Infra-void-structure integrates design, function and environment at ABENO HARUKAS, the tallest building in Japan

Soichiro KUSHIMA
Architectural Engineer
Takenaka Corporation
Osaka, Japan
kushima.souichirou@takenaka.co.jp

Soichiro Kushima, born 1976, received a master's degree in engineering from Osaka University, Japan in 2001 and a Ph.D. in engineering from the same university in 2006.

Summary

ABENO HARUKAS uses a Infra-void-structure that connects vertical frames in which multi-dimensional pathways and environmental voids in a department store, offices, and a hotel are constructed as structural systems, through the outrigger floors that are horizontal frames mainly used as infrastructure floors. This Infra-void-structure not only forms the main architecture of a supertall compact city but also achieves the top-grade seismic and wind performance. Thus, ABENO HARUKAS is an energizer for the city where it is situated, as a supertall compact city, going beyond a simple building, providing an elegant integration of structure, architectural design and environment.

Keywords: Japan’s tallest building, Infra-void-structure, higher seismic grade, aerodynamic performance, 4 types of vibration control dampers, hybrid pendulum ATMD

1. Introduction

ABENO HARUKAS is Japan’s tallest skyscraper rising 300 meters from the ground. (Fig.1) It is situated in Osaka, the largest city in West Japan. ABENO HARUKAS, a building developed directly above the Abeno-bashi Station, is a 60-story supertall vertical city with 5 basement levels, having a gross floor area (GFA) of approx. 212,000 square meters, into which various functions are integrated.

Fig. 1: West view

2. Spatial configuration of supertall complex

The whole structure of ABENO HARUKAS is composed of the different frames each of which is optimum for its function that were constructed and then stacked up on and interlinked to one another. Trusses are so positioned as to link those functions and provide a network for the whole structure. Trusses are in a infra Void Structure that consists of vertically located voids and horizontally located outriggers which are connected to one another. This structure protects the building from such short-term forces as earthquakes and winds, and simultaneously plays several roles , serving as the lift shafts, staircase space and other flow lines connecting the functions, as the machine rooms that supply energies, and as the environmental voids for ventilation and daylighting.(Fig.2)

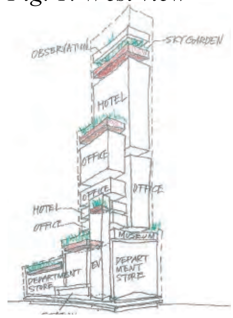

Fig. 2:Diagram of ABENO HARUKAS

3. Outline of structural plan

We have established our design policy including assumption of a seismic grade higher by one grade than that of a general skyscraper, that is, no plastic deformation of members should be allowed against any Level-2 external force as a part of the design criteria in order to ensure safety of the building in case of an extreme earthquake, such as an earthquake along the Nankai Trough or caused by the Uemachi fault zone (UFZ), which is highly likely to occur in the future.

4. Innovative framing plan

ABENO HARUKAS has an outrigger system connecting, through truss floors, the steel core using corrugated steel plate walls and braces to the peripheral frame. (Fig.3). The floors with sub-outriggers of ABENO HARUKAS to match the centres of rigidity and gravity of its asymmetric volume serve for such purposes as a transfer between office lifts and a cafeteria space. These sub-outriggers contribute to suppressing the intermediate deformations equivalent to the antinodes in higher vibration modes of deformations and work effectively to reduce the responses throughout the whole building. The sub-outriggers also make the building look dynamic and yet stable like a Tentoki, a wooden statue at the Kohfukuji Temple, giving a different look from a symmetrical building. (Fig.4)。

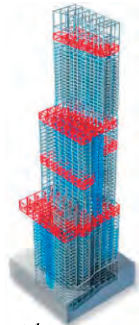

Fig. 3: Infra void structure

5. Excellent aerodynamic performance generated by setbacks

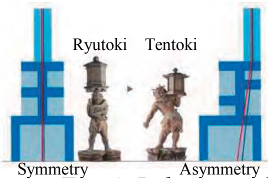

Fig. 4: Balancing of frame structure

The quality of aerodynamic characteristics is extremely critical in wind resistant design of a skyscraper as high as 300 meters. A setback type building like ABENO HARUKAS has a building shape with excellent aerodynamic performance that minimizes the effect of a Karman vortex and efficiently reduces overturning forces acting on the building, compared with a rectangular solid building. (Fig.5)

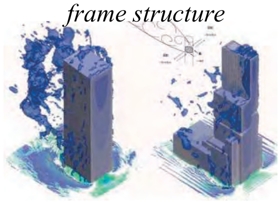

Fig. 5: Karman vortex

6. Effective energy absorbing mechanism

Energy absorbing devices (4 types of vibration control dampers) installed in ABENO HARUKAS in addition to the robust structure enhance damping performance.

Core truss dampers, modelled after the central pillars used in the Japanese old five-story pagodas, are installed in the central void to restrain deformation of the high-rise hotel section. (Fig.6) The core trusses extend down for five high-rise stories from the top outrigger, and then the viscous dampers, installed at the positions where the five-story deformations are concentrated, absorb energies efficiently. This combination of ancient wisdom with modern technology reduces the hotel component's deformation by approx. 10%.

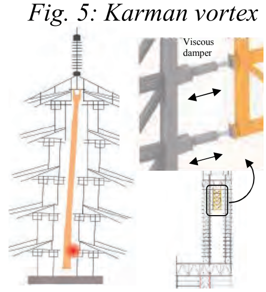

Fig. 6: core truss damper

7. Conclusion

Infra Void Structure enabled us to materialize a vertical city ABENO HARUKAS providing architecturally, environmentally and structurally elegant integration, from an approach unlike those employed for the previous supertall buildings, and consequently build one of Japan's leading hubs for information release to the world.

Kazutaka KOJIMA
Architectural Engineer
Takenaka Corporation
Osaka, Japan
kojima.kazutaka@takenaka.co.jp

Kazutaka Kojima, born 1981, received his architectural engineering degree from Osaka University, Japan.

Kazuhiro SABURI
Architectural Engineer
Takenaka Corporation
Osaka, Japan
saburi.kazuhiro@takenaka.co.jp

Kazuhiro Saburi, born 1968, received his architectural engineering degree from Kobe University, Japan.

Kiyoaki HIRAKAWA
Manager
Takenaka Corporation
Osaka, Japan
hirakawa.kiyoaki@takenaka.co.jp

Kiyoaki Hirakawa, born 1963, received his architectural engineering degree from Kyoto University, Japan.

Rikuta MURAKAMI
Director
Takenaka Corporation
Osaka, Japan
murakami.rikuta@takenaka.co.jp

Rikuta Murakami, born 1958, received his architectural engineering degree from Kyoto University, Japan.