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Case Study: Abeno Harukas, Osaka

Forging a Supertall Compact City



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Tetsuo Harada

Tetsuo Harada is the general manager of the architectural design department of Takenaka Corporation in Osaka. The projects he has led – including Hep Five, Hilton West, as well as other cutting-edge commercial buildings – have been featured in a variety of architectural magazines. In all of the buildings that he has designed, the connection of architecture, city, and nature is the main theme. The background of his design approach is Machiya, or the wisdom in Japanese traditional urban dwellings, as represented by highly sophisticated environmental architecture in the high-density city.

Masaomi Yonezu

Masaomi Yonezu is the manager of the architectural design group of Takenaka Corporation in Osaka. He has designed a number of distinctive buildings based on careful observation of the city.

Abeno Harukas is the tallest building in Japan and one of the world's tallest buildings directly over a railway terminal. It connects the metropolitan area railway network to a new vertical urban network, reducing energy consumption and providing a variety of activities and services. Abeno Harukas is a high-density urban complex incorporating a department store, art museum, school, hospital, office, hotel, observatory, and rooftop gardens above the railway station. This supertall “compact city” demonstrates a way forward for reorganizing cities to optimize the value of the city center and integrate it with the surrounding area through the railway network.

Countering Suburbanization

To understand this building and its significance, it is important to first reflect upon the context in which it is built.

Despite its reputation as a crowded and highly-dense country, population decline has become a serious problem in Japan. Additionally, suburbanization has taken hold here as elsewhere, and this has resulted in underutilized city plots and infrastructure, and poorly distributed commercial and government services. To rectify this, the roles of Japan's suburbs, which became highly dependent on automobiles during the period of population growth after World War II, and its city centers need restructuring. In a sense this has already begun; in recent years, development of commercial facilities connected to stations and housing within walking distance of rail stations has increased in Japan's provincial cities. Such development is one approach to increasing the compactness of these areas, which have become increasingly integrated with railway networks. Now, the practice of increasing the use of land around railway hubs in city centers – in other words, creating cities that are more vertical and more compact – is gaining traction.

The GDP of the Keihanshin metropolitan area (Osaka, Kyoto, and Kobe) is second only to Tokyo among Japanese metropolitan areas, and is ranked seventh-largest in the world. The region has an extensive passenger rail network, comprised of numerous national and private lines, and the city subway.

Abeno project site is a busy rail hub in Osaka (see Figure 1), of comparable importance to the Osaka and Umeda stations in Umeda, and the Namba Station in the Namba district. The Osaka Abenobashi – Tennoji Station serves as a terminal for trains bound for southern Osaka and Yoshino (southern Nara prefecture) on the Kintetsu Railway. The number of passengers exceeds 70,000 per day, and an additional 34,000 people per day visit the department store, pass through the area on local streets, or enter the subway here.

Abeno is situated on the Uemachi Plateau, the backbone of the Osaka Plain. The plateau has



Figure 1. Abeno Harukas with the Osaka Abenobashi – Tennoji Station. © Nakamichi Atsushi

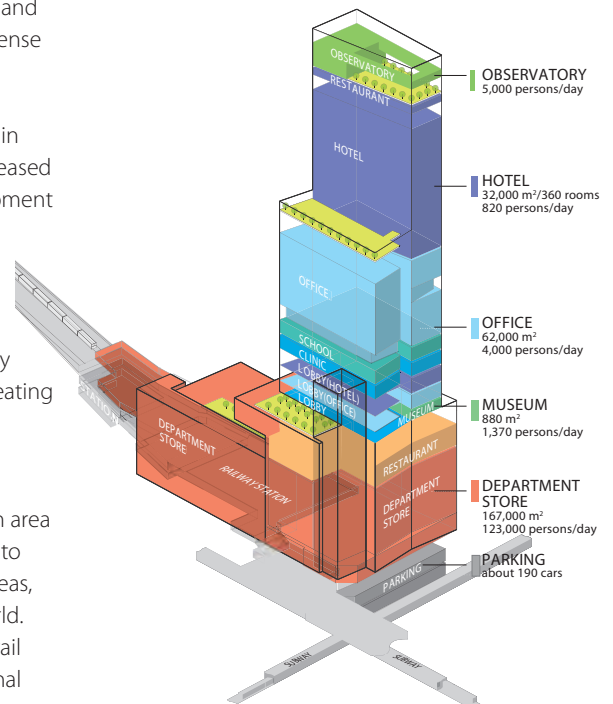


Figure 2. Abeno Harukas – “Supertall Compact City.”

many historic buildings, including Shitennō-ji Temple, Naniwa Palace, and Osaka Castle, and is the historical and cultural center of Osaka. Abeno is also near an upscale residential district. In recent years, however, it has been greatly outstripped by Umeda and Namba with regard to commercial development. The original goals for this project were therefore to revitalize Abeno and the areas along the railways, and to reorganize Osaka's city structure by establishing Abeno as a place with a unique character that functions as a "third pole" of Osaka (the other two being Umeda and Namba). To achieve these goals, the developers proposed a supertall building of formidable volume, in which various uses would be networked and built directly above an existing rail terminal that would bring traffic to the site.

A Supertall Compact City

Abeno Harukas is a 60-story building with five basement levels, built directly above Abeno station. It has a total floor area (TFA) of approximately 306,000 square meters and contains a university, a day nursery, advanced medical facilities, and a small theater, in addition to office space, a department store, hotel, museum, and an observatory (see Figure 2). At a height of 300 meters, it is the tallest building in Japan and the nation's first supertall building.

The main tower portion of the building, with a TFA of approximately 212,000 square meters, was treated as an extension of an existing building with a TFA of approximately 94,000 square meters. This enabled the developers to use the local "Act on Special Measures Concerning Urban Reconstruction" advantageously, affording a zoning variance such that Abeno Harukas has a floor area ratio of 16.0, rather than the usual 8.0.

A "Supertall Compact City" such as Abeno Harukas integrates the wide range of activities normally found throughout sprawling cities into supertall buildings (see Figure 3). By accessing the railway network, these buildings can have an impact that is sufficient to reorganize not only the surrounding buildings,



Figure 3. Abeno Harukas, Osaka – overall view from North. © Suzuki Hisao

“The following three architectural elements are key to converting the possibilities inherent in the innumerable *encounters* in supertall compact cities into *effects*: three-dimensional routes affording various choices, networks of voids, and three-dimensional networks of greenery.”

but the entire urban region. The compact, railway-based structures of such cities help reduce energy consumption and carbon emissions and provide a variety of services and activities in a compact area. The developers of Abeno Harukas believe that such cities will be able to stimulate intellectual and economic activity, even as the general population declines.

Today, we live in an age of worldwide interurban competition – cities compete globally. Regarding future urban and economic activities, it is no longer just efficiency that will receive attention, but also its effects. In other words, it is not enough to plan cities for pure expedience – it is necessary to set the right goals. Also, the concept of serendipity – finding something that one was not looking for, but is nonetheless of value – is becoming increasingly important in nonlinear creative activities, and has already had an effect on space planning and other aspects of design.

The following three architectural elements are key to converting the possibilities inherent in the innumerable encounters in supertall compact cities into effects: three-dimensional routes affording various choices, networks of voids, and three-dimensional networks of greenery. The

interactions between these elements generate serendipity, which attracts people, and has a regenerative and multiplying effect on the economic vibrancy and character of the area.

Three-dimensional routes affording various choices

One indicator of the attractiveness of a city is how much fun it is to explore. When big streets, small alleys, and plazas are all interlinked, it provides pedestrians with various choices in selecting routes and encourages exploration. This condition facilitates unexpected encounters with people and things.

In the case of Abeno Harukas, this concept is adopted to the vertical condition.

The basement, first, and second stories of the supertall compact city form a three-story pedestrian network that is integrated with the surrounding area. The developers and architects located the circulation of cars and delivery vehicles at the base of the building to

prevent the disruption of pedestrian traffic. This established natural connections between the building and surrounding streets, which are comparatively narrow in width and have a familiar atmosphere that is conducive to rambling (strolling and observing) (see Figure 4).

A commercial space allowing for the enjoyment of rambling by means of integrating passageways in building interiors with street paths, regionally spreads out across the vicinity of Kintetsu Abenobashi Station. A tunnel underpass beneath the railway that stretches from the neighboring district manages the extensive logistics of the largest department store by floor area in Japan (100,000 square meters). In such a manner, Abeno Harukas creates an intimate relationship between the streets and the building, as it is accessible by pedestrians from multiple directions. Furthermore, on the first floor of the building, foot traffic leads to the adjacent Hoop office and retail building just to the south, connected by a pedestrian bridge and street-level entrances. This 300-meter-long flow of pedestrian traffic intersects with the 300-meter height of Harukas at its

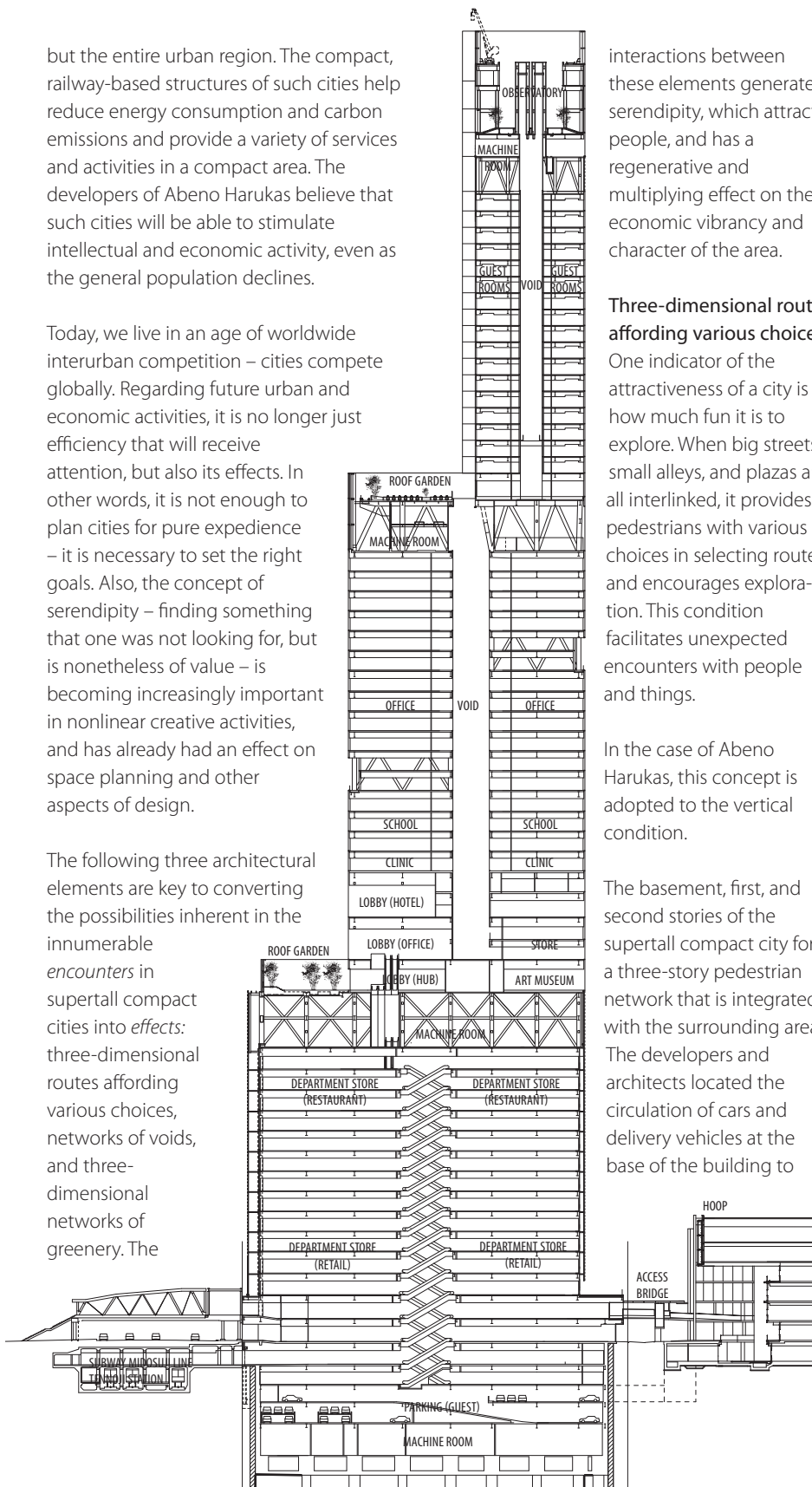


Figure 4. Section diagram.

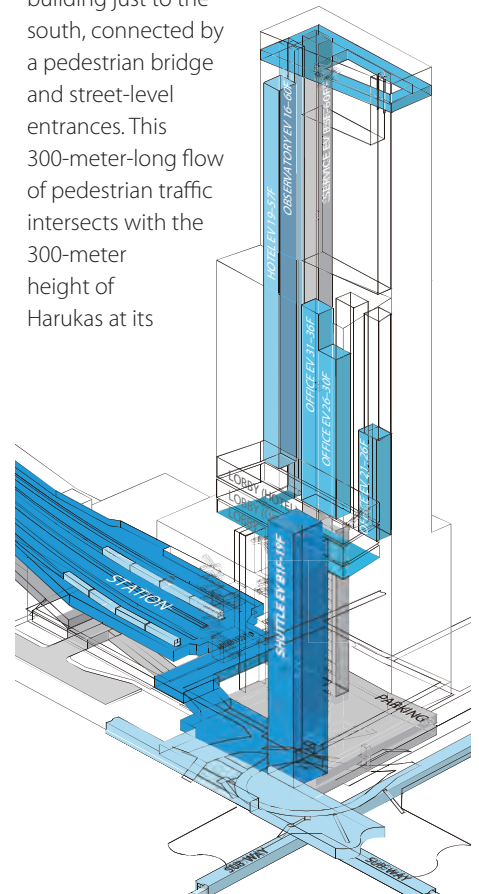


Figure 5. Horizontal and vertical circulation links.

“The outrigger system of Abeno Harukas connects through truss floors to the steel core, using corrugated steel-plate walls and braces, with the peripheral frame made of steel concrete-filled tubes (CFTs), thus providing very flexible, column-free workplaces measuring 22 meters by 72 meters, each with good views.”

origin, creating a three-dimensional rambling zone that is integrated with the street.

The second level comprises a roof garden and a three-story lobby space, linked to the rest of the building by elevators and escalators. Circulation paths to the department store, offices, hotel, museum, and observation deck converge here. These three-dimensional routes afford occupants various choices when moving through the building vertically.

The six minibus-sized shuttle elevators, with a capacity of 60 passengers each, are installed in the corners of the building. The cabs whisk large numbers of people to the three sky lobbies, creating a vertical extension of the horizontal urban transport network (see Figure 5). Trajectories further branch off from the lobby floors, establishing a complex network of multifaceted spaces. These selectable trajectories incorporate the city's dynamism – one that is full of extemporaneity and synergy – into a building that densely consolidates versatility.

Void Networks

Void networks, which use atria (voids) to connect interior spaces in three dimensions (see Figure 4), help people relax and locate themselves, thereby imbuing a sense of well-being in a specific place. At Abeno Harukas, the architects first clustered together and integrated programmatic elements that are usually treated as separate buildings. The result was the formation of multiple clusters of floors, based on structures that were optimized according to their programs. These clusters were then connected in three dimensions using a network of voids. When clustered programs are stacked together in the air, but visually connected by intervening voids, they assume a dynamism that

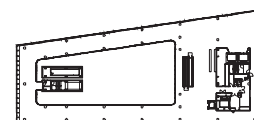
overflows with urban vitality. Urban spaces connect with the programs of the building, highlighting the supertall compact city's potential for facilitating a myriad of unexpected encounters that are impossible in cities that are flat and expansive.

Three-dimensional networks of greenery

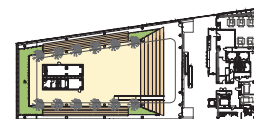
When planning this supertall building in a dense urban area, the architects modeled and planned the effects of wind on the surroundings, the relationship between the new building and existing infrastructure, the circulation of visitors and goods, and emergency evacuation routes pertaining to elevators. By shifting and stacking the building's three main volumes, each with a unique footprint, light and wind can be directed into the central core of the building's office portion. Cascading green roofs help create a pleasant urban landscape in Osaka, a city short on green spaces. They also resonate with the neighboring Tennoji Park. The floors with green rooftops function as open lobbies that provide segues between the building's various programs. When moving vertically through the network of voids between the building's different programmatic zones, one suddenly catches an expansive view of high-ceilinged lobby spaces, rooftop gardens, and the urban spaces beyond, all of which overlap in layers (see Figures 6, 7, and 8). The interplay between architecture and nature, and between architecture and the city, is intended to foster serendipity.

Design: Drawing from the Vernacular

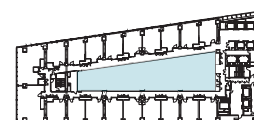
Kyoto's *machiya* (urban vernacular houses) contained layered spaces, as seen in their *toori* (passages leading from the front street to the warehouses, workshops, and other facilities



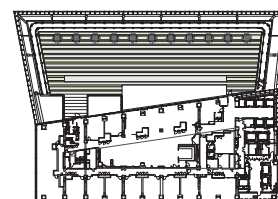
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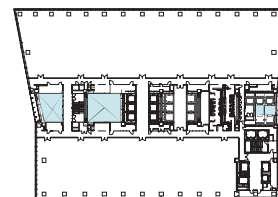
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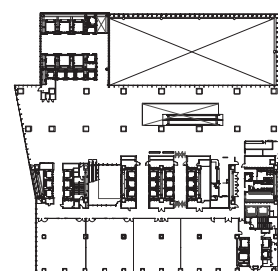
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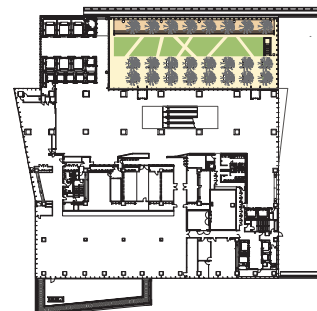
Level 38



Level 29



Level 17



Level 16

Figure 6. Floor plans.



Figure 7. 17th floor lobby overlooking escalator void network and roof garden beyond. © Tomoki Hahakura



Figure 8. 16th floor roof garden overlooking Osaka. © Hisao Suzuki

occupying the rear of the plot) and *tsuboniwa* (small gardens that helped draw light and fresh air into the long, narrow buildings). Such spaces create richness and charm in dense urban residential environments and foster different types of communication, depending upon their degrees of intimacy. Furthermore, the gentle ventilation and evaporative cooling effects of the *toori* and *tsuboniwa* substantially moderated the Kyoto Valley's intense thermal environment.

Abeno Harukas' architects adapted these refined "urban spatial methods," which allowed the transfer of the benefits of low-energy, high-density urban living to the high-rise office portion of the building. The result was productivity-enhancing *engawa* (verandas) that serve as places to meet and think. This is but one approach to practicing

energy conservation in supertall compact cities, but it's worth highlighting because its origin is decidedly "low-tech."

Similarly, structural planning requires not only advanced analytic techniques, but also the wisdom of our ancestors, who lived together with nature. Inspiration was found in a sculpture from Kofuku-ji Temple called *Tentoki* (see Figure 9), which was crafted in the Kamakura period (1185–1333). It portrays a figure whose limbs convey a remarkable sense of dynamism and resemble asymmetrical outriggers (projecting supports). The design team also took hints from *shinbashira*, the stationary pendulum structures suspended at the centers of wooden pagodas. These function as early versions of the tuned mass dampers that mitigate wind and earthquake forces in tall buildings. The architects collaborated with

engineers to address the issues of eco-friendliness and safety during typhoons and earthquakes. These issues were treated as opportunities to enrich the spaces of Abeno Harukas and the activities taking place within it.

Structural Engineering

The first priority in the structural design of the building was to achieve maximum performance and safety. But there was also an opportunity to incorporate the lessons of vernacular architecture and the objective of replicating some of the diverse aspects of city life into a building typology that can be inherently monolithic and isolating. The team thus made the structural scheme an expressive and prominent demonstration of the resolution of these objectives.

Analysis

The 2011 Tohoku Earthquake triggered new measures for reducing disaster risk, including assuming previously unanticipated levels of earthquake and typhoon intensity. The design of Abeno Harukas began in 2006, before the Tohoku Earthquake, but the possibility of an outsized event affecting this important building led engineers to conduct detailed studies on potential magnitude and resultant tolerable damage (fragility).

Engineers simulated the building's movement by using the acceleration data obtained by a seismometer, and conducted a prior study on procedures for checking the fragility of

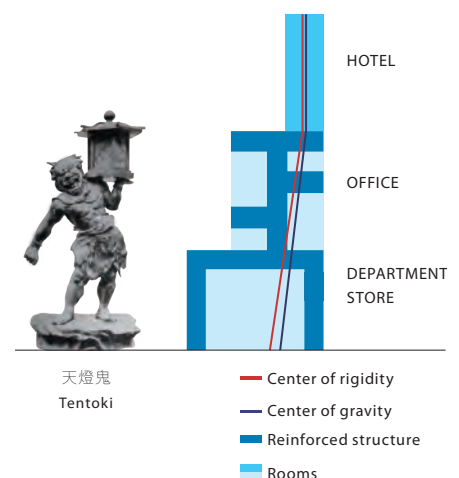


Figure 9. Framing plan concept.

members and for rehabilitation. The seismic grade reference chart (see Figure 10) shows the seismic grades of buildings represented by the oblique bars along the intersections of the earthquake magnitude (horizontal axis) and the level of assumed damage (vertical axis). The seismic grade of Abeno Harukas is one level higher than that of a typical supertall building. The building is rated to withstand a 2,000-year earthquake.

Outrigger strategy

The engineers used outrigger structures to effectively control bending deformations that would otherwise result from the tremendous lateral forces that act on a supertall building during earthquakes and strong winds. In addition to core bracing, truss beams (outriggers) with heights of 8 to 13 meters were deployed in the transfer areas between the building's low-, mid-, and high-rise portions.

The outrigger system of Abeno Harukas connects through truss floors to the steel core, using corrugated steel-plate walls and braces, with the peripheral frame made of steel concrete-filled tubes (CFTs), thus providing very flexible, column-free workplaces measuring 22 meters by 72 meters, each with good views (see Figure 11). The application of light braces to the shorter direction of the core has created an innovative framing system.

The floors with sub-outriggers match the centers of rigidity and gravity of this asymmetric volume, and serve to connect office elevators and open spaces, such as café space. These sub-outriggers make the building look dynamic and stable like a *Tentoki*, (see Figure 9), and give the building a distinctive look from a symmetrical building.

By supplying sub-outriggers at intervals of approximately 30 meters, bending deformations were reduced by approximately 20% in the building's office portion, which has a core height of approximately 100 meters.

Those floors with sub-outriggers are used as sky lobbies, in which people transfer

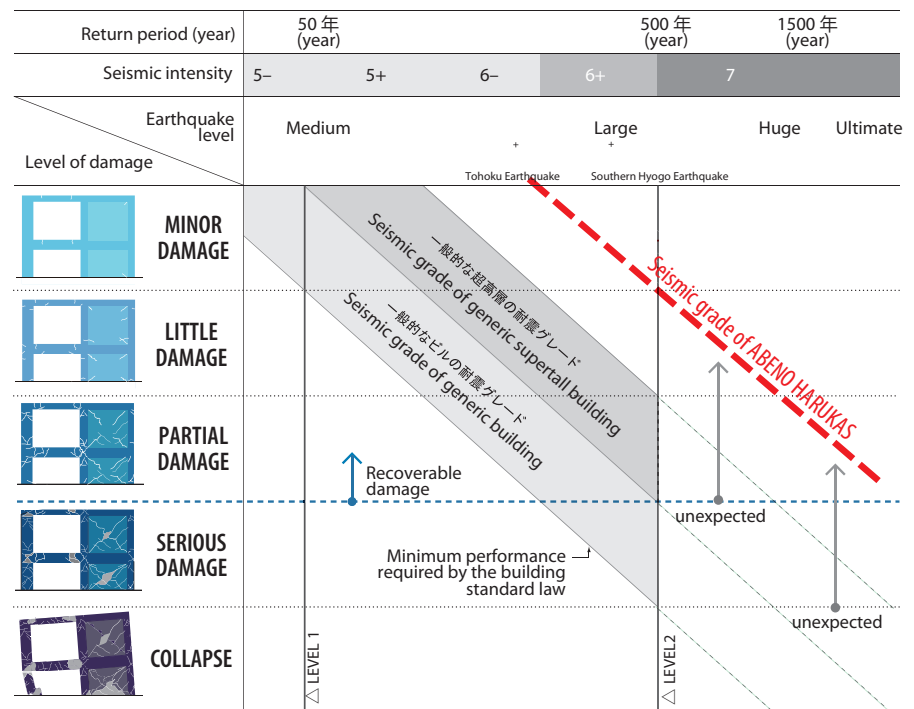


Figure 10. Abeno Harukas seismic grade reference chart.

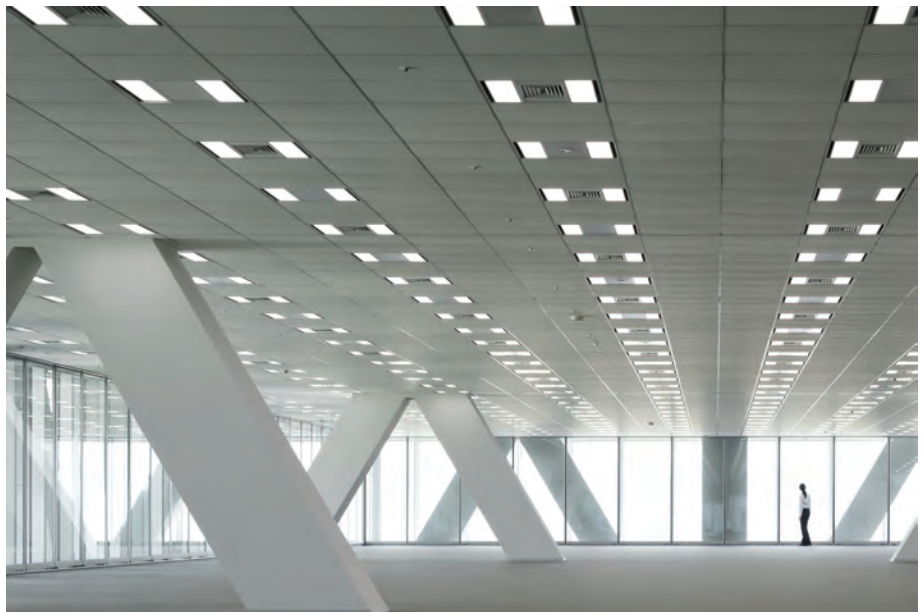


Figure 11. Typical office space. © Nakamichi Atsushi

between elevators servicing the low-, mid-, and high-rise portions of the building. These floors also provide ancillary facilities servicing the offices: conference rooms, cafeterias with terraces, etc. The floors with sub-outriggers are also "transmitting structures" that allow light and wind to pass into the building, and allow activities inside the building to be seen from the outside (see Figures 12 and 13).

Damping and energy absorption

Energy-absorbing devices (vibration control dampers) in addition to the robust structure enhance damping performance and restrain the shaking in earthquakes and strong winds, thus contributing to achievement of a high level of safety and security. The building has three core truss dampers in the high-rise component, and 225 corrugated steel-plate



Figure 12. Transparent sky lobbies are visible up the height of the building. © Hisao Suzuki



Figure 13. Transparent observatory allow activities inside the building to be seen from the outside. © Nakamichi Atsushi

walls (see Figure 14) in the mid-rise component. A total of 307 dampers of two types, oil dampers, and rotational friction dampers are intensively installed in the low-rise component, where the shear deformation is larger and vibration control dampers work well. Achieving a higher damping property of the building effectively absorbs the vibrational energies caused by long-period earthquakes and strong winds, thus not only ensuring the safety of the building, but also affording anti-tipping protection for art objects and office equipment.

A “transparent” core

In supertall architecture, center cores are typically braced to increase rigidity, and are usually used as windowless utility zones that block out natural light. Instead, Abeno Harukas contains light-transmitting cores, and uses them as interfaces between nature and the

city. When one rides a train over a steel railway bridge, the truss structure creates a rhythm of dappled sunlight resembling the light that reaches the ground beneath trees. With this image in mind, the team designed part of the core as an outdoor space (a void) (see Figure 15), allowing the application of glass walls to the stairwells and elevator shafts abutting the space.

This consisted of multiple layers of transparent spaces, each with a distinct character, which convey natural light to the innermost parts of the office floors. The spaces are comfortable and help occupants orient themselves. As a result, they encourage fortuitous encounters.

Environmental Design

The Supertall Compact City can be used as an urban strategy to support the realization of

sustainable societies, by reducing environmental impacts and maximizing the comfort and creativity of its inhabitants. It does this by using active and passive technologies and by facilitating communication.

Active technologies

Active technologies include incorporating leading-edge building equipment and performing energy management that uses the building’s multi-functionality to the greatest advantage.

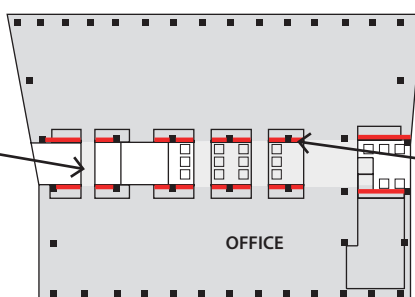
This can be seen in the intersection of environmental systems, which take advantage of the building’s height and multiple, intersecting programs.

Water reuse

In addition to storing rainwater collected from the tower section’s roof and wall surfaces, general service water, such as drainage from



Core brace



OFFICE



Corrugated steel wall

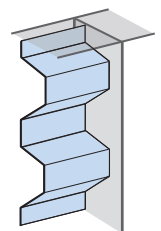


Figure 14. Core braces and corrugated steel-plate walls. Source: International Journal of High-Rise Buildings (IJHRB), March 2014.

the hotel's showers is treated through an activated sludge process and downcycled as cleaning wastewater in the department store's toilets. This saves approximately 20% of water usage in the tower section, equating to a maximum of 450 cubic meters of advanced treated city water (tap water) per day. This reduction in the usage of city water also contributes to lessening burdens on sewage treatment.

Energy recovery

An energy-recovery system combines the height of the building with its graywater use strategy. Relatively clean water, such as the drainage from bath units in the hotel, is stored in an intermediary water tank, then released through pipes to a mechanical room on Level B5. The water activates a 6 kW generator, and produces approximately 10 kWh of electricity per day. After generating electricity, the water is reused for flushing sewage (see Figure 16).

Energy is also recovered from the braking systems of the building's elevators. In Abeno Harukas, 39 elevators (76% of the total) have regenerative devices, including the main shuttle elevators. Through such regenerative devices, an 18% reduction in operative power is achieved.

Lastly, heat is recovered through shared program adjacencies. The department store requires air-conditioning throughout the year, whereas there is a large demand for hot water in the hotel, for use in its bathrooms. Therefore a water-cooled heat-pump chiller was introduced in order to recover exhaust heat generated from the department store's air-conditioning, which was then used to preheat water at 18 °C to 43 °C through exhaust heat for the hotel guest rooms. Through this extremely simple mechanism, Abeno Harukas succeeds in energy reductions that correspond to 40% of its central hot water usage.

Biogasification

New environmental technologies were developed and introduced for Abeno Harukas, including energy generation through the biogasification of wet refuse from the department store and the hotel's

restaurants. The wet refuse is shredded in disposers and then carried via the ductwork to the fermentation tank on Level B5. Methane gas, generated through the methane fermentation of solid content, is used as fuel for cogeneration, thereby allowing a 5% reduction in gas consumption.

Further, through effluent treatment of the liquid content prior to its discharging as sewage, the wet refuse (3 tons per day) is completely decomposed without the necessity of transporting it off-site, resulting in a reduction of CO₂.

Instrumentation

Further, by instrumenting the building's operational phase, details about energy use can be shared with building inhabitants and used to further reduce environmental impact. A-EMS (Abeno Area Energy Management System) is a mechanism that promotes energy conservation activities by providing feedback regarding energy usage performance (see Figure 17). For example, Abeno Harukas not only informs tenants of the total amount of electricity used, but also provides feedback that graphs these values according to areas, uses, and time



Figure 15. Office interior void. © Nakamichi Atsushi

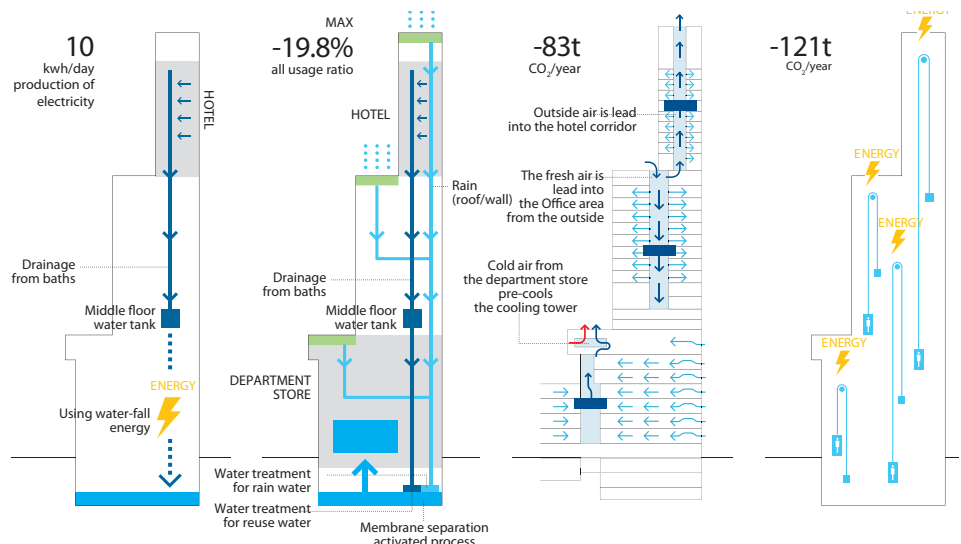


Figure 16. Energy recovery system.

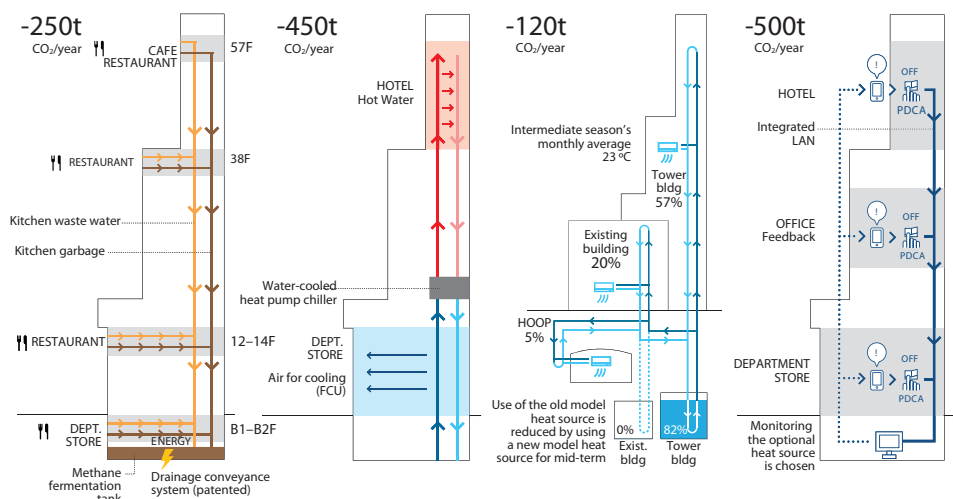


Figure 17. Energy usage performance.

frames. As the energy usage performance and the amount of standby power at nighttime are clearly comprehensible through this system, the users themselves are able to devise and implement effective energy reduction plans. A reduction in approximately 2% of the entire city block's energy is anticipated through the energy management system.

Passive technologies

Passive technologies include creating connections with nature and the city and using voids and roof gardens to create comfortable environments, while using little energy. Passive architecture, rather than placing restrictions, continues to expand psychological adaptability, and in fact succeeds in expanding human comfort zones to accept temperatures that require less energy. Beyond contributing significantly to energy conservation, it provides a variety of benefits that influence the sensitivities of individuals.

The voids inside the building are useful for ventilation and heat exchange. The

department store's void channels waste heat inside ceilings and sends the cooled exhaust air to the upper floor's cooling tower by way of a buoyancy ventilation system. Voids in the office area intake natural light and wind to the central core section and render perimeter hallways as portico-like spaces. At night, cool fresh air is taken into a cool storage system, while hot air is purged.

Through these active and passive approaches, Abeno Harukas' CO₂ emissions were reduced by up to an estimated 38% against a conventionally designed building of similar scale, inclusive of operational improvements and the reduction of standby power use (see Figure 18).

Conclusion

The combination of diversity of uses, concentration of activities around an urban transport center, and the innovative use of both passive and active environmental strategies makes Abeno Harukas an

exemplar project for the Supertall Compact City prototype. The range of program, the balance and variety of gathering spaces, the expressive and functional structural and façade designs, and the interpolation of greenery with advanced technology work together, rendering a tall building that is truly an extension of the city. ■

Unless otherwise noted, all photography credits in this paper are to the authors.

Project Data

Completion Date: 2014

Height: 300 meters

Stories: 60

Total Area: 212,000 square meters (tower), 306,000 square meters (development)

Use: hotel/office/retail

Owner/Developer: Kintetsu Corporation

Architect: Takenaka Corporation

Structural Engineer: Takenaka Corporation

MEP Engineer: Takenaka Corporation

Main Contractor: Takenaka Corporation; Okumura Corporation; Obayashi Corporation; Dai Nippon Construction; The Zenitaka Corporation

Other Consultants: Bonbori Lighting Architect & Associates, Inc. (lighting); Hiromura Design Office (wayfinding); Infix Design Inc. (interiors); Kanko Kikaku Sekkeisha (interiors); Kinso (interiors); Nihon Sekkei (interior); Pelli Clarke Pelli Architects (façade); Studio on Site (landscape); Takenaka Corporation (façade)

“In Abeno Harukas, 39 elevators (76% of the total) have regenerative devices, including the main shuttle elevators. Through such regenerative devices, an 18% reduction in operative power is achieved.”

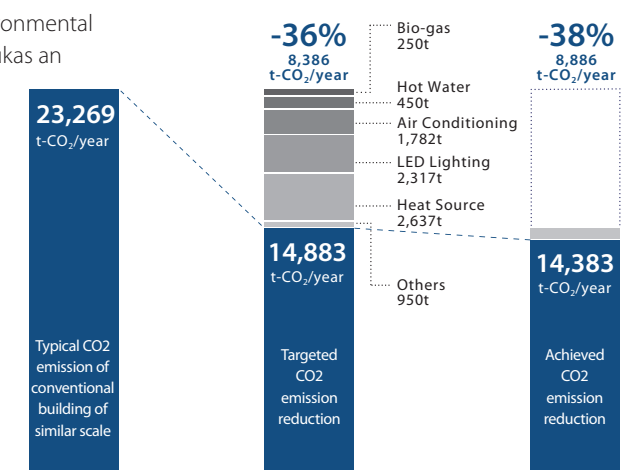


Figure 18. CO₂ emission reduction of Abeno Harukas.