物，酒店大堂和餐饮区域则将统一采用略有不同的植被。绿色景观不仅可以遮阳和提供清新空气，还有助于呈现舒适且稳定的室内环境。

水晶廊桥的室内和建筑设计还衍生出较小的微气候环境。在巨大的屋顶围护之下，许多业态空间内都有较小的场馆结构。这些内部空间的气候、照明和内部氛围与大环境脱离，进一步营造出舒适且高效的内部环境。纵观整个水晶廊桥，这些场馆结构有其独立的空间和流线模式。随着人们探寻的脚步前进，高大广阔的空间逐渐变

interiors to be isolated from the greater whole, further creating comfortable and efficient interior environments. Across the Conservatory, these pavilions create their own spaces and circulation patterns. One journeys from soaring expansive areas into smaller more intimate environments, as the building is discovered. In many respects, the Conservatory becomes its own cityscape in the sky (Figures 12).

Conclusion

The Conservatory is representative of a new building type, spawned from dense urban environments. As a pioneering concept derived from requirements of increased density, the Conservatory is one example of a new typology. Further evolution of this typology will undoubtedly unfold, perhaps integrating itself across multiple projects and sites, and creating a true three-dimensional matrix of our urban fabric. One could imagine a day when these horizontal structures do not just sit atop buildings, but pierce through and weave around them. Whatever type of iterations evolve, what is evident is that the challenges of their design and appropriate design solutions will represent a new chapter in the development of building practices. One day, in addition to tracking tall buildings, the CTBUH may need to develop new metrics to monitor and measure the success of these new structures.

Figure 12. View of conservatory pool (Source: Safdie Architects)
图12：暖房水池（来源：萨夫迪建筑师事务所）

成规模较小更私密的环境。从许多方面而言，水晶廊桥将成为别具一格的城市空中景观（图12）。

总结

水晶廊桥是高密度城市化环境中新颖建筑类型的代表。作为从提高建筑密度需求中衍生的创新概念，水晶廊桥将成为新类型建筑的典范。毫无疑问，这种建筑类型还将进一步发展完善，也许将融合到更多项目和场地中，为我们营造出真正的三维城市结构。人们可以想像到，有一天这些横向结构将不只出现在建筑顶端，而是贯穿建筑或萦绕在其周围。无论任何类型的迭代演变，显而易见的是，所面临的设计挑战和相应的设计方案将成为建筑实践发展的新篇章。有一天，除了关注高层建筑外，“高层建筑与都市居住委员会（CTBUH）”可能需要制定新的标准来监督和衡量这些新结构的成功实践。