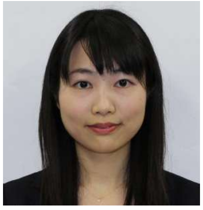
G. Itoya



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Introduction

In densely populated urban areas, it is essential to develop architectural plans that maximize site utilization. Especially when the building frontage is small, the result is inevitably a one-span, pencil-shaped building, and extremely small column sizes are required to secure interior space. For buildings with a height of 60 meters or less, design is carried out in accordance with the Seismic design route 3 of the Building Standard Law, namely Calculation of Lateral Load Carrying Capacity. However, it is difficult to assess the appropriateness of seismic force evaluation using the vibration characteristic coefficient Rt or to identify issues such as concentration of deformation in specific stories through only static design. Furthermore, in such one-span, pencil-shaped buildings, it is crucial to ensure sufficient column strength to allow for an overall collapse mechanism during major earthquakes. If a building of about 60 meters in height is designed only to the minimum code level to satisfy architectural requirements, it may result in a structure with low robustness, such as local story collapse.

Although the design of this building adopts the Seismic design route 3, a time history response analysis was conducted to examine safety in greater detail in order to address issues such as concentration of deformation in certain stories and the predominance of torsional vibration, even though the building has a standard shape.

Outline of the Building

- **Location:** 2-7-15 Ginza, Chuo-ku, Tokyo
- **Owner:** Itoya Co., Ltd.
- **Building area:** 344.22 m²
- **Total floor area:** 4,195.46 m²
- **Building height:** 55.98 m
- **Floors:** 2 basement floors, 13 above-ground floors, 2 penthouse levels
- **Usage:** Retail store, office
- **Foundation type:** Spread foundation
- **Structural type:** Steel structure
- **Vibration control devices:** Braced-type oil dampers, horizontal oil dampers, continuous wall-columns
- **Structural Designer:** Taisei Corporation, First-class Architect Office
- **Supervisor:** Taisei Corporation, First-class Architect Office
- **Constructor:** Taisei Corporation, Tokyo Branch

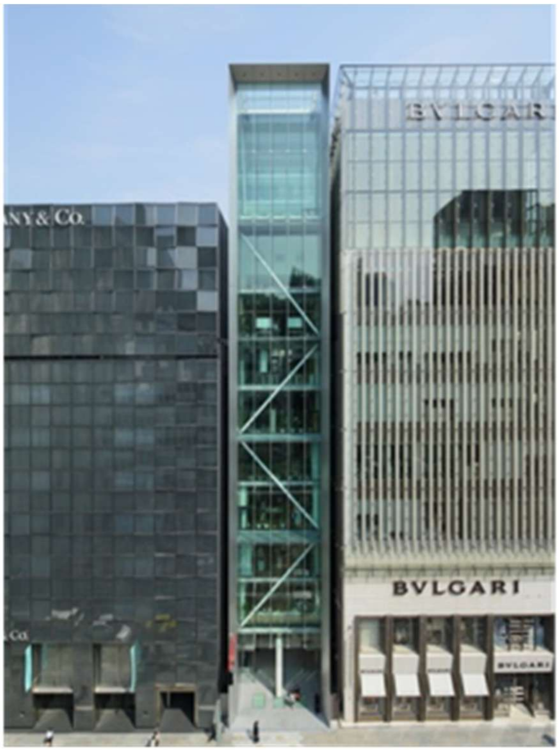


Photo1 View of Building exterior

Overview of Architectural Planning

This building is a reconstruction plan for the flagship Ginza Itoya store, a long-established stationery retailer long cherished as the "Stainless Building" facing Chuo-dori avenue in Ginza. The site is approximately 8 meters wide and 38 meters deep, resulting in a slender plan inspired by a "galleria (path)" running east-west, and an elevation with an aspect ratio of about 7. To achieve a flexible building that maximizes site use, the clearance from the exterior wall to the boundary line was set at the minimum dimension feasible for construction, about 300 mm. Within the 565 mm thick exterior wall finish, building services, air-conditioning, and structural elements are contained; therefore, the columns use a flat box section of □-390×500, and the plan was designed to maximize interior space. The flat columns are arranged at 2.4-meter intervals to ensure overall building rigidity.

Overview of Structural Planning

The basement floors employ a steel-reinforced concrete (SRC) frame with shear walls, while the above-ground floors use a steel frame: the long-span direction uses a braced frame with buckling-restrained braces, and the short-span direction employs a one-span rigid frame. Columns from the first to the fifth floor are concrete-filled steel tube (CFT) construction to increase the axial and lateral stiffness of the lower stories. The structural frame model is shown in Figure 1.

To address the challenges associated with one-span, pencil-shaped buildings as described in the Introduction, the following countermeasures were implemented:

1. To control deformation during earthquakes and avoid concentration of deformation in specific stories, a highly rigid continuous wall-column was installed at the building's center of mass, running through from the basement to the top floor.
2. To control deformation and torsional vibration, oil dampers were installed at both ends of the building.

The design overview of these two points is described below.

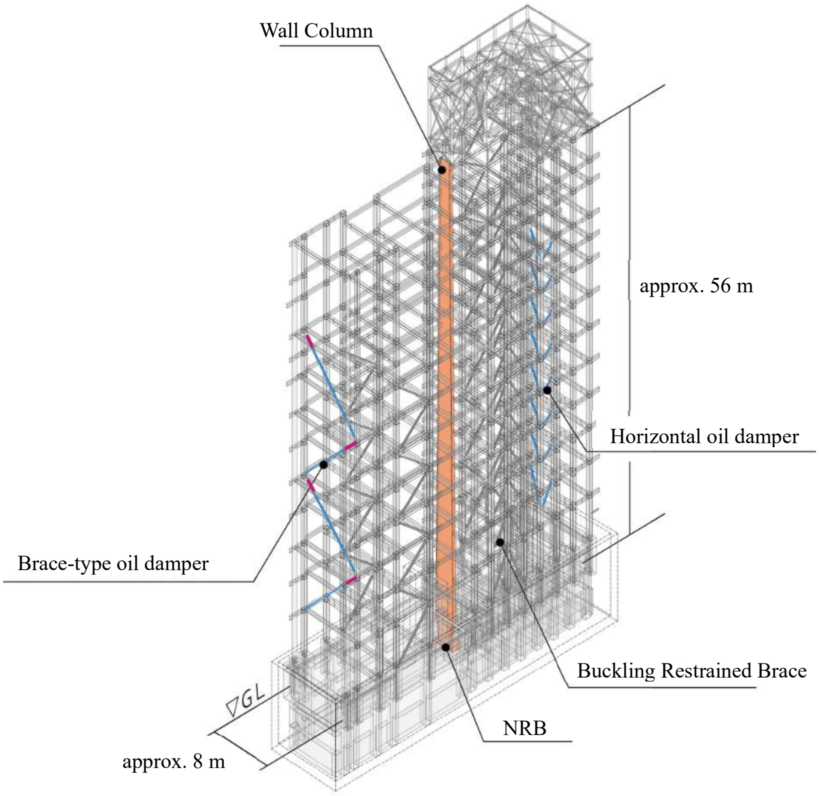


Figure1 View of Framing 3D model

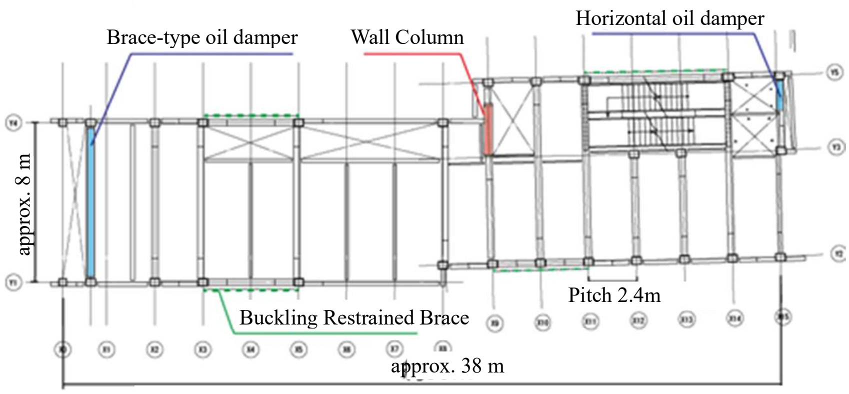


Figure2 View of frame plan in standard floor

Design of the Continuous Wall-Column

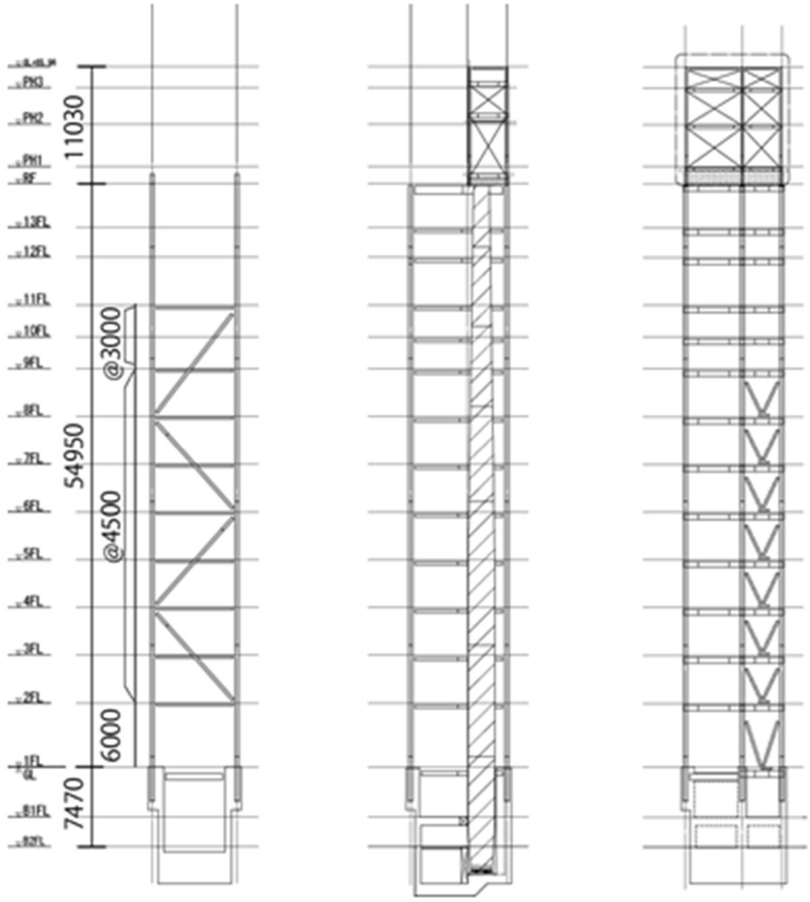
Although adding damping using vibration control devices is effective for keeping the frame members as elastic as possible against disturbances, this alone cannot address the concentration of deformation in specific stories due to unexpected external force distributions or material variability, leaving concerns regarding the formation of a global collapse mechanism (see Figure 5). As a solution, a continuous shear wall, a basic element in seismic design of high-rise buildings (Figure 4-2), was considered effective, so a highly rigid built-up H-section steel wall-column was installed at the building's center of mass, running through from the basement to the top floor.

When deformation during an earthquake concentrates on a specific story, the aim is to use the high-stiffness wall-column to distribute that deformation to the upper and lower stories. However, installing a highly rigid wall-column in a frame causes excessive concentration of seismic shear force in the wall-column. To address this, the base of the wall-column was spring-supported to avoid concentration of shear force. The deformation distribution capacity and optimal stiffness calculation method for the wall-column are described below.

In the model shown in Figure 6-1, assuming story collapse by applying a unit shear force to an intermediate story, the distribution of strain energy stored in the frame was compared while varying the wall-column stiffness. As shown in Figure 6-View2 and its enlarged view3, as the wall-column stiffness increases, the strain energy in the story with forced deformation decreases, while that in the upper and lower stories increases. This confirms that increasing wall-column stiffness enhances the effect of distributing strain energy to the upper and lower stories, making the structure less likely to experience local collapse even if unexpected external forces concentrate on a particular story.

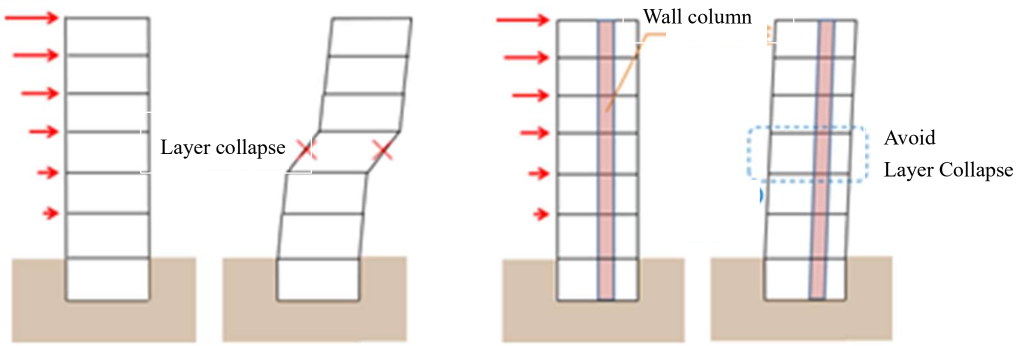
Next, the required stiffness of the wall-column is considered. Figure 7 shows the change in absolute strain energy for the entire frame and for each member. As the wall-column stiffness increases, the total strain energy in the frame decreases, while that in the wall-column increases, but leveled off at a stiffness ratio of 1.0. Based on these results, the wall-column section was selected as built-up H-section steel BH-2500×400×28×60 (for 1F), corresponding to a stiffness ratio of 1.0. As shown in Figure 8, the wall-column acts as a cantilever with the 1st floor as the fulcrum. If the wall-base were fixed, seismic forces would concentrate there, so the support condition was set as horizontal spring support, and a rubber bearing was installed as the spring member.

The effectiveness of the wall-column was verified by time history response analysis using the 3D elastoplastic frame model shown in Figure 1. The input seismic motion assumed a level 3 earthquake (1.5 times the level 2 design earthquake), which is greater than design expectations. Figure 9 shows the difference in inter-story drift angle response with and without the wall-column. Without the wall-column, the 11th floor (with an open ceiling) exhibits significant deformation under the observed record of El Centro NS direction. With the wall-column, displacement does not concentrate on any particular story and is distributed as intended in the design. The wall-column remains elastic throughout all stories.



X1-Axis **X9-Axis** **X15-Axis**

Figure3 View of frame elevation



2) without Wall Column **1) With Wall Column**

Figure4 images of collapse mode

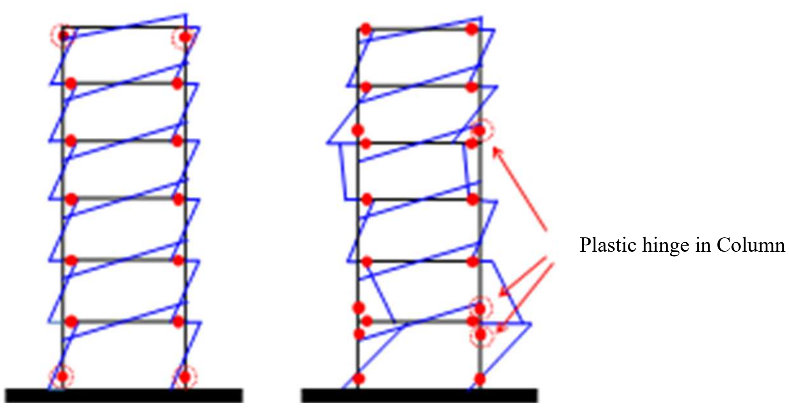
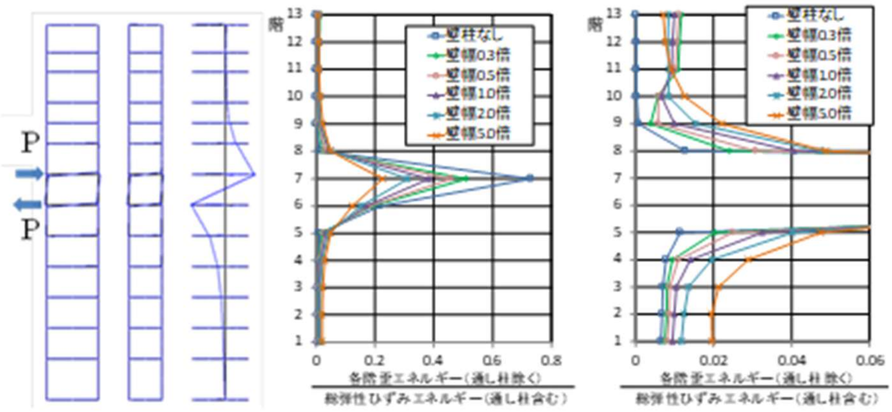


Figure5 images of collapse mechanism



1) External Force・Bending M　　2）3）Strain energy ratio for Main frame

Figure 6 Vertical distribution of stress and strain energy

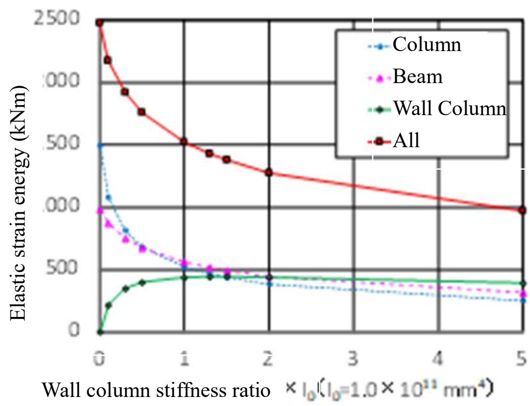


Figure 7 Variation of strain energy in the entire frame and in individual members

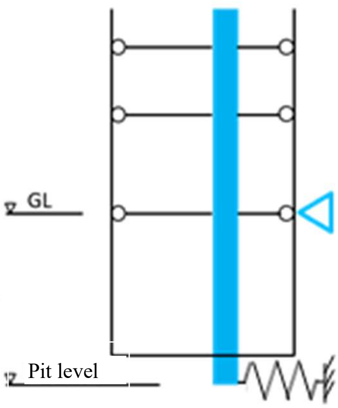
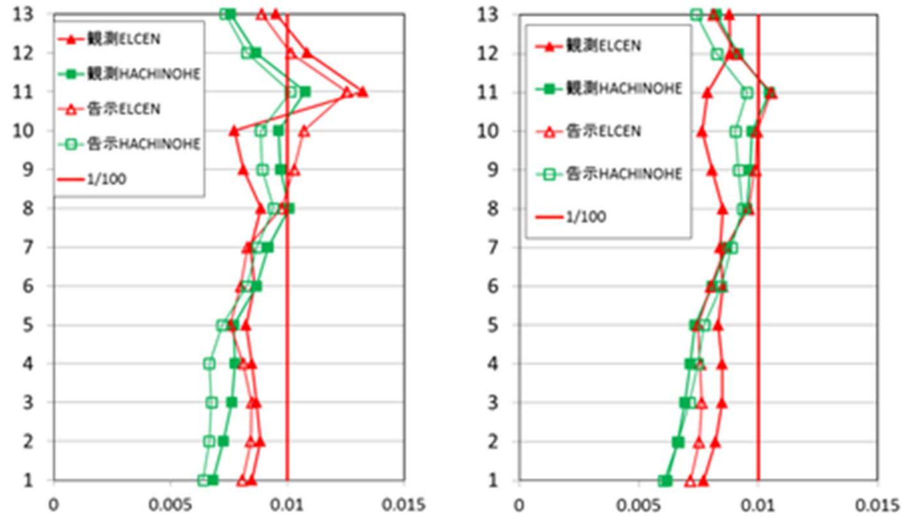


Figure 8 Column base model



Without Wall Column With Wall Column

Figure 9 Time history response analysis (seismic level 3)

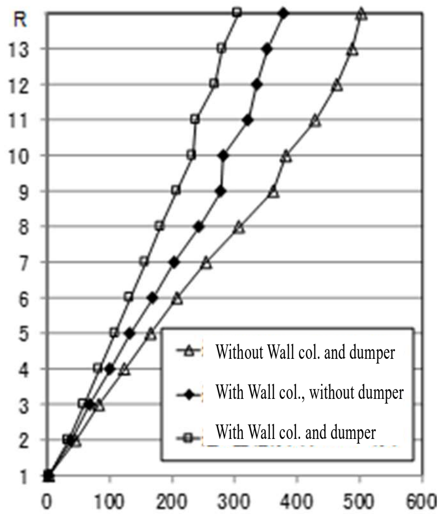


Figure 10 Maximum response displacement

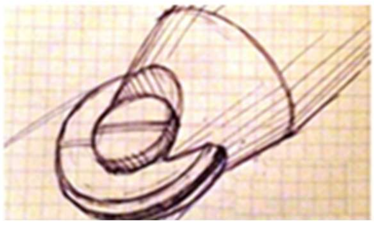


Figure 11 Sketch of Brace end

photo 2 Photo of Brace end

Design of Braced-Type Vibration Control Dampers

Although the building's plan is regular and the eccentricity is small, dynamic analysis shows that the fundamental torsional period (1.708 s) is close to the fundamental period (2.05 s), resulting in significant torsional vibration and large deformation, particularly at both end faces. This torsional vibration, which could not be predicted by static analysis, is partly attributed to reduced torsional stiffness caused using flat columns to maximize interior space. To control torsional vibration and horizontal displacement, oil dampers were installed at both end faces of the building where deformation is greatest.

On the X1-end facing Ginza Chuo-street, a highly transparent glass double-screen facade was designed to match the glamorous Ginza streetscape. Slim braced-type oil dampers (four units per floor from the 2nd to 11th floors, maximum damping force: 1000 kN/unit) were installed and integrated into both the architectural and structural exterior design (see Photo 1). At the X15-end, eight horizontal oil dampers (maximum damping force: 500 kN/unit) were installed from the 1st to 8th floors.

Figure 10 shows the maximum response displacement during a level 2 earthquake for cases with and without the

wall-column and oil dampers. The top displacement is reduced by about 25% by the wall-column, and an additional 20% by the oil dampers, demonstrating their effectiveness in reducing deformation.
The braced-type oil dampers are 12.6 meters in length and use extremely slender members, with a slenderness ratio $\lambda = 147$ (both the brace shaft and damper diameters are ϕ 267.4 mm).

Construction

Given the narrow site—8 meters wide and 38 meters deep—and the minimum construction clearance of 300 mm from the exterior wall to the site boundary, steel erection was carried out by Erection starting from one end up to the top floor, progressing horizontally across the building until a tower crane could be installed. Because the available construction equipment was limited by the site width, the steel frame erection was planned in segments to suit this. The tower crane was installed on the 7th floor to avoid exceeding the height of adjacent buildings.
The wall-column, having a much larger cross-section than other members, was planned to be segmented by floor (see Photos 3 and 4). To ensure structural performance, it was necessary to prevent vertical loads on the wall-column during construction; at each construction stage, vertical load was released using jacks installed at the column base. For the on-site welded joints, the root gap at the lowest joint was designed with sufficient clearance to accommodate deformation during load release.
For the braced-type oil dampers, the connecting pins were also a design feature, so absorbing construction errors at the pin locations was a challenge. Construction errors were adjusted using the root gap of the gusset plate; as shown in Photo 5, erection pieces were used for positioning and field welding was adopted, with reliable quality control ensured by welder qualification tests.
For the flat CFT columns, the concrete press-in method was used to ensure stable quality when filling with concrete. To prevent friction with the skin plate during concrete placement, the fill opening was made as large as possible at the center of the diaphragm, given the internal dimension of 310 mm × 420 mm. To improve the ease of pressing, the fill height was limited to 10 meters, and the filling condition inside all columns was checked by video camera during construction

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. Conclusion

By installing a highly rigid wall-column, it became possible to avoid concentration of deformation in particular stories, achieving a highly robust structure even in a pencil-shaped building. In addition, the installation of oil dampers enabled control of both horizontal deformation and torsional vibration, successfully combining high seismic performance with flexible architectural design.
Finally, we would like to express our sincere gratitude to the owner and all parties involved for their deep understanding and cooperation.

photo 3 Erection of continuous wall columns

photo 4 Joint of wall columns

photo 5 End joint of damper