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Structural Design of Torch Tower:
Development of Robust Structural System Utilizing Damped Braced Tube System

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Abstract This paper introduces the structural design of Torch Tower, which will be the tallest building in Japan upon completion. Torch Tower is a large-scale mixed-use complex standing 385 meters tall, with 62 stories above ground and a total floor area of approximately 550,000 square meters. The central Tokyo area, where Torch Tower is located, is an area with an extremely severe seismic environment for super-tall buildings. In designing the structural system for Torch Tower, we conducted extensive studies on structural framework planning and response control systems for super-tall buildings, ultimately developing a structural system well-suited for large-scale development in central Tokyo. This paper introduces the structural design of Torch Tower, including the Damped Braced Tube System, which enables the building to achieve extremely high seismic performance even under severe seismic conditions.

Keywords: Response control system, Damped braced tube system, Super-tall buildings; Mega brace; Oil damper)

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1. Introduction

In recent years, construction of tall buildings exceeding 200 meters height above grade are progressing in Japan where severe earthquakes occur. And, there are several projects of supertall buildings exceeding 300 meters height above grade. In central Tokyo, Azabudai Hills Mori JP Tower having approximately 330 meters height has completed in June 2023 and has come to the tallest tower in Japan [1]. The approximately 385 meters height TOKYO TORCH Torch Tower expected to be the future tallest tower in Japan, has also commenced construction since October 2023 and is scheduled to be completed in 2028 financial year [2].

Designing supertall buildings in earthquake-prone Japan, coping with not only wind loads but also severe seismic is very essential although it is typically not easy to ensure a sufficient buffer under earthquake. In particular, the huge earthquake expected to occur along the Nankai Trough is announced as imminent earthquake exceeding 70 to 80% event probability in 30 years and is predicted to cause M8 to M9 class earthquake when it occurs [3]. The long-period seismic motions induced by such mega earthquakes should be given special attention and should be accepted as one of well considerable earthquakes for tall buildings design. Furthermore, super tall buildings fundamental period, which is typically 6 seconds or longer, is highly close to predominant period of the Kanto Plain. Therefore, super tall building design in Kanto region needs more careful consideration for mega earthquake inducing long-term-period seismic motions. Additionally considering resilience after disaster, building damage should be mitigated as much as possible. Furthermore, authors consider that huge scale building like Torch Tower should minimize damage under severe earthquake to let occupant keep staying and continue their activity.

Based on consideration above, the development of robust response control system that combines high rigidity letting mitigated damage of deformation related component and high damping mitigating building response is very essential for the structural design of a supertall in central Tokyo. Damped Core System, in which dampers stroking with inter-story drift and dissipating seismic energy effectively are assigned from bottom through mid-top of building core, is mainstream in Japanese super high-rise buildings design [4]. However, when the system is applied to a supertall, an excessive slenderness ratio at both or either the entire building shape and/or core frame loses the damping efficiency and building rigidity due to amplified building bending deformation.

Alternatively, there are many supertalls adopting RC core wall + Outrigger structural system in the world. Additionally, there are examples adopting Damped Outrigger structural system [5], which is a further developed system rather than typical RC core wall + Outrigger structural system. But there is very few adopting the former mentioned systems in Japanese supertall buildings since design is

typically governed by earthquake not by wind. When design criteria under earthquake are empowered, this trend becomes clearer. When building lateral design is dominant by earthquake the building weight is preferred to be lighter to reduce earthquake load. Hence heavy RC core wall tends to lose its benefit.

In addition, one of the unique characteristics of central Tokyo's large-scale super high-rise buildings is strong demand of extremely large typical floors plan without intermediate columns. This demand invites very long spanned structural frame which affect deeply to structural seismic design although this huge floor plate can bring benefit for wind-resistant design with high vertical density. Following above background, simple Damped Core System has limit to achieve significantly higher seismic performance in central Tokyo as earthquake-prone region. Following this design background, authors have been studying a response control system to achieve extremely high seismic performance in the design of a supertall with large typical floors planned for central Tokyo.

As a result, authors proposed Damped Braced Tube System [6,7] enabling both building stiffness and damping performance at an extremely high level beyond conventional Damped Core System. This paper presents an overview of the system and its application to structural planning and seismic design of actual project model.

Due to this background, the structural design of Torch Tower involved extensive studies on structural framework planning and response control systems for super-tall buildings, resulting in the development of a structural system well-suited for large-scale development projects in Japan—a country prone to earthquakes—and particularly in the central Tokyo area.

As of the end of February 2026, we have completed the podium steel erection (up to the 9th floor above ground) and have moved on to the steel erection of the typical floors above podium. This paper provides an overview of the structural plan adopted for the Torch Tower, which is currently under construction.

2. Overview of the Project

2.1. Tokyo Torch

"TOKYO TORCH", a redevelopment project in front of Tokyo Station, is a large-scale development covering a site area of over 30,000 m². It consists of four buildings, including two skyscrapers, where one is 212-meter-tall Tokiwabashi Tower completed in 2021 and another is this paper introducing Torch Tower scheduled to complete in 2028 financial year. In addition to four buildings, district includes large plaza "TOKYO TORCH Park" (area approx. 7,000 m^2) locating between these two skyscrapers.

2.2. Torch Tower

Torch Tower is a mixed-use 385 meters tall skyscraper with 62 above-ground floors and has approximately 550,000 m^2 floor area. it will be Japanese tallest building when it is completed. The typical floors are designed for tenant offices, while the upper floors are composed of hotel and residential units. The lower section (Figure 2) is characterized by cantilevering outdoor terraces, which impresses commercial occupancy in parallel with large commercial hall where approximately 2,000 seats are assigned. There is another attractive open area at 350 meters above grade where is surrounded by glazing but opens to the sky and let place to act as observation looking toward both central Tokyo and far Mt. Fuji. Additionally, Sky Hill located 300 meters above grade works as another attraction of tower.



Figure 1. Rendering of Torch Tower.

Torch Tower is currently under construction. The erection of the diagonal columns that characterizes the exterior of the lower sections was completed at the end of February 2026, and the magnificent steel framework has now appeared right in front of the Nihonbashi Exit of Tokyo Station (Figure 1). Construction is currently proceeding at full speed toward the scheduled completion in 2028 financial year.

2.3. Building Form, Seismic Environment, and Structural Plan

Torch Tower adopts a very common plan shape of large-



Figure 2. Rendering of Tower Podium.



Figure 3. Rendering of Sky Hill.

Table 1. Building Outline

Project Name	TOKYO TORCH Torch Tower
Address	1-Chome Otemachi, Chiyoda-ku, Tokyo, etc.
Total Floor Area	Approx. 553,000 m^2
Maximum Height	Approx. 385 meters
Number of stories	5 basements / 62 stories

scale skyscrapers in central Tokyo. Most skyscrapers in central Tokyo have huge column-free tenant space spanning more than 20 meters from building spandrel toward interior bay.

The building is 100 meters square in plan. Hence, the building reaches nearly 400 meters tall, however its slenderness ratio is limited less than approximately 4 and slightly apart from the global trend in super-tall buildings, which typically have more than slenderness ratio of 6.

Small slenderness ratio have the impact of wind loads mitigated and sets seismic load affect greater. Furthermore, because the design target under earthquake is set exceptionally high in order to withstand Japanese severe seismic conditions, the importance of seismic design is further increased. In particular, the long-period ground motion expected in central Tokyo has a significant impact on super-tall buildings.

Whilst, wider building elevation achieving up to 100 meters contributes to the effective application of the response control system utilizing building outer shell discussed later.

3. Structural Design Overview

3.1. Overview of the Response Control System

Figure 4 shows concept of Damped Braced Tube System. This damping system is based on a braced tube structure composed of elastic mega-braces arranged across the entire building facade. While the braced tube structure is a framework system capable of achieving extremely high horizontal stiffness, it is desirable to add significant damping in order to proceed with rational seismic design under severe seismic environment.

Therefore, we conducted extensive studies with the aim of developing an effective response control system by replacing a portion of the elastic bracing that wraps around the outer shell with vibration dampers. Based on these studies, we devised Damped Braced Tube System in which the portions of the outer shell's elastic bracing replaced by dampers are arranged as a series of vertical slits and adopted this system for the Torch Tower.

The portions replaced by dampers in the form of vertical slits, hereinafter referred to as damped slits, provides vertical differential displacement between two braced frame under lateral force. Utilizing this differential displacement of Damped Slits, the system functions as Damped Braced Tube achieving very high damping.

4. Structural Planning

The overall structural plan was determined by consideration of mixed-use building component whereas retail and BOH are assigned at the lower level, tenant office are assigned at middle of tower and residential and hotel are assigned at the upper floors.

The most distinctive feature of this building's structural design is the outer shell structure, which forms a specialized response control system. On the lower floors, the structure consists of a diagrid System (DGS), with massive columns arranged diagonally, supporting both vertical and horizontal loads.

Meanwhile, on the typical floor, a moment frame structure composed of vertical columns and beams is integrated into the outer shell to support permanent loads. By placing vertical columns within the outer shell, a double-tube moment frame structure based on mixture of 7.2, 10.8 and 21.6 m bays has been created, forming a floor system that rationally supports the standard-floor slab having maximum 20 meters column distance. To resist horizontal loads, mega-braces spanning multiple stories have been added to the outer shell, forming an outer brace system (OBS). The column layout of the outer frame is arranged

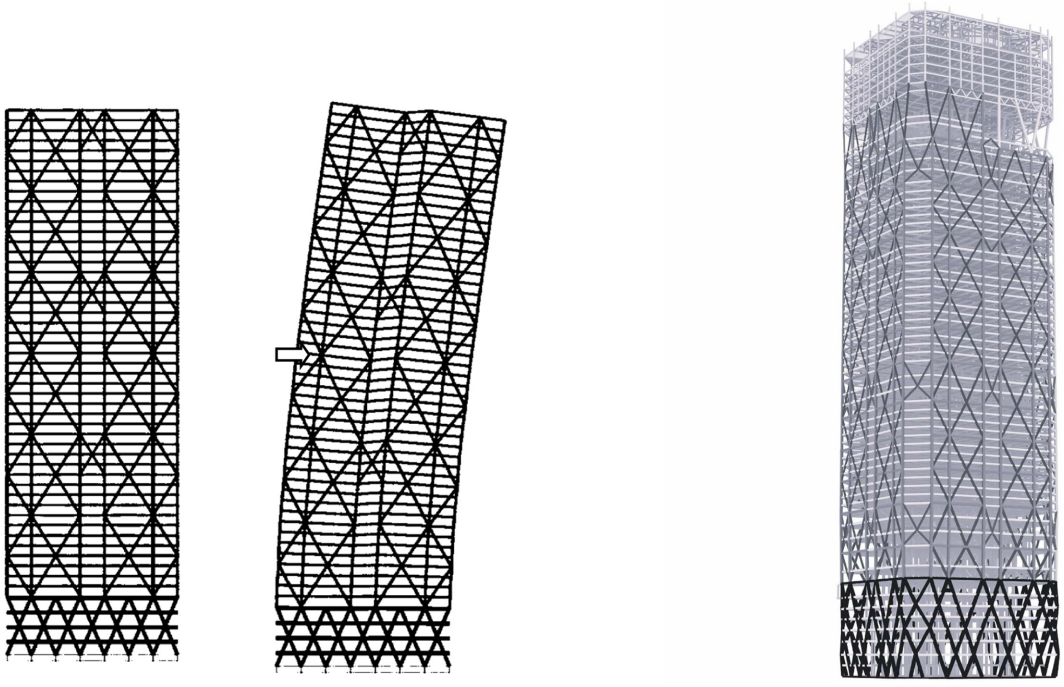


Figure 4. Conceptual Diagram of the Damped Braced Tube System.

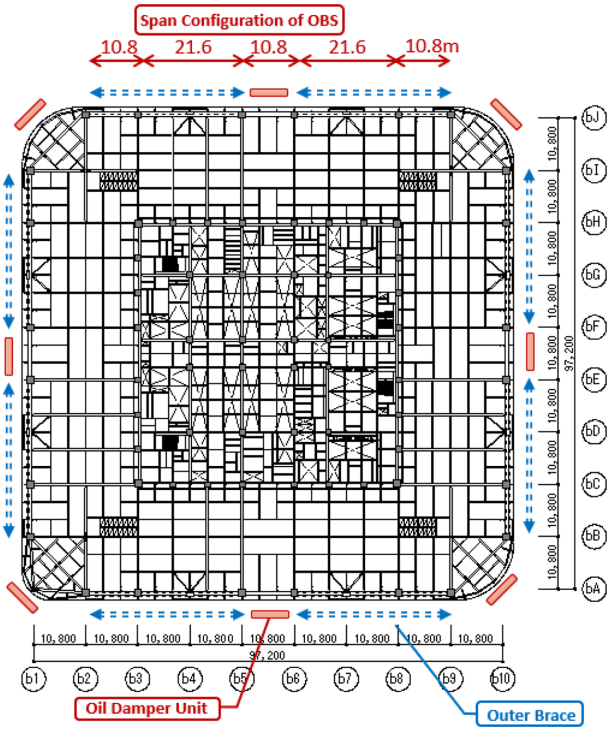


Figure 5. Typical Floor Plan.

with combination of 21.6 m and 10.8 m span to reduce the heavy steel section in addition to making sure views from interior toward outside. (Fig. 5)

Furthermore, the structural framework within the core of the lower and standard floors does not apply bracing or damping devices, resulting in a core structure that offers a high design flexibility.

The column-span configuration along the perimeter of the standard floors, designed to maximize views; the highly flexible core structure; and the open spaces of SkyHill are made possible by the highly effective performance of Damped Braced Tube System.

5. Primary Structural Components

Figure 6 shows the overall configuration of Damped Braced Tube System. Figure 7 show the configuration and specifications of the oil damper unit, which is a key component of the system and Table 2 shows the cross-sections of the main structural members.

The OBS is designed with elastic mega-braces approximately 21 meters long that span three to four stories. Except at the floors where the braces cross, they are offset from the main beams to avoid direct connection, however it is partially linked to beam to provide buckling resisting stiffness in the out-of-plane direction.

The DGS on the lower floors consists of diagonal columns arranged in a diamond pattern. These diagonal columns span two to three floors with large floor-to-floor heights where some of them reach approximately 12 meters. The main columns, including the diagonal columns of the DGS, utilize a box-section CFT structure.

The use of steel grade is limited up to 590 N/mm^2 considering weldability. For CFT infill concrete, ultra-high strength concrete up to Fc150 is used, thereby enhancing the rationality of the DGS members where compressive forces are the dominant design factor.

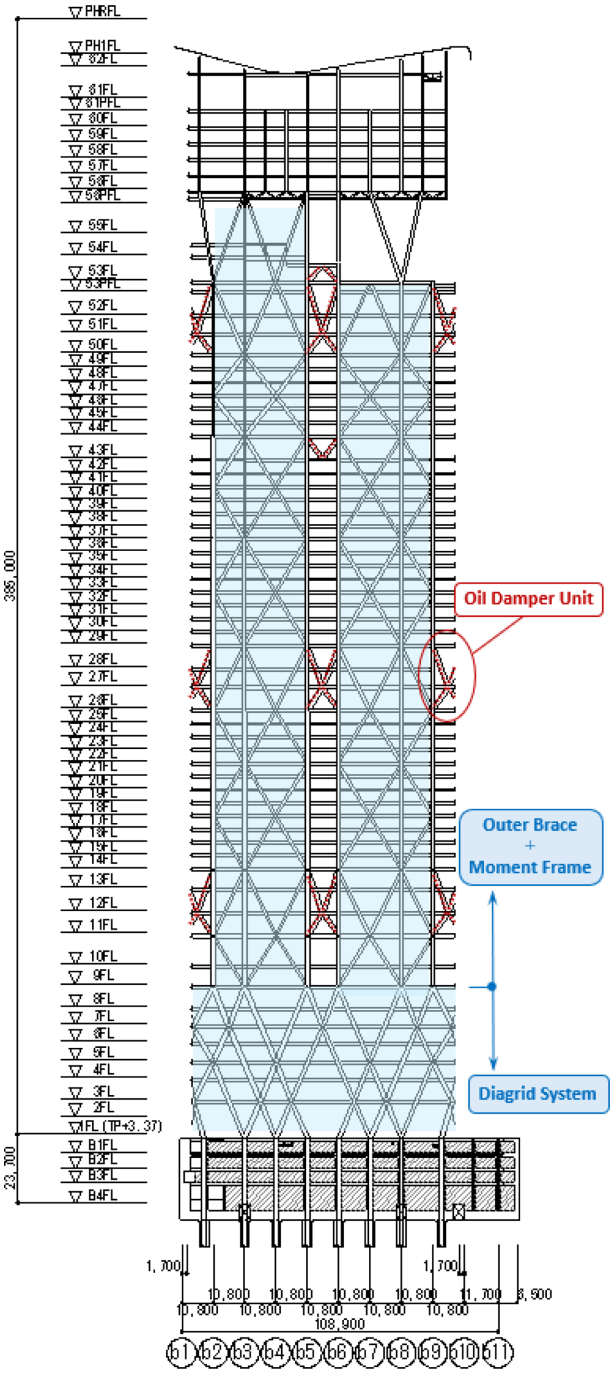


Figure 6. Overall Configuration of the Damped Braced Tube System.

On the other hand, the mega-braces that make up the OBS are designed with flat box-shaped steel sections using steel grade up to 590 N/mm^2. For OBS mega-braces located on the same structural plane with the vertical columns, the erection plan is scheduled to delay on-site welding joints as late as possible to avoid unexpected axial load applied under gravity load case.

The energy dissipation system applied onto Damped Slits consists of multiple oil dampers arranged in parallel to form an oil damper unit capable of approximately 16,000 kN capacity per diagonal unit.

Two different configurations of damper units are used. Configuration of eight 2,000-kN-class oil dampers with 1,600kN relief damping force is used in parts spanning two levels, while a configuration of four 4,000-kN-class oil dampers with 3,200 kN relief damping force is used in parts spanning in single story.

Table 2. Cross Section of Major Component

Component	Cross-section
DG Column	B■-1400 × 1600
DG Girder	BH-1200 × 1400 ~ BH-1000 × 600
Column	B■-1400 × 1600 ~ B■-800 × 800

4. Overview of Seismic Design

4.1. Seismic Design Criteria

It is widely acknowledged that the probability of a major earthquake occurring along the Nankai Trough and the scale of potential damage are extremely urgent concerns. It is assumed that buildings constructed in the future are highly likely to experience such an event during their operating period. Furthermore, in the Tokyo area, due to the geological characteristics of the Kanto Plain, there are concerns about the occurrence of long-period seismic motions with extremely high impact levels in the 6-9-second range, which is ranked at major frequency of super-tall buildings.

In Japan, the first natural period of many existing tall buildings is generally 5 seconds or less, which is outside the dominant period range of the Kanto Plain; therefore, only super-tall buildings are likely to experience extremely large seismic responses. In other words, we cannot rule out the possibility that only super-tall buildings will face significant damage.

Furthermore, there is a possibility that the intensity of long-period ground motion reaching the Kanto region in the event of a massive earthquake along the Nankai Trough could exceed current predictions. Furthermore, public attitudes toward earthquake damage in Japan have changed significantly in recent years. There is a strong consensus that simply avoiding collapse during a major earthquake is no longer sufficient. Taking these factors into account, we aimed to achieve a higher level of damage control performance with further limiting the inter-story drift during an earthquake rather than that of conventional upgraded seismic design criteria.

6.2. Seismic Design Objectives and Assumed Earthquake Motions

For Level 2 seismic motion defined in Japanese building codes as extremely rare seismic motion with an Sv value of approximately 80 kine, the seismic design objective was set as no damage which significantly exceeds the

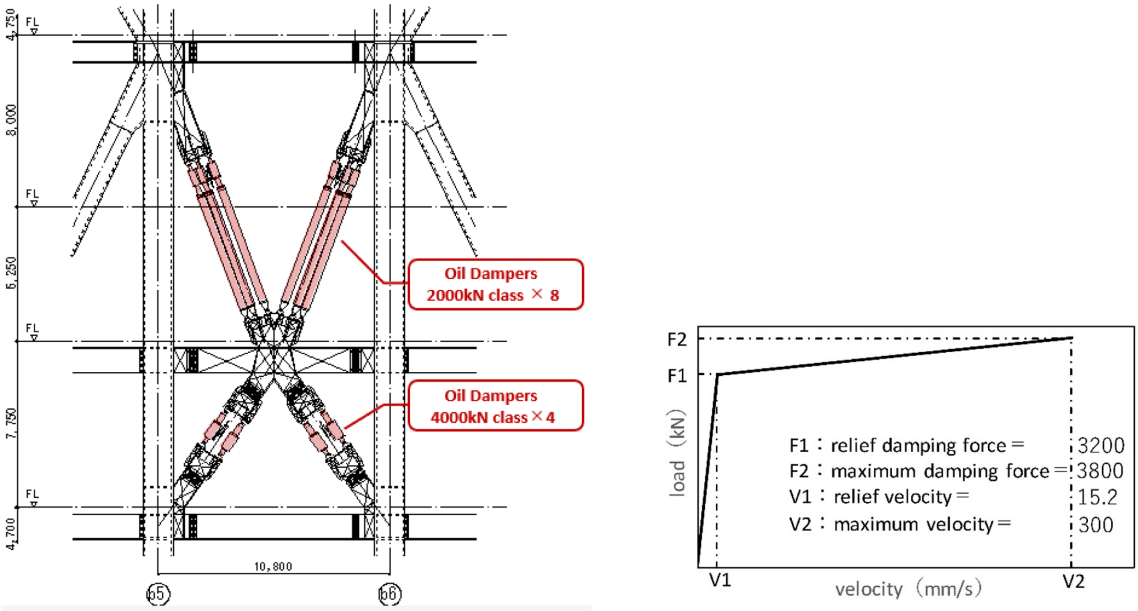


Figure 7. Configuration and Specifications of the Oil Damper Unit.

Table 3. Design Criteria for Design Earthquake

standard earthquake motion for design		
level 1 Rare Earthquakes	level 2 Extremely Rare Earthquakes	level 3 level 2 × 1.5
inter-story deformation angle: 1/400[*1]or below maintain elasticity	inter-story deformation angle: 1/250[*1]or below maintain elasticity	inter-story deformation angle: 1/150[*1]or below member plasticity rate: 4.0 or below (maintain the elasticity of the outer braces)

Table 4. Design Criteria for Huge Earthquake along Nankai Trough

huge earthquake along the Nankai Trough?KA1?			
Level 1 (Rare Earthquakes)	Equivalent level 2 (KA1)	Level 3 (level 2 × 1.5)	Level 4 (KA1 × 2.0)
-	inter-story deformation angle: 1/300[*1]or below maintain elasticity	-	inter-story deformation angle: 1/150[*1]or below member plasticity rate: 4.0 or below (maintain the elasticity of the outer braces)

NOTE: *1: Shear Deformation Component

legal minimum requirement that of avoiding collapse and set as maximum 1/250 inter-story drift aiming to avoid damage occurring on both interior and exterior non-structural component. Furthermore, the design also accounted for seismic input levels up to 1.5 times that of Level 2.

Regarding the mega thrust earthquake along the Nankai Trough, we have established even higher design targets, taking into account the extremely high probability of its occurrence and the possibility that prolonged long-period ground motion could cause severe damage specifically to super-tall buildings. Specifically, for KA1 defined by Ministry of Land, Infrastructure, Transport and Tourism in its "Countermeasures Against Long-Period Seismic Motion Caused by a Mega-Earthquake Along the Nankai Trough" [8], the limit value for the inter-layer deformation angle is set more strictly to approximately 1/300 or less and also 200% amplified KA1 (Sv = 160 kine) is involved with the seismic design protocol (Table 3, 4).

It is also note that the inter-story deformation angle used in this paper is defined as shear deformation component meaning overall building displacement is divided into flexure and shear displacement and meaning design criteria is set focusing on shear deformation, which has a strong correlation with building damage.

7. Conclusion

To rationally achieve extremely high seismic performance in the design of super-tall buildings for large-scale development projects in central Tokyo, we proposed the

Damped Braced Tube System, response control system that provides both high stiffness and high damping, and applied it to the design of Torch Tower, which will be the tallest building in Japan of its completion.

Installing oil damper units only on specific floors of the outer shell, we have created an effective vibration control system that combines high rigidity with effective damping. This design meets the extremely high seismic design objectives ensuring overall building including both interior and exterior components undamaged during up to Level 2 earthquake.

Furthermore, to ensure adequate protection against seismic motions exceeding the standard levels, the structure was designed to prevent significant damage even under extreme seismic events at maximum considerable earthquake levels such as 1.5 times of Level 2 earthquake or 200% amplified KA1 level.

While this paper focuses primarily on seismic design, careful analysis has also been conducted for wind loads as well.

Through the application of a response control system that achieves both high stiffness and high damping, a sufficient safety margin has been secured even for wind load levels exceeding 1.5 times the design wind load. Furthermore, regarding habitability during strong winds, it should be noted that the building exhibits extremely high habitability performance, achieving evaluation level H-I [9] for strong winds with a return period of 1 to 5 years without additional countermeasures such as mass dampers.

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