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High-rise Building with Core Walls and Seismic Isolation Systems: TODA BUILDING

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Abstract TODA BUILDING is a skyscraper in Tokyo that is 165 meters tall. To achieve seismic isolation structure for a 165 m tall high-rise building, a novel structural system is adopted, combining RC core walls with outrigger frames. As a result, we were able to secure a high level of rigidity that is difficult to achieve with steel-frame seismic isolation structures. Furthermore, two types of oil dampers were developed and applied to the seismic isolation layer to provide optimal response reduction effects in response to a wide range of external disturbance input levels. TODA BUILDING achieves the highest seismic grade in Japan for a high-rise isolated structure, By limiting floor response acceleration to 200 cm/s² or less and the inter-story drift angle to 1/300 or less during major earthquakes. This ensures not only structural integrity but also prevents the toppling of furniture and minimizes damage to equipment and interior materials.

Keywords: High-rise building, Seismic isolation structure, RC core wall, Oil damper

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1. Introduction

TODA BUILDING is a seismic isolation structure with a height of 165 m, representing the largest scale of such construction in Japan. This development utilized the Special District for Urban Renaissance system and, with "strengthening regional disaster prevention and response capabilities" as one of its themes, conducted structural planning with the objective of achieving the highest class of seismic resistant performance.

The superstructure is designed with a core wall acting as a central spine to secure the requisite stiffness for the high-rise seismic isolation structures while connecting to outrigger frames to resist the overturning moments. Two types of oil dampers were developed and implemented in the seismic isolation layer to achieve optimal response reduction effects corresponding to a wide range of input levels of external disturbances. This report presents an overview of the structural design of TODA BUILDING.

2. Building Outline

Location: Chuuou-ku, Tokyo
Building Type: Office, Museum, Meeting Hall, Exhibition Hall, retails
Developer: Toda Corporation
Designer: Toda Corporation
Constructor: Toda Corporation
Building Area: 94,912 m^2
Building Height: 165 m



Fig. 1. Overall Exterior View.

3. Architectural Planning Overview

3.1. Development Overview

TODA BUILDING is a large-scale development facing Chuuou-dori on the Yaesu side of Tokyo Station. Together with the adjacent site, it utilizes the Urban Renaissance Special District System as a unified project comprising two developments within a single special zone. Under the theme of "Creating an Art and Culture Hub Open to the City," the project offers a urban contribution through the development and operation of art and culture spaces, alongside proactive area management. With 120-meter frontage along Chuuou-dori, the project establishes an integrated urban block with a unique and sophisticated cultural atmosphere.

3.2. Architectural Planning

This project is a 165-meter-tall high-rise, mixed-use building featuring 28 floors above ground, 3 basement floors, and single-story penthouse. The lower volume (1st



Fig. 2. Large Canopy and Plaza.



Fig. 3. Interior View of Lower Level with Multi-story Atriums.

to 7th floors) accommodates a hall, a museum, retail spaces, and the office entrance lobby. Leveraging its location in a district traditionally dense with museums, galleries, and antique dealers, the lower levels provide "museum and exhibition facilities" for accessible and cultural experiences, "creative and exchange facilities" to support emerging artists, and "information dissemination facilities" to showcase art to global audience. At the ground level, an expansive plaza (Art Square) has been established to host art, cultural events, and community activities.

A foyer space with a depth of approximately 35 meters on the 4th floor forms a large canopy over the plaza facing Chuuou-dori, creating an inviting entrance for visitors (Figs. 2 and 3). Furthermore, this sheltered under-eave space is situated above the seismic isolation layer, providing a safe and secure temporary evacuation site for the community. The building is also equipped with temporary shelters for stranded people's disaster storage.

4. Structural Planning Overview

4.1. Structural Planning

Fig. 6 presents an overview of the structural design. To achieve seismic isolation for a 165 m tall super high-rise building, a novel structural system was adopted, combining RC core walls with outrigger frames. By three-dimensionally arranging the core walls as a central spine, seismic energy in the superstructure is distributed across all stories, suppressing localized deformation and damage. Furthermore, as the core walls bear most of the seismic forces, this system enables slender perimeter columns and creates attractive, large-span spaces on lower floors. This configuration achieves high stiffness—difficult to realize in typical steel-framed office buildings—and mitigates swaying and deformation, which are common challenges for high-rise isolated buildings. By limiting floor response acceleration to 200 cm/s² or less and drift angle to 1/300 or less during major earthquakes, the design aims for the highest seismic grade in Japan. This ensures not only structural integrity but also prevents the toppling of furniture and minimizes damage to equipment and interior materials.

The structural system comprises reinforced concrete (RC), steel (S) with concrete-filled steel tube (CFT) columns, and partially steel-framed reinforced concrete (SRC). This constitutes a mid-story seismic isolation structure with the isolation layer positioned beneath the 1st floor. The building employs a hybrid structure combining a "double H-shaped core wall"—formed by two H-shaped RC walls matching the shape of elevator shafts—with a perimeter steel frame. To enhance flexural strength and constructability, high-strength precast (PCa) columns

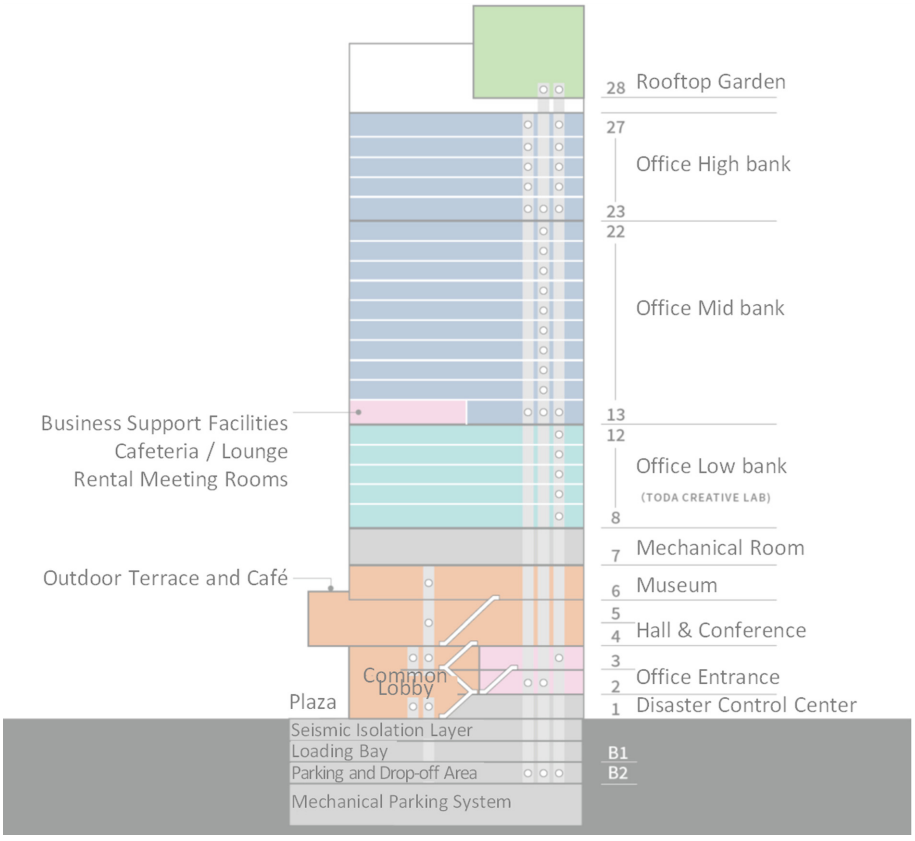


Fig. 4. Sectional Configuration.

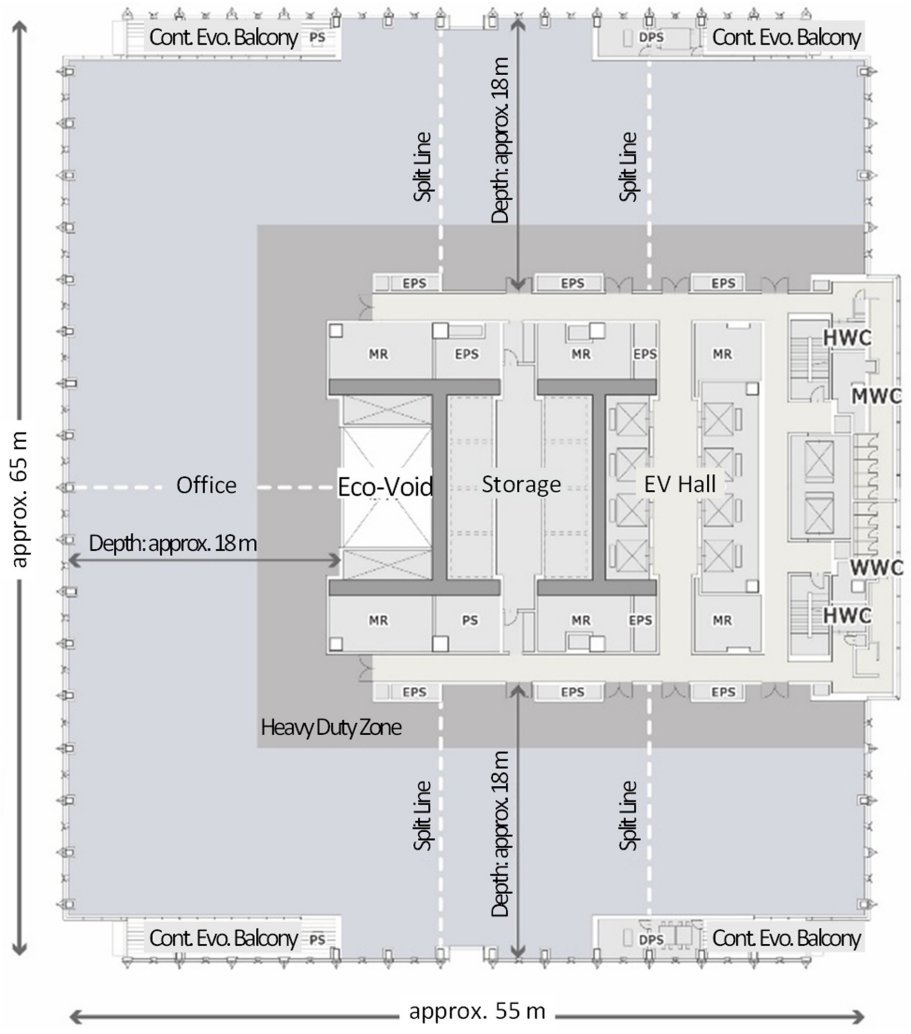


Fig. 5. Typical Floor Plan.

were integrated at the boundaries and intersections of the H-shaped walls, which bear high axial loads (Fig. 7). Fig. 8 shows the typical floor framing plan. The core wall is connected to the perimeter frame via an outrigger system consisting of RC-S composite beams and high-strength CFT columns. This configuration enhances the restoring moment of the core wall and ensures smooth stress transfer between the different materials. Furthermore, shear-yielding damping beams connect the two H-shaped walls via high-strength PCa columns to absorb seismic energy and control damage in short-span members.

4.2. Overview of seismic isolation Materials

Two types of oil dampers—semi-active oil dampers and oil dampers with a self-restoring trigger mechanism—were developed and implemented to achieve seamless response reduction across a wide range of disturbances. This system effectively enhances performance according to input levels: it reduces response acceleration during small-to-moderate earthquakes without increasing Level 2 response values, decreases the overturning moment of the core wall during Level 2 events, and suppresses seismic isolation layer displacement during earthquakes exceeding Level 2.

The semi-active oil damper (Fig. 11) is a variable-damping device with two primary damping coefficients: high-damping (CH) and low-damping (CL). The semi-active control (MINMAX control) is a simplified method referencing only the response displacement of the seismic isolation layer. By switching damping levels via electrical signals based on the direction of displacement, the system reduces acceleration and ensures effective energy absorption. This simple system monitors response displacements at four points on the perimeter; control is divided into four sectors relative to the center of gravity to accommodate torsional response. Under normal and wind loads, the CH state is fixed to maintain high equivalent damping, ensuring that the response shear force during severe wind does not exceed the yield shear force of the isolation layer.

Fig. 13 shows the damping force-deformation relationship of the semi-active oil damper. A tendency for the damping force to decrease is observed in the first and third

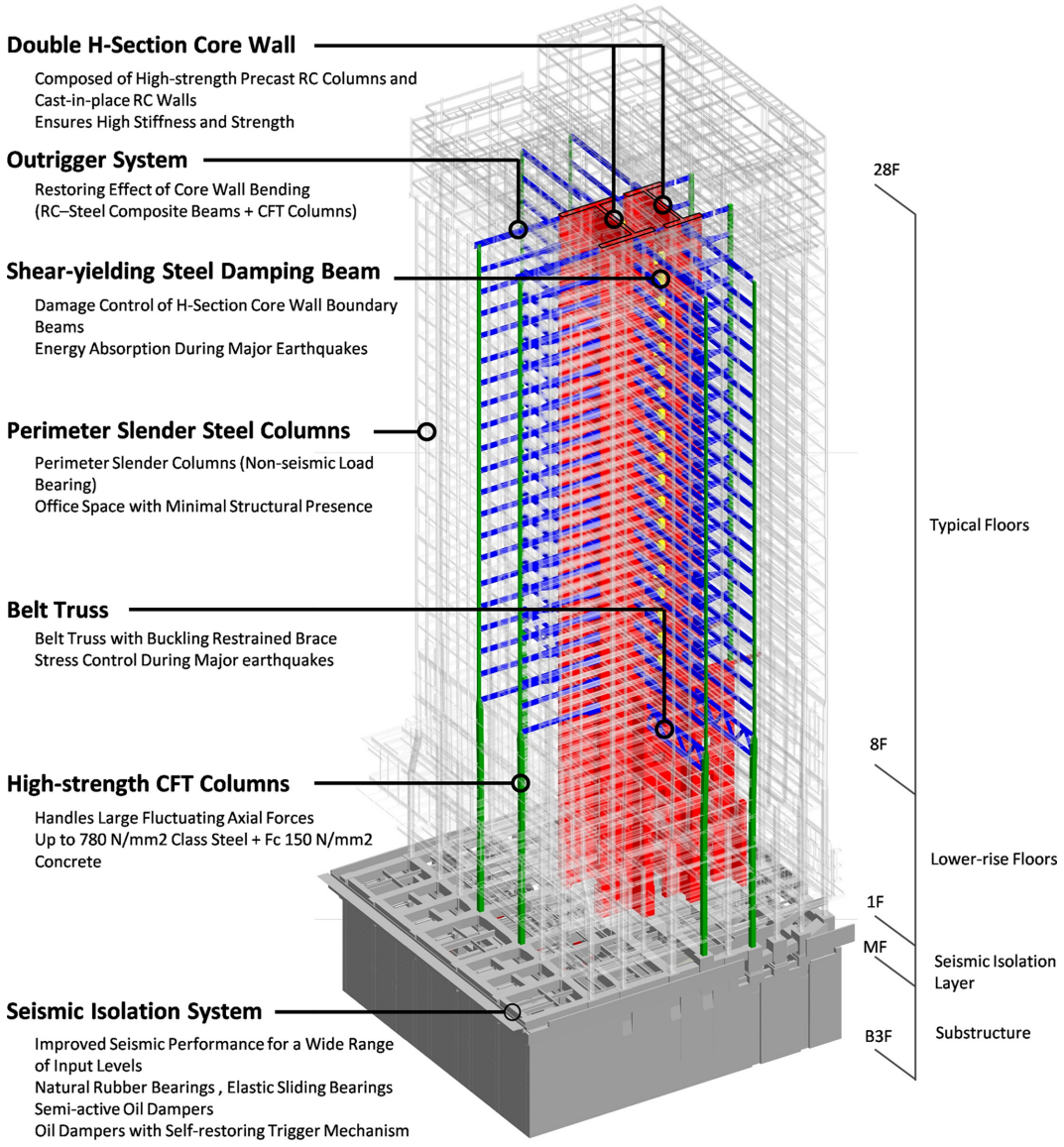


Fig. 6. Overview of Structural Design.

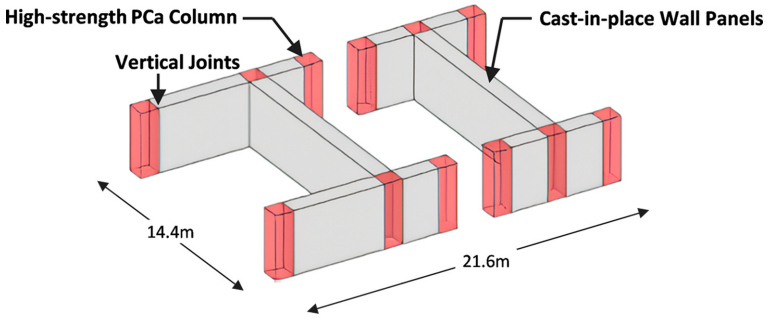


Fig. 7. Core wall model (single-story extract).

quadrants, becoming more pronounced at lower input levels. During L2 earthquakes, the load exceeds the relief level, resulting in a hysteresis loop similar to that of a passive damper.

The oil damper with a self-restoring trigger mechanism (Fig. 8) incorporates a deliberate “dead zone” where the damper remains inactive. This prevents increased response acceleration during small-to-moderate earthquakes while

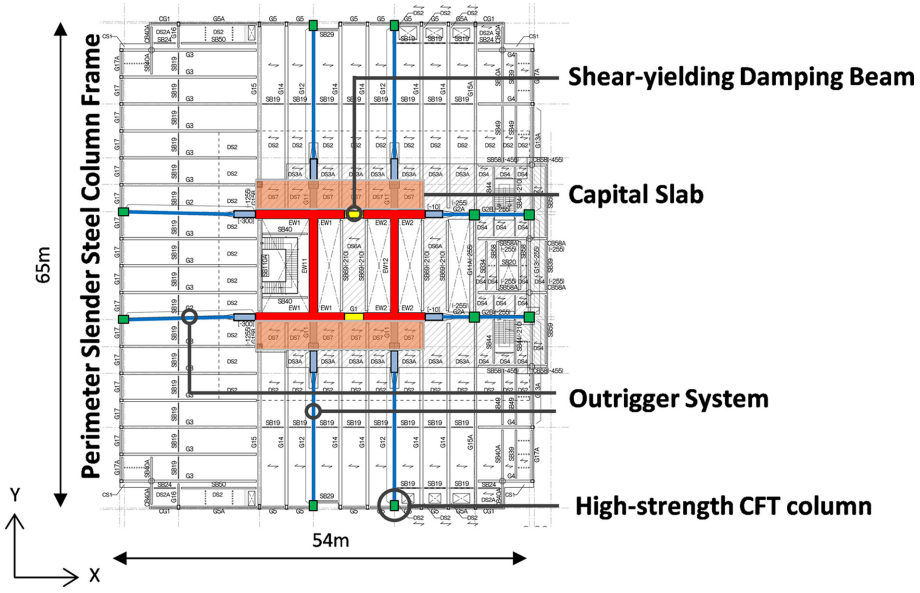


Fig. 8. Core wall model (single-story extract).

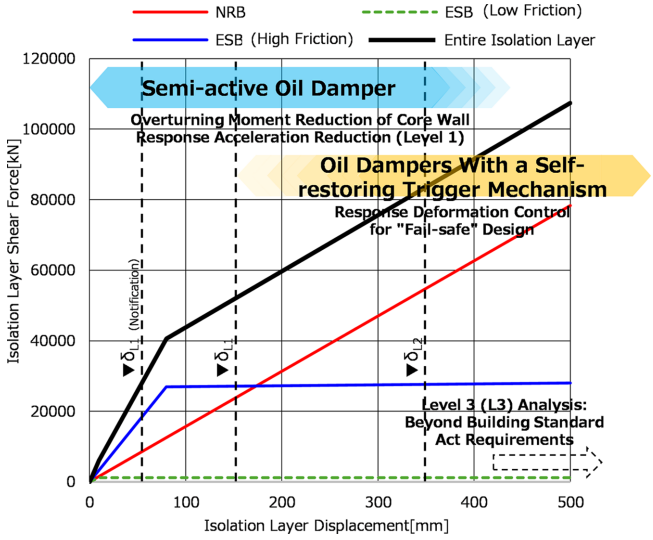


Fig. 9. Concept of Seismic Isolation Method.

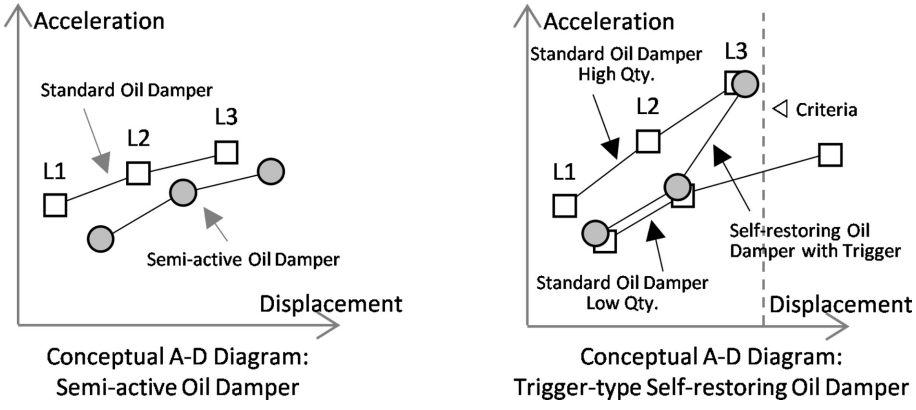


Fig. 10. Conceptual Diagram of Acceleration vs. Displacement Relationship in the Isolation Layer. (Left: Semi-active Oil Damper) (Right: Self-restoring Oil Damper with Trigger)

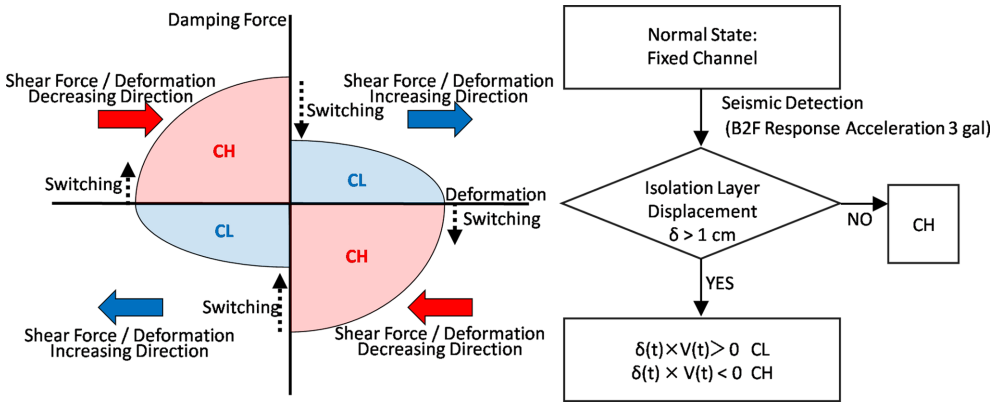


Fig. 11. Semi-Active Control Overview.

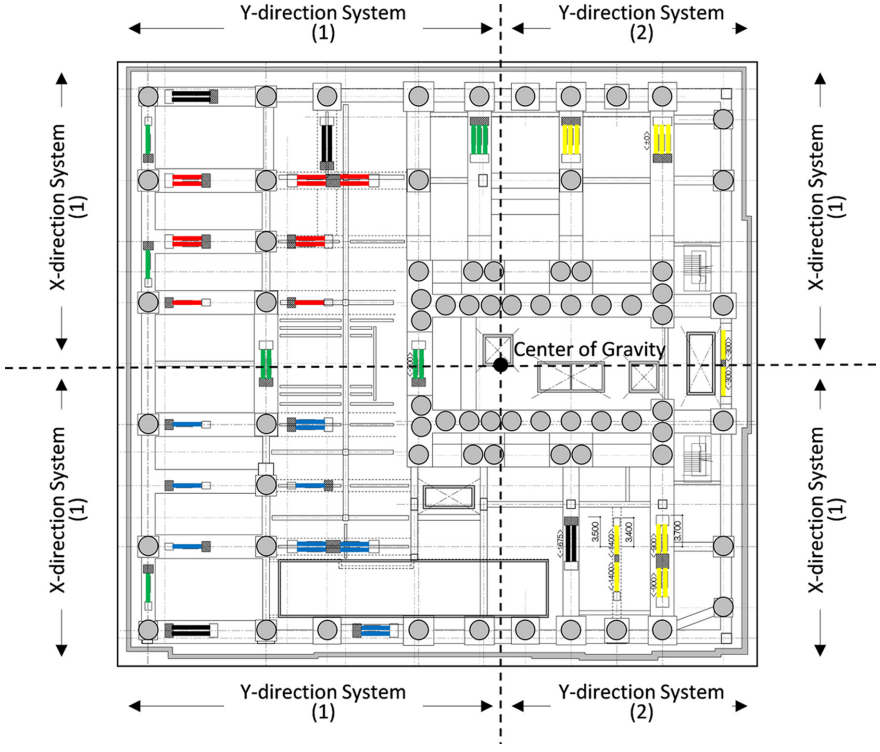


Fig. 12. Semi-Active Control System.

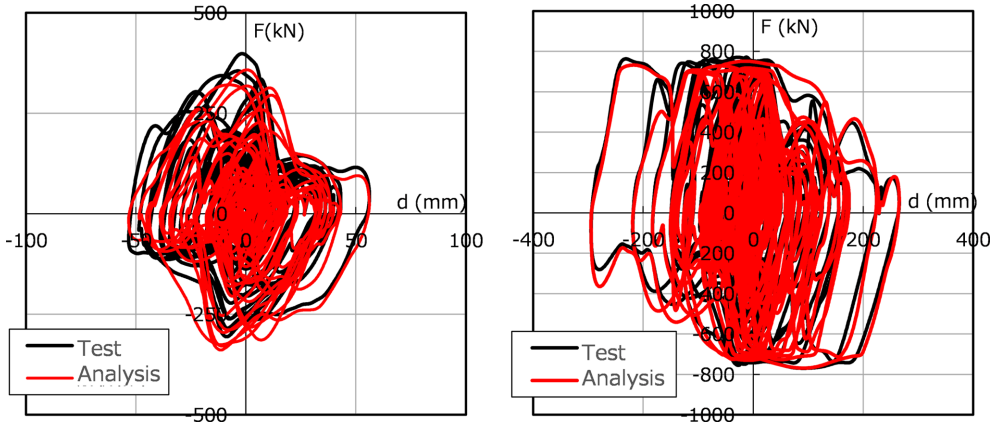


Fig. 13. Damping Force vs. Displacement of Oil Damper. (Left: L1 Response Wave Input, Right: L2 Response Wave Input)

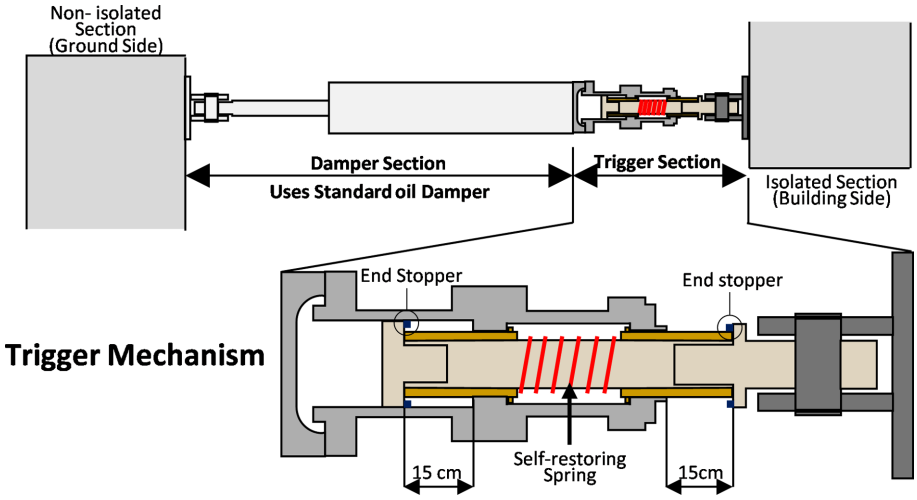


Fig. 14. Overview of Self-Restoring Trigger Mechanism.

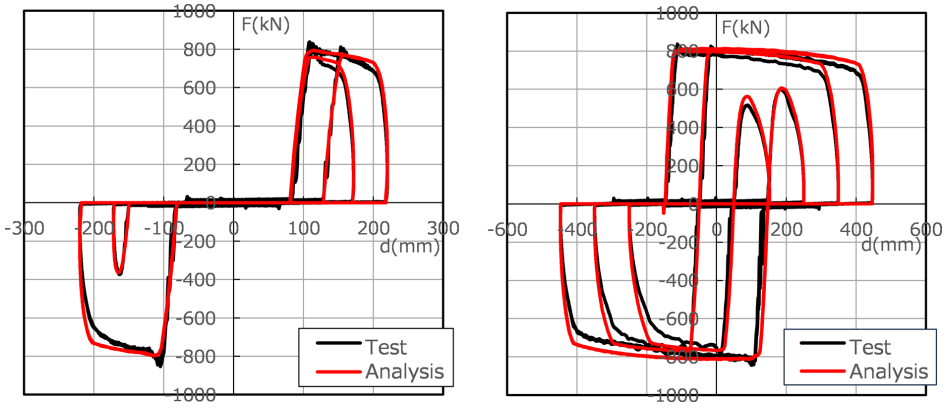


Fig. 15. Damping Force vs. Displacement (Self-Restoring Type). (Left: amplitude 220 mm, Right: amplitude 440 mm)

Table 1. Seismic Design Objectives

Design Ground motion			Rarely occurring seismic motion (Level 1)	Seismic motion that occurs very rarely (Level 2)
Superstructure		Member Condition	Within Allowable(ST)	Within Allowable(ST)
		Drift Angle (CG)	1/400 or less	1/200 or less
Damping Device		Safety Factor (CDF)	10 or more	2 or more
Seismic Isolation Materials	Horizontal Displacement		Stable Def. Limit: 372 mm (150% of TRT)	Guaranteed Def. Limit: 620 mm (250% of TRT)
	Natural Rubber Bearing	Compressive Stress	Within Short-term Allowable Compressive Stress (2.0 × Reference Pressure)	
		Tensile Stress (Strain)	No Tensile Force in the Member	Tensile Strain of 5% or Less (Tensile Stress of 1.0 N/mm2 or Less)
	Elastic Sliding Bearing	Compressive Stress	Within Short-term Allowable Compressive Stress (2.0 × Reference Pressure)	
		Tensile Stress	No Uplift in the Member	
	Oil Damper	Maximum Velocity	Within 150 cm/s	
Substructure		Member Condition	Within Short-term Allowable Stress	Within short-term allowable stress

engaging the damper only during major earthquakes to suppress excessive isolation layer displacement. The trigger displacement, at which damping force initiation occurs, is set at 15 cm. Upon reaching this relative displacement, the internal plate (PL) makes contact, activating the oil damper. A cushioning material is installed at the contact interface to absorb impact forces. Following a seismic event, the system immediately self-restores to its neutral position via the restoring force of internal springs.

Fig. 15 illustrates the relationship between damping force and deformation for the oil damper with a self-restoring trigger mechanism. The damper exhibits negligible energy absorption at small-amplitude input levels, whereas it is designed to provide effective energy absorption at large input levels exceeding L2.

4.3. Time-History Response Analysis

Table 1 shows the design criteria. In addition to securing the "Special Grade for Seismic Isolation" based on the JSCA (Japan Structural Consultants Association) seismic grade table, high-level objectives were set to achieve "Rank A (highest grade)," an optional category defined by maintaining response acceleration at 200 cm/s^2 or less.

The seismic response analysis employed observed waves, notification waves, and site-specific waves, including the South Kanto Earthquake (Genroku Kanto Earthquake source, KANTO) and long-period seismic waves (NT-KA 1) (Fig. 16). The equivalent first natural period of the entire building under Level 2 deformation is approximately 5.6 seconds in both directions. The elastic first natural period of the superstructure alone is approximately 2.2 seconds in both directions (approx. 1.3% of the building height). This demonstrates that even for a 165 m tall structure, high stiffness is achieved through the integration of the core wall system.

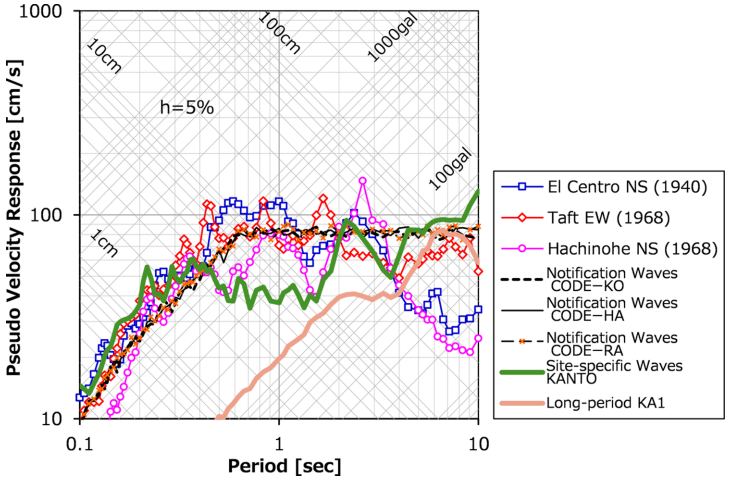


Fig. 16. Design Input Ground Motion (L2)

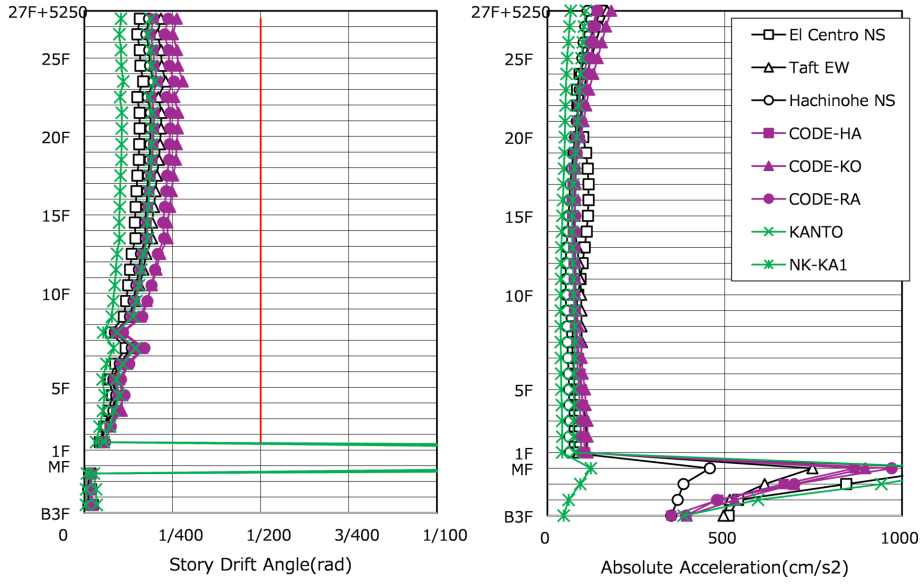


Fig. 17. Results of Time History Response Analysis (L2)

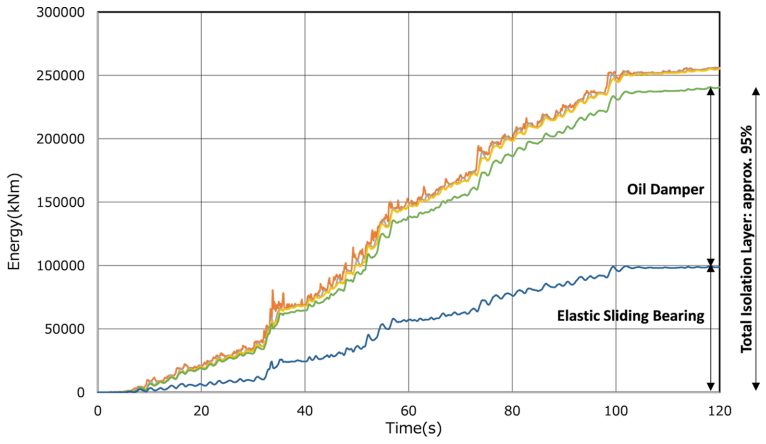


Fig. 18. Energy Absorption of Isolation Layer.

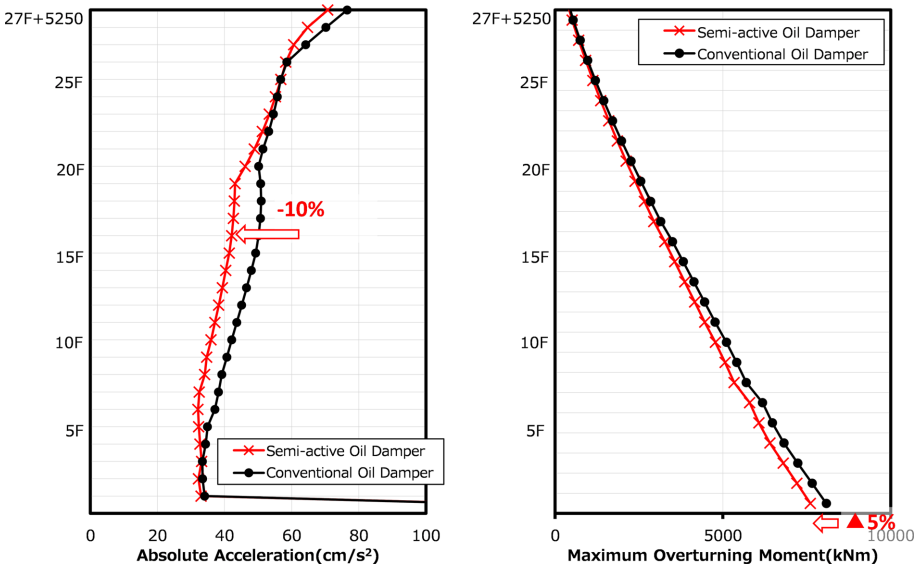


Fig. 19. Results of Time History Response Analysis. (Left: Max Acceleration (L1), Right: Max Overturning Moment (L2))

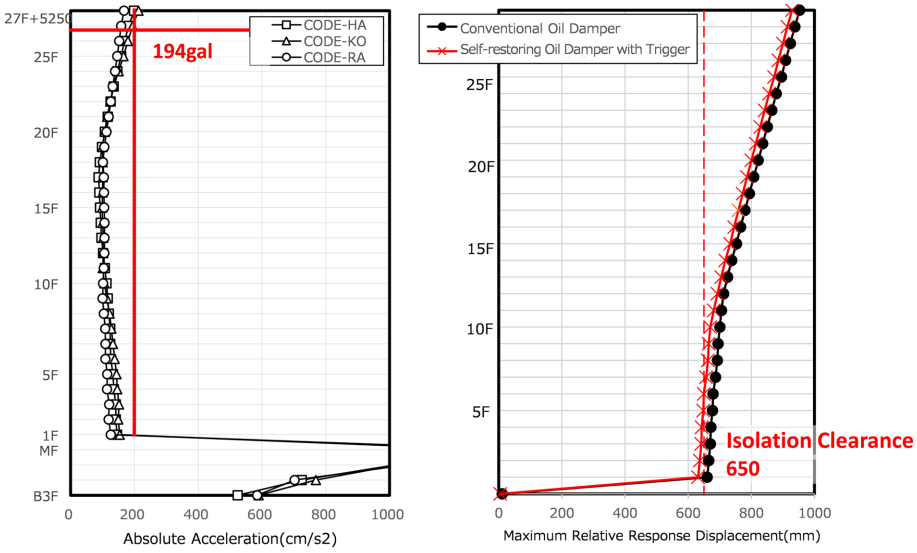


Fig. 20. Results of Time History Response Analysis (L3). (Left: Max Acceleration, Right: Max Displacement)

Figs. 17 to 20 present the time-history response analysis results for Level 1 to 3 seismic ground motion. The maximum inter-story drift angle is approximately 1/350 rad, satisfying the target of 1/300 rad or less for the "Special Grade" seismic isolation category. The maximum response acceleration is approximately 150 cm/s^2, even on upper floors, meeting the target of 200 cm/s^2. Under L3 seismic motion (1.5 times the Level 2 notification wave), the acceleration remains below 200 cm/s^2. These results confirm that all indices meet the seismic performance criteria for the "Special Grade," one rank higher than conventional isolated structures. Approximately 95% of the seismic input energy is absorbed by the elastic sliding bearings and oil dampers, demonstrating response characteristics typical of seismic isolation even for a 165 m tall structure.

With the semi-active oil dampers, the maximum response acceleration under Level 1 ground motion is reduced by approximately 10% compared to cases with passive dampers. Furthermore, the maximum response overturning moment under Level 2 ground motion is reduced by approximately 5%. Under Level 3 ground motion, the maximum response displacement is limited to 65 cm or less, attributed to the oil dampers with a self-restoring trigger mechanism.

5. Conclusion

This paper reported on a design case study of one of Japan's largest high-rise isolated buildings. By applying an "RC core wall structure with outrigger frames," the design achieved high stiffness quality difficult to secure in typical steel-moment-framed office buildings. Furthermore, the implementation of two novel types of oil dampers, which provide seamless response reduction across a wide range of disturbances, conferred significant added value to the seismic isolation system.