Title: **Abeno Harukas: Vertical City Toward Natural Symbiosis and Sustainability**

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Abeno Harukas: Vertical City Toward Natural Symbiosis and Sustainability

阿倍野Harukas: 走向自然共生和可持续发展的立体都市

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Abstract

Abeno Harukas is a 300 meter tall skyscraper scheduled for completion in Spring 2014; it will be the tallest building in Japan. Sited in a highly dense urban area, the building form is optimized considering a variety of factors, including the wind influence on the surrounding area, connection to existing utilities, vertical circulation, and evacuation planning. Three volumes with different footprints are shifted and stacked to allow sunlight and ventilation into the office atrium. Furthermore, these manipulations create continuous steps of "three-dimensional green zones" relating to the adjacent Tennoji Park. For the building occupants, these "green zones" provide places for interaction with nature and a dynamic urban experience.

Keywords: Environment, Nature, Activity, Void, Mixed-use, Context

摘要

Abeno Harukas是一座高300米的摩天大楼，计划于2014年春季完成修建，竣工后将会成为日本最高的建筑。该建筑位于高密度的市区，建筑形态的优化考虑了各个方面的因素，这包括周边区域的风力影响，与已有公共设施的联系，竖向流线和疏散规划。通过三个有着不同占地面积体块的移位与堆叠，能使办公中庭能获得充足的光照和通风。此外，这种处理还创建与其相邻的Tennoji公园相关的“三维绿色区”。对于建筑的居住者，这些绿色区域也提供了与自然互动的场所和动态的城市体验。

关键词：自然环境，自然，活动，间隙，复合功能，周边环境

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Tetsuo Harada, Architect, is the senior manager of the building design department in the Osaka office of Takenaka Corporation. Harada's projects have been published in architectural magazines include his Hep Five, Hilton West, and some cutting edge commercial buildings. In the buildings that he designed, the connection of architecture, city, and nature is the main theme. The background of his design approach is wisdom in Japanese traditional urban dwellings, as represented by "Machiya", a highly sophisticated environmental architecture in high-density cities.

Tetsuo Harada，建筑师，是株式会社竹中工務店大阪总部建筑设计部门高级主管。Harada的项目包括Hep Five、Hilton West和一些已在建筑杂志中发表的前沿的商业建筑。在他设计的建筑中，主题往往都围绕着建筑、城市与自然的联系。他的设计方式，背景源于日本传统城市住宅的智慧，以町屋为代表。这是一种在高密度城市中高度精致且与环境紧密相连的建筑。

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Overview

Abeno Harukas, scheduled to be completed in the Spring of 2014, will be 300 meters tall and become the tallest building in Japan (see Figure 1). The site of this building is located at Abeno in Osaka, in the Keihanshin area, which stretches from Kyoto to Kobe. The region is by GDP one of the largest areas in Japan, second only to Tokyo, and seventh largest in the world. Abeno is a thriving transportation node located on the Uemachi plateau and is considered the birthplace of the history and culture of Osaka.

Abeno Harukas is planned above the terminal station Abenobashi, which is operated by Kintetsu Corporation, a private railway company with the longest railway network in Japan. This building will be the tallest railway terminal building in the world, with 60 stories above the ground and an additional five underground stories. At approximately 212,000sqm in the total floor area, it is a supertall vertical city with various functions, including retail, a museum, offices, a hotel, an observatory, and parking. The design and structure maximize the performance of each

概述

阿倍野Harukas高300米，计划于2014年春季建成。竣工后将成为日本最高的建筑（见图1）。建筑的选址位于大阪的阿倍野区，从东京延伸到神户的京阪神地区。这一区域以GDP来看，是仅次于东京的日本最大地区之一，是世界第七大地区。阿倍野是位于上町高原上繁荣的交通枢纽，同时也被视作大阪文化和历史的发源地。

阿倍野Harukas拟建于阿倍野桥站之上。此站由日本近铁集团，即拥有日本最长铁路系统的私人铁路公司所运营。这也将成为世界上最高的客运站建筑。其地上60层，地下五层，总建筑面积约为212,000平方米。这是一座拥有零售商店，博物馆，宾馆，观景台以及停车场在内的超高层立体城市。设计与结构使每一项功能的性能都得到最大化。结构和环境核心联接起不同的元素形成了独一无二的纵向组织。

这些只是通过打造立体都市来提升车站功能性，增加阿倍野这个交通枢纽的吸引力并促进带动此地区发展的一个起始点。此项目旨在为大阪乃至日本提供一个有影响力的地标，同时提高阿倍野地区的全球知名度并使其成为这一地区的象征（见图2）。

Figure 1. Rendering of ABENO HARUKAS
图1. 阿倍野HARUKAS渲染图

function. Structural and environmental cores connect the elements to create a unique vertical organization.

These are the beginning points for improving the functionality of the station, enhancing the appeal of Abeno as a transportation node, and contributing to the activation of the region through building a vertical city. This project aims to offer landmark appeal for Osaka and Japan and to improve the global visibility of the Abeno district and becoming a symbol of the region (see Figure 2).

Form

Abeno is a crossroads of seven railway routes around which a commercial district has developed with adjacent parks and a residential quarter. An important design factor was maintaining a relationship with the existing context.

Cascaded Section

Sited in a highly dense urban area, the building form is optimized considering a variety of factors, including the wind influence on the surrounding area, connection to existing utilities, vertical circulation, and evacuation planning. Three volumes with different floor areas are shifted and stacked to allow for intake of sunlight and wind to the center atria voids; these create three-dimensional green gardens like a cascade from the roof to the ground plane (see Figure 3).

The environmental influences played a key role in determining the volumes. Green gardens positioned on the rooftop setbacks create a vertical urban landscape relating to the adjacent Tennoji park. For the building's occupants, the green gardens provide places for contact with nature as well as encourage more dynamic and abundant urban activities. They also offer a "sense of the place" that is necessary for mental health of people inside in the large building.

Expression of Activities

The envelope of this building consists of the curtain wall units, each unit is the size of two Tatami mats. Symbolically, one unit provides space for two people. The building occupants operate blinds and lights depending on type of activities and the time of day. Activities

Figure 2. Aerial photography of the site in February 2012
图2. 2012年二月场地鸟瞰照

形态

阿倍野是七条铁道路线的交汇点，此处有发达的商业区以及毗邻的公园和住宅区。设计中很重要的因素就是维持与已有环境的关系。

梯级剖面

坐落于高密度的市区，建筑形式的优化考虑了各个方面的因素。这包括周边区域的风力影响，与已有公共设施的联系，竖向流线和疏散规划。通过三个有着不同占地面积体块的移位与堆叠，能使办公中庭能获得充足的光照和通风。从楼顶到地面也就建立起了瀑布式层叠的三维绿色花园（见图3）。

在决定体量时，环境的影响起着关键的作用。绿色花园位于屋顶的回退处，建立了与毗邻的Tennoji公园相关的立体城市景观。对于建筑的居住者，绿色花园则提供了一个与自然交流同时促进动态且丰富的城市活动的平台。并且还提供了一种“空间感”，这对在大型建筑内人们的心理健康是很有必要的。

活动的表达

建筑的表皮是由幕墙单元组成的，每个单元是两个榻榻米垫的大小，象征了一个单元能提供两人所需的空间。建筑的居住者可根据活动类型和时刻来操控百叶窗与灯光。活动由通透的幕墙传达到城市中，同时随着时间的流逝，墙上所呈现的活动表达也将各式各样（见图4）。

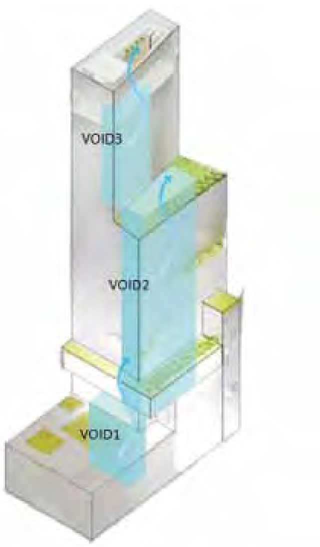

Figure 3. Layout of voids for natural ventilation
图3. 自然通风间隙布局

Figure 4. West view at dusk ("Akari" is light through a façade, gives sense of living.)
图4. 黄昏西景（"Akari"是透过外墙的光，给人以存在感）

transmit to the city through the transparent curtain wall, and various expressions appear as time passes (see Figure 4).

Another significant design priority is the expression of activities of the occupants connecting the large scale building to the urban context. Furthermore, rooftop gardens that are visible through the glass facade bring comfortable scenery to the city (see Figure 5).

Form of Micro-Topography

Since the 16th century, the city of Osaka developed based on an east-west street grid, starting from Osaka Castle toward Osaka BayThe Abeno area has a conjunctional street that expands from the Osaka Castle toward Abeno. The grid is deflected from the north by 10 degrees referencing the Uemachi grid, and is influenced by the ridge line in Uemachi plateau (seeFigure 6). The angles of the street corners formed by the intersection of the two grids provide a delicate richness to the street views.

Significant features of the site

Earthquakes and typhoon

While there are many taller buildings all over the world, Japan is an earthquake and typhoon-ridden country shown in the dark-colored areas of the Fig 7. In this country, the heaviest lateral forces in the world are applied to building designs.

At the same time, the seismic and wind resistant design criteria of this building are set higher than usual high-rise buildings for ultimate structural safety. For example, elements of this building are not allowed to be deformed against level of an earthquake that recurs at an interval of 475years.

Significant points for structural design

Japanese super high-rise building must be designed against very large earthquakes and wind loads as previously noted , and three significant points are set for mitigating the effect of both loads.

First, the natural period of this building sets 5 to 6 seconds as a targeted period. This building's natural period is about 5.7 seconds, with very robust frames and a strong center of gravity and rigidity very close together with a large torsion stiffness in the structure.

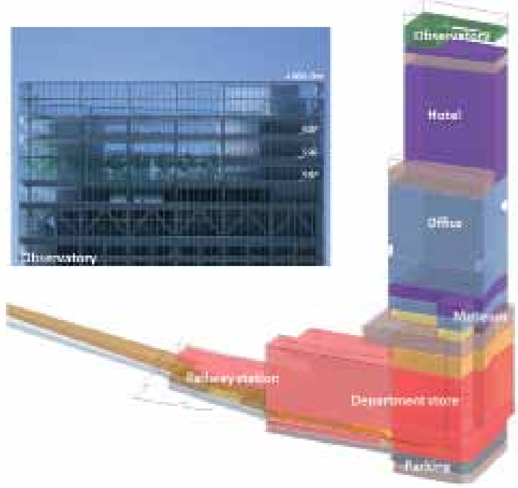

Figure 5. Diagram of ABENO HARUKAS
图5. 阿倍野HARUKAS图示

另一个在设计中要优先重点考虑的是联系着大型建筑与城市环境的居住者的活动表达。此外，从玻璃外墙可见的屋顶花园，为城市提供了宜人的景色 （见图5）。

微地形的形态

自16世纪以来，大阪市是基于从大阪城到大阪湾，东西走向的街道网格发展开来的。阿倍野地区有一条相连的街道，从大阪城延展到阿倍野。以上町网格为参考，此网格向北偏离的十度，并且会受到上町高原山脊线的影响（见图6）。两个网格相交形成的街道拐角的角度提供了精致丰富的街景。

基地的显著特点

地震和台风

虽然在全世界已有很多高层建筑，但日本是一个地震与台风频发的国家，显示于图7中深色的部分。这个国家，在建筑设计中运用的侧向力是世界上最大的。

同时，出于最终结构安全的考虑，此建筑的抗震抗风设计标准也比一般的高层建筑要高。譬如，这座建筑的构件就要求即使在遭遇重现期为475年的地震时，仍不允许有任何形变。

Figure 6. Micro-topography in Osaka
图6. 大阪微地形

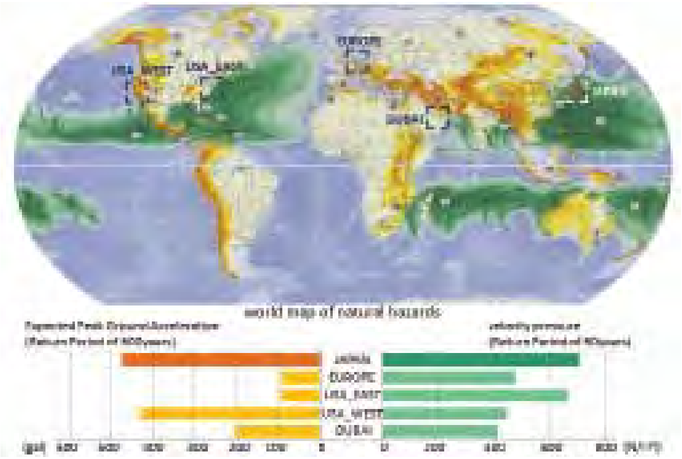

Figure 7. World map of natural hazards [Left] The expected peak ground acceleration maximum intensity of earthquake which recurrence interval is 475 years is about 475gal. [Right] Velocity pressure based on basic wind speed, the recurrence interval is 50 years in Japan, is about 700 N/m² which is largest level in the world.
图7. 自然灾害世界地图。[左]重现期为475年的地震，其预期地面加速度最大强度峰值约为475gal。[右]基于基础风速，在日本重现周期为50年的风压约为700 N/m²，是世界最强水平。

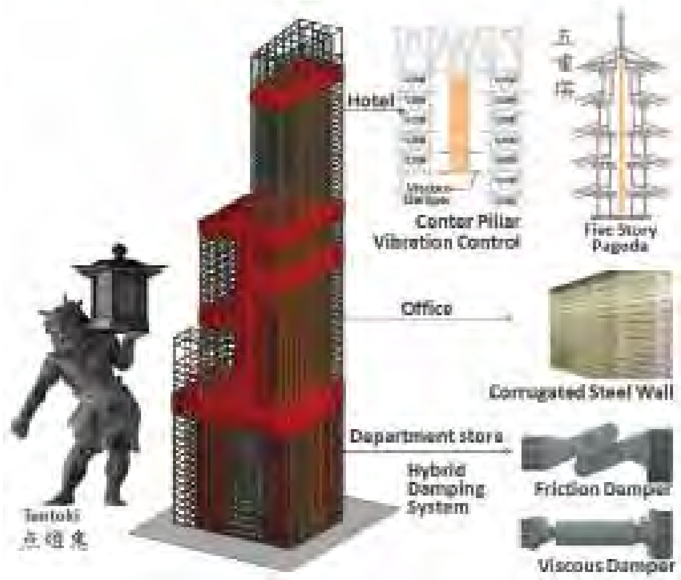

Figure 8. Structural system ("Tentoki" gives asymmetrical dynamic impression)
图8. 结构体系（"Tentoki"给人以非对称的动态印象）

Second, in an earthquake and typhoon-ridden country, some adequate dampers are included at appropriate locations against unexpected external loads to ensure redundancy. Additionally in structural analysis, we used presumed maximum input earthquake motions and regional seismic waves which are not categorized by the law.

Third, concerning the hotel function in the high-rise component of this vertical city, comfortable habitability, in addition to safety and security, will be provided by reducing acceleration in strong winds with effective devices.

Structure system

Superstructure

Structural planning is shown in Fig 8. For the purpose of supporting heavy weight, this building uses concrete-filled steel tubes (CFT) with high strength steel (tensile strength: 590N/mm²) and high-strength concrete (cylinder compressive strength: 150N/mm²) is used for the columns. This building has three significant truss braces between the low-rise and medium-rise structures and medium-rise and high-rise structures and immediately above the high-rise component of the building. For the purpose of additional deformation reduction, other effective large outrigger braces are added in the middle of office floors and core braces throughout the office cores.

Most of the superstructure is moment resistant steel frames, with the addition of some adequate dampers.

In the low-rise department store floor, there are some viscous dampers and rotational friction dampers around the core. Viscous dampers are highly velocity-dependent and friction dampers are highly deformation-dependent. A rotational friction damper generates a given frictional force via the friction pads sandwiched between steel pads. On the medium level floors, corrugated steel plate walls are installed in the office elevator lobbies. A corrugated steel plate wall is an earthquake-resisting member consisting of a steel plate corrugated in the direction of the height and surrounding flanged steel plates that are integrated with the frame.

On the upper floors, core truss dampers are installed in the hotel atrium. The truss frame is hanging from the hat truss and some viscous

结构设计要点

正如上述，日本超高层建筑设计必须能抵抗巨大的地震与风荷载。因而确立了三个要点来减轻这两种荷载的影响。

其一，此建筑把自振周期5到6秒设置为目标周期。在拥有非常稳定的框架，同时在结构中较大的扭转刚度与其较强的刚度重心靠近的情况下，其自振周期为5.7秒。

其二，在地震与台风频发国家，需要在合适的位置安置一些适当的阻尼器来抵抗意料之外的外部荷载从而保证结构具有一定的冗余度。另外，在结构分析中，我们所用的假定最大输入震动和区域震波是不按规律分类的。

其三，考虑到在立体都市中的酒店部分的功能，舒适的可居性，除了安全性外，是通过运用有效的装置降低强风中的加速来实现的。

结构体系

上部结构

结构规划显示在了图8中。出于支撑重压的目的，此建筑采用了高强度（抗拉强度：590N/mm²）的钢管混凝土(CFT)，柱体则采用了高强混凝土（圆柱体抗压强度：150N/mm²）。这座建筑在低层与中层结构之间、中层与高层结构之间以及高层部分上方设置了三个重要的桁架。出于减小额外形变的目的，在办公楼中间添加了其他有效的大型伸臂桁架，在办公核心区添加了核心支撑。
大多数上部结构是抗弯钢框架，加装有一些足够的阻尼器。

低层百货楼层中，在核心筒附近，有一些粘滞阻尼器和旋转摩擦阻尼器。粘滞阻尼器是主要基于速度的，而摩擦阻尼器是基于形变的。旋转摩擦阻尼器通过夹在钢板之间的摩擦垫产生给定的摩擦力。中间的楼层，在办公电梯门厅安装了波纹钢板墙。波纹钢板墙是由在高度方向上有波纹的钢板和周围与此框架相集成的凸缘型钢板组成的，是抗震的构件。

在较高的楼层，核心桁架阻尼器安装在酒店中庭。桁架框架悬挂在塔帽桁架，一些粘滞阻尼器则安装在吊式桁架和酒店结构之间（见图8）。

地基系统

建筑采用由桩和底板组成的桩筏基础，两者都用于承载建筑的负荷，同时地下室柱体的使用则采取了倒置法。在底板安装之前，上部结构已建到56层。因此，桩承载了高达约90%的柱轴力，底

dampers are installed in between the hanging trusses and the hotel structure (Figure 8).

Foundation system

A piled raft foundation consisting of piles and bottom plate--both of which bear the building load--are used for the building, with an inverted placing method applied, using basement columns. The superstructure was constructed up to about 56th floor level prior to the bottom plate installation. Accordingly, the piles bear as much as about 90% of the column axial forces, and the bottom plate bears the remaining forces (only about 10%). One pile is located per column as shown by the pile plan, but the existing building frame is buried in the circumference, which makes it difficult to drive piles. Consequently, the SMW (soil mixing wall) construction method is used. The column axial forces are transferred to the core steel of the soil cement retaining walls through the headed studs from the exterior wall of the basement and finally transferred to the ground due to the friction between the soil cement walls and ground. Furthermore, a loading test will be performed during construction to check the bearing capacity. The SMW method is environmentally friendly because about 40% of the soil can be reused.

Improving comfort

The inclusion of a hotel in the high-rise component of this building requires special consideration for the comfort of the guests. The impact of a large earthquake will be reduced by a core truss damper as noted before and active-tuned mass damper on the hat truss floor.

Core truss dampers are installed in the hotel atrium. A viscous damper mounted between the truss and hotel frame reduces the story drift of the high-rise component by up to 10% through the mechanism. (Figure 9).

To increase the comfort of hotel guests, active tuned mass dampers (ATMD) for the narrow side (north-south) of the building are installed on the hat truss floor to reduce the response accelerations at the Class H-30 level (about 30% of the habitants present perceive the tremor) in case of strong winds with the recurrence interval of one year. We adopted an inverted-pendulum system because the building period is very long. Although the length of the pendulum is not so long, the period of this damper is as long as that of the building.

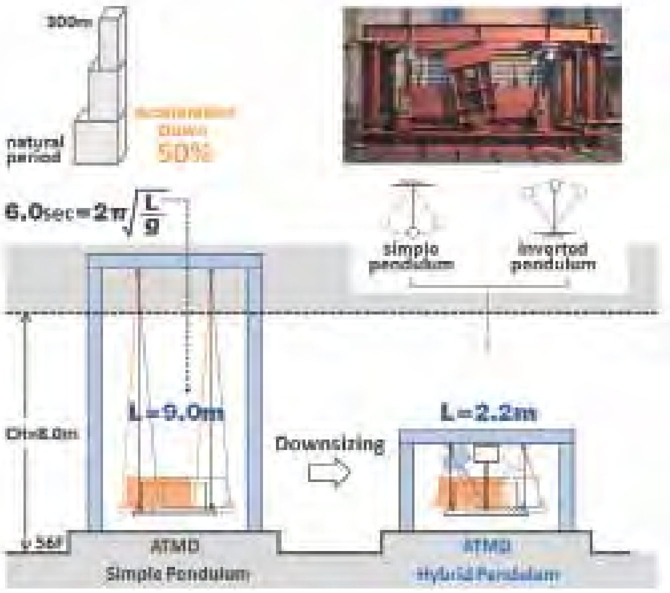

Figure 9. Active tuned mass damper for improving dwelling ability in strong wind
图9. 在强风中提高住宅性能的主动调谐质量阻尼器

板则承担剩余的部分（只有大约10%）。如桩平面图所示，一桩位于一柱之上，但因原有建筑框架在周围进行掩埋，为打桩造成了难度。所以采用了SMW（土混墙）施工法。柱轴力通过地下室外墙的栓钉转移到水泥土挡土墙的核心钢材上，由于水泥土墙和地之间的摩擦而最终转移到地面。此外，在施工过程中会进行载重试验来检验其承载能力。SMW方法因其40%的土壤可回收再利用，对生态环境是无害的。

提高舒适度

由于此高层建筑包含了酒店的部分，所以要求对客人的舒适度有特殊的考虑。剧烈地震的影响能通过之前提到的核心桁架阻尼器和桁架楼板上的主动调谐质量阻尼器来减小。

核心桁架阻尼器安装在酒店的中庭，粘弹性阻尼器会安置在桁架和酒店框架之间，通过此装置可降低高层构件的楼层侧移达10%（见图9）。

为了提供酒店住客的舒适度，建筑窄边（南北）的主动调谐质量阻尼器安装在桁架楼板上，来降低在H类-30级（大约30%现有居住者能感知到的振动）的加速度响应，以防重现期为一年的强劲风力。因为建筑周期很长，我们采用了一种倒立摆系统。虽然吊摆的长度不是很长，但其周期是同建筑一样的。

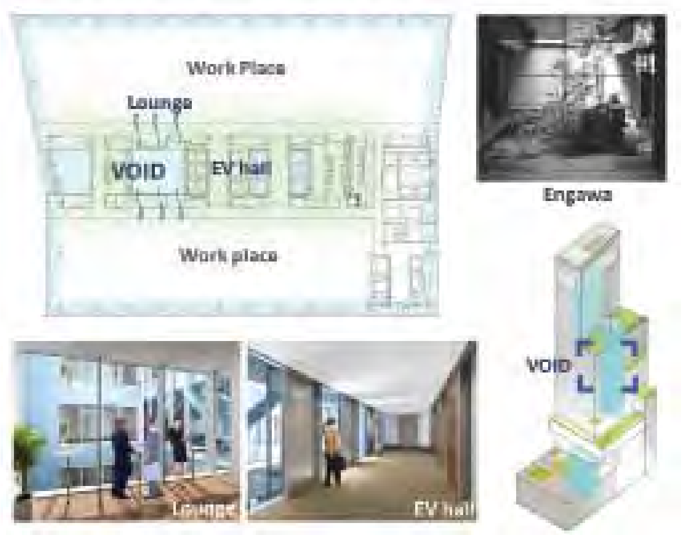

Figure 10. Void for a office in harmony with nature
图10. 与自然相和谐的办公室间隙

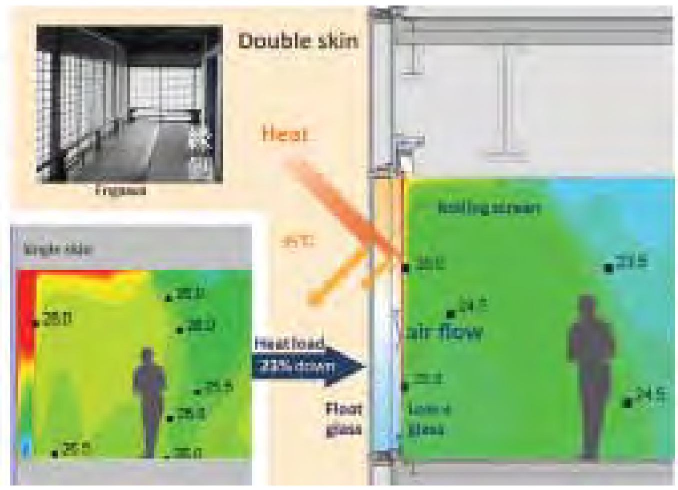

Figure 11. Façade system
图11. 外墙系统

Void

The asymmetric mega truss optimized to the program of the building forms void spaces that are available for the inner traffic trunk line, such as stairways and elevators, and also become the routes of natural light and the natural ventilation.

Appropriate placement of environmental voids is achieved by utilizing the height of the super-high-rise building (Figure10). For the building's peripheral area, an internal air-flow window system is adopted, taking into consideration the stringent wind pressure (993kg/cm^2) constraints and safety for the surrounding area (Figure 11).

Furthermore, voids inside the building are used to actively ventilate and exchange heat. The department store's voids channel waste heat inside ceilings and send the cooled exhaust air to the upper floor's cooling tower via a buoyancy ventilation system, in order to exchange heat. Voids in the office area admit natural light and wind to the central core section, which would otherwise be dark, and convert common hallways into sunny portico-like active spaces. During the night, cool outside air is taken in for cool storage and night purging is also performed. In the hotel, voids carry out buoyancy ventilation and admit sunlight from the top section.

Various environmental voids help to materialize an environment that is compatible with nature by adopting passive environmental technologies in appropriate areas of the super-high-rise complex, which is subject to stringent wind pressure constraints.

Energy management for complex usage

In this project, CO2 emissions are reduced by various means. Due to the complex usage pattern of the building, energy management is implemented specifically by utilizing the time difference in energy load for each element. For example, energy for the hotel is mainly used during nighttime, while the offices and department store consume power during daylight hours. Similarly, whereas the offices are closed on weekends, the department store is busy at that time. In addition, heat is recovered throughout the elements. For example, waste heat from the department store, where air conditioners are used year-round, is utilized in the hotel and offices where hot water needs to be supplied constantly. Thus, even from the perspective of energy conservation, environmental loads are reduced overall by maximizing the complex's characteristics of multiplicity (Figure 12).

Conclusion

Even under the severe condition of super-high-rise buildings in Japan, the project unites not only design and engineering, but also the wisdom found in a traditional urban dwelling in Japan.   A connection to nature helps support the realization of the vertical city, which looks toward natural symbiosis and sustainability.

Ancient wisdom coexists and lives on in the modern design, such as the "asymmetric outrigger" system and "core truss dampers" that work on the same principle of the five-Storied pagoda, providing the engineers with inspiration for the ultimate structural design.

间隙

非对称的巨型桁架优化了建筑方案，形成的间隙空间可用于内部交通主干线，比如楼梯和电梯。同时也成为自然采光与通风的路径。

环境间隙的适当位置是通过利用超高层建筑的高度来确定的（图10）。对于建筑的外围区域，考虑到严格的风压(993kg/cm^2)限制和周围环境的安全，采用了内部送风窗系统（见图11）。

此外建筑内的间隙被用于促进通风与热交换。百货商场的间隙通道能消耗天花板内的热，并通过浮力通风系统将冷却的废气送达上层楼面的冷却塔，以便热交换。办公区的间隙让自然光和风进入中央核心区，否则将会很暗。同时将普通的走廊转换为阳光的门廊式活动空间。在夜间，室外的冷空气会被储藏并进行夜间净化。酒店中的间隙则能完成浮力通风并从顶部引入光照。

在严格的风压限制下，通过在复合超高层适当区域采用被动式环保技术，多种环境间隙有助于实现一种与自然兼容的环境。

复合使用的能量管理

在这个项目中，二氧化碳的排放量通过多种方式得到降低。由于建筑的复合使用模式，能源管理是通过每个部分能量荷载的时间差来进行专门实施的。譬如，酒店能源的消耗主要在夜间，而办公区和百货商店则一般在白天。类似的，办公室在周末关闭时，百货商场却非常忙碌。另外，热能也可通过每个部分得到修复。比如，空调全年使用的百货商场，其余热能被用于需要不断供应热水的酒店与办公室。因此，即使从能源保护的角度，环境负荷也能通过最大化多样性的复合特点得到总体的减少（见图12）。

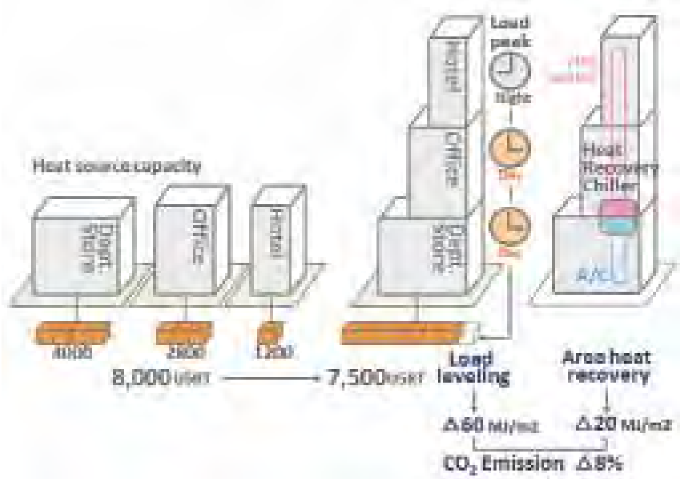

Figure 12. Energy management for reduction of CO2 emission
图12. 减少二氧化碳排放的能源管理

结语

即使在日本高层建筑的苛刻条件下，此项目不仅仅结合了设计与工程，还有日本传统城市住宅中所寻得的智慧。与自然的联系有助于立体都市的实现并走向自然共生和可持续发展。

先贤的智慧在现代设计中的运用与共存，如“非对称伸臂桁架”系统和“核心桁架阻尼器”与五重塔相同的工作原理，为工程师们最终的结构设计提供了灵感。