A Base-Isolated Super-High-Rise Using a Precast Prestressed Concrete Wall Tube Structure
— Tokyo No.5 Data Center —

PCaPC 壁式チューブ構造による超高層免震建物
— 東京第 5 データセンター —


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Keywords: Wall tube structure, super-high-rise, PCaPC, base isolation system
DOI: 10.11474/JPCI.NR.2014.33

Synopsis
This building is a 16-story urban high-rise data center planned to be built in central Tokyo. An architectural plan that allows the required total floor area was developed to be created with a minimum building area and a high-rise design on a limited site in the central area and a structural plan that uses precast prestressed concrete (PCaPC) construction and a base-isolation system. These plans made it possible to effectively isolate the building, a super-high-rise with a high aspect ratio, from ground motion and reduce floor response acceleration while ensuring its seismic safety. Rigid-frame construction with seismic walls is used for the 5th floor and below, which require large equipment openings, and a wall tube structure with minimum openings is used for the 6th floor and above. These structures create a flat space with no pilasters, contributing to the maximization of the number of server racks. Aluminum louvers and greens are used on the exterior concrete walls, providing a state-of-the-art, uplifting exterior look while making the building environment-friendly.

Structural Data
Structure: PCaPC construction (base-isolated)
Foundation: Cast-in-place concrete piles with an enlarged base
Building area: 975.56 m^2
Total floor area: 13227.09 m^2
Primary Use: Office (server room)
No. of Stories: 16 stories above ground, 2-story penthouse
Eave Height: 89.1 m (maximum height: 90.3 m)
Owner: NTT Communications Corporation
Designer: NTT Facilities Inc.
Construction Period: Aug 2009 – Mar 2011

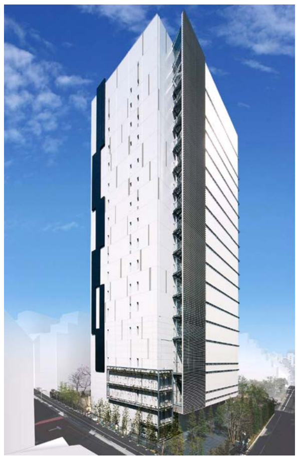


Fig. 1 Tokyo No.5 data center

1. Introduction
This is a 16-story super-high-rise communications building constructed in central Tokyo. A large building to be built in the central area must be planned with consideration given to the surrounding environment and meet challenging structural requirements. In this project, the following solutions were used to meet these requirements and achieved by PC technology.
1) Create an optimal space by combining PCaPC

construction, a wall tube structure and a base isolation system.
2) Improve the load-bearing capability and achieve long clear spans.
3) Reduce the construction period using PCaPC pressing construction.
4) Extend the life of the building and reduce the environmental load.

This paper outlines the design concept for the building, the issues in translating the concept into reality, the structural solutions and plan to address the issues.

2. Architectural Plan

(1) Design concept

The design concept for the building was to plan a large data center with the highest disaster prevention capability and the highest security while giving consideration to the neighborhood by reducing the environmental load. The following issues needed to be addressed to translate the design concept into reality:

1) Ensure a high level of sustainable seismic safety.
2) Reduce floor response acceleration to bring the reliability for ICT equipment to the highest level (less than 200 cm/s^2).
3) Support heavy floor loads from server racks and electric power equipment (server room: 9.8 kN/m^2 of floor area, power receiving room: 24.5 kN/m^2 of floor area).
4) Create a space that maximizes the number of server racks to be accommodated.
5) Reduce the construction period.

In addressing the issues, it was an essential requirement for the architectural plan to provide a distance from the neighboring buildings by minimizing the building area. With this requirement met, a floor area was then created by adding floors within the floor area restriction to maximize the number of server racks.

(2) Description of the plan

Fig. 2 shows the typical floor plan. **Fig. 3** shows the cross section of the building. The building consists of rooms required for the data center stacked (**Fig. 3**). The 3rd floor and above have equipment balconies on the east and west exterior walls. The aluminum louver attached to the front of the balcony mitigates the oppressive look of the concrete structure and creates an uplifting exterior look, as well as blocks solar radiation to reduce the cooling load. It provides both functional and environmental benefits.

The building is rectangular in plan, with the short side consisting of 2 spans of 11.2 m each and the long side consisting of 6 spans of 4.8 and 6.6 m. The floor height is 7.2 m for the lower floors and 4.6 m for the typical floor.

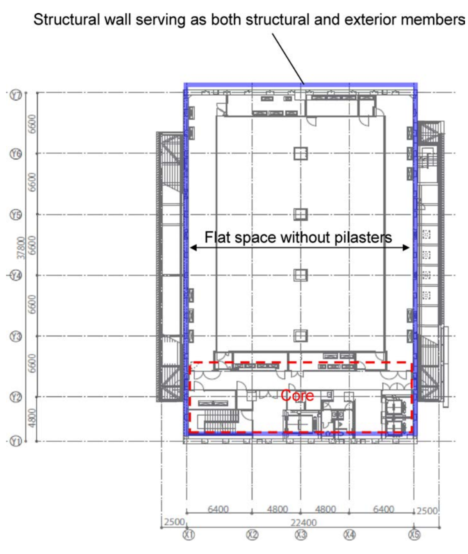


Fig. 2 Typical floor plan

3. Structural Plan

(1) Construction types

To address the issues based on the design concept, a base isolation system was used to ensure the seismic safety of the building, maintain its function and reduce floor response acceleration.

Construction types for the upper structure were compared on the basis that a base isolation system is used. **Table 1** is a comparison of different construction types. Steel frame construction (S-construction) is often

Table-1 Comparison of different construction types

Construction Type	S Construction	RC Construction	PCaPC Construction
Floor Response Reduction	△	○	○
Beam Depth	○	△	◎
Long Span	○	×	○
Useful Area	○	△	◎ (When a wall tube structure is used)
Construction Period	◎	×	○
Cost	△	○	△
Overall Rating	△	×	○

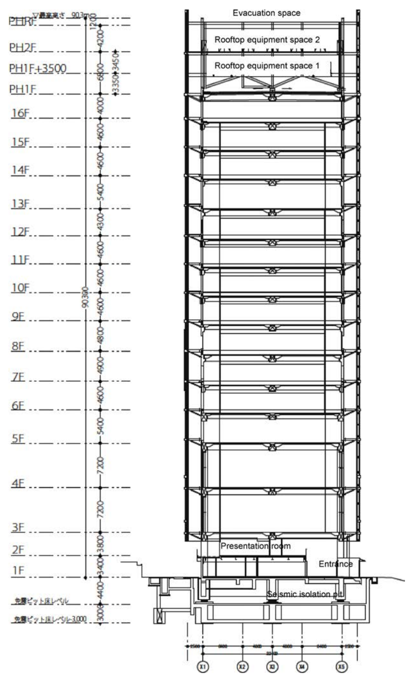


Fig. 3 Cross section

used in high-rises such as office buildings. To meet the high requirements for response acceleration, it is necessary to increase the rigidity of the upper structure supported by the base isolation system. In this regard, reinforced concrete construction (RC construction) is advantageous for this building. However, if RC construction is used, long clear spans cannot be achieved for heavy floor loads. If cast-in-place concrete construction is used, the building cannot be completed with the specified period. To address these issues, PC construction was employed to achieve long clear spans, and precast concrete (PCa) components and PC pressing construction to reduce the construction period. Based on the comparison, PCaPC construction, shown in Table 1, was used.

The combination of PCaPC construction and a base isolation system made it possible to effectively isolate the building, a super-high-rise with a high aspect ratio, from ground motion, reducing floor response acceleration for the bottom to the top floor while ensuring seismic safety.

(2) Framing

Since the primary function of the building is "a box to contain servers," a simple structure with a focus only on this function was aimed to design. Rigid-frame construction with seismic walls is used for the 5th floor and below, which require large equipment openings. A box structure (a wall tube structure) having four walls enclosed by floors is used for the 6th floor and above, which require equipment openings to be minimized to ensure the function of the data center. This is an efficient, robust structure.

The wall tube structure has the following advantages (**Fig. 4** and **5**). The use of the wall tube structure:

- Maximizes the usable floor area because the structure serves as both structural and exterior members.
- Creates a flat space with no pilasters on the peripheral walls, contributing to the maximization of the number of server racks, which is critical for the operation of the data center (**Fig. 5**).

The wall tube structure contributes to the increased rigidity of the upper structure and to the achievement of good seismic isolation. Since the peripheral walls resist the vertical force and most of the seismic forces, no columns are required and the long span beams inside the structure are free from seismic forces. Long clear spans, with a reduced beam depth, are achieved using ST (single tee) floor slabs in the floor system, making it possible both to increase spatial freedom and to reduce the floor height.

A large frame with seismic walls arranged in a gate shape is used for the 5th floor and below so that the stress from the wall tube structure above can be smoothly transferred to the building legs. For the rooftop equipment space, a hybrid structure, a combination of PCa walls, as a seismic component, and an S-frame, a frame to support vertical loads, is used for structural continuity with the structure below (**Fig. 4**).

(3) Assembly method

To meet the requirement for completing the structure, consisting primarily of the wall tube structure, within the target period, half-precast slabs were used for the floors, and PCaPC with post-tensioning and PCa construction were used for the columns and beams and for the walls. The construction period was reduced with combining these precast technologies and PCa construction. The use of PCaPC construction has contributed to increasing the life of the structure through quality improvements and to a reduction in the environmental load through a reduction in the amount of tropical lumber used for concrete forms. The PCa wall panels were 2200 mm wide and as high as the floor height, and were joined together on site. As shown in **Fig. 6**, the PCa walls were joined together

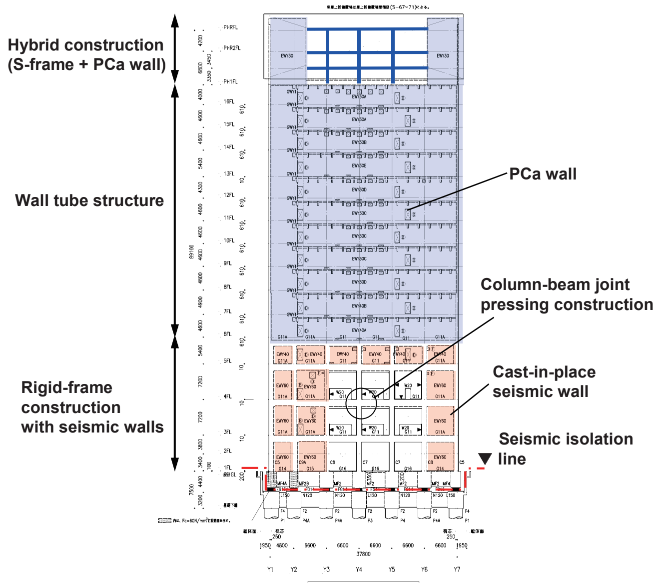


Fig. 4 Framing elevation through X5

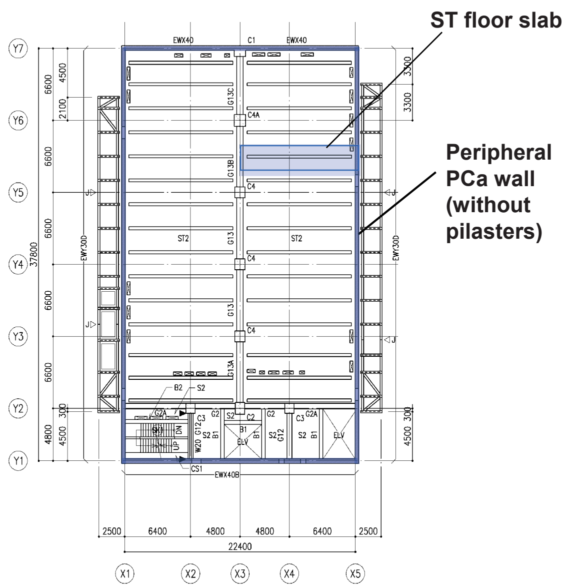


Fig. 5 Typical floor framing plan

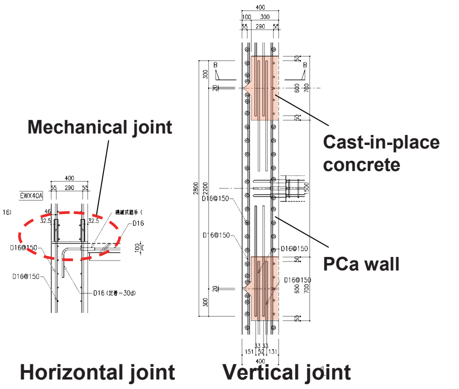


Fig. 6 Details of the PCa wall joints

Table-2 Materials used

Component		Concrete (N/mm^2)	Steel
PCa	Column	60	SD390(RC component)
	Girder	60	SD345 SWPR7B 12.7φ SWPR7B 15.2φ
	ST floor slab	50	SWPR7B 15.2φ
	Wall	30～60	SD295A, SD345 (RC component)
Cast in-Place	Topping concrete	30	—
	Wall	60	SD345（RC component)
	Foundation below 1st floor, girder, foundation beam	36	SD390（RC component)

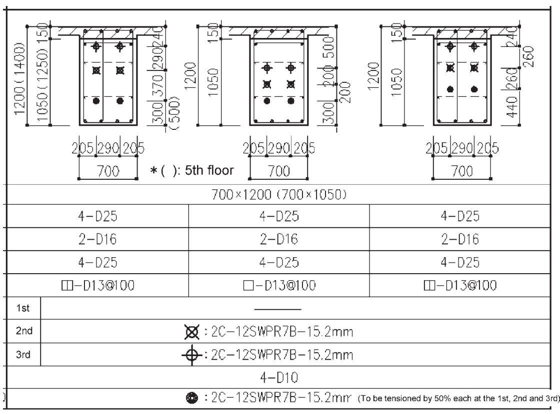


Fig. 7 Cross section of the large beam in the Y-direction

by mechanically tying vertical wall reinforcements on the horizontal side and, by overlapping horizontal wall reinforcements or welding and casting concrete in place on the vertical side.

(4) Component design

Fig. 2 shows the materials used. The columns were designed as a RC component, and are 1000 × 1000 mm to 1200 × 1200 mm. The large beams were designed as a PC component and post-tentioned to the columns by placing and tensioning secondary and tertiary stressed PC cables on site (**Fig. 7**).

The ribs of the ST floor stabs were pretensioned to apply a prestress, and the slabs were designed to have a cross section that can support the design loads as well as the loads during construction.

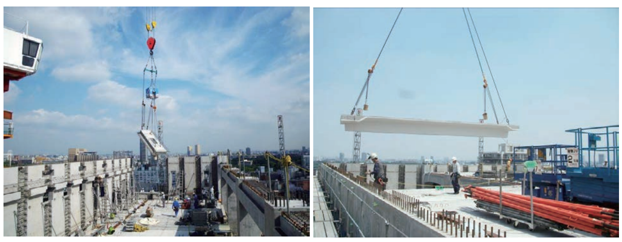
4. Construction Plan

The overall construction schedule for a high rise with many floors, such as this building, is significantly affected by the floor tact schedule. It is important in reducing the construction period to plan the construction by efficiently combining case-in-place concrete and PCa components. The component that particularly affected the construction schedule for this building was the cast-in-place seismic wall at the lower levels.

The support work was planned so that the PCa wall load could be supported by the beams for the 6th floor where the frame structure changes from the rigid-frame structure for the lower levels to the wall structure for the upper levels, and the PCa walls for the upper levels were erected before the cast-in-place seismic walls for the lower levels were cast. The construction schedule described above made it possible to achieve an 8-day tact per floor (a 9-day tact for the 5th floor and below). **Fig. 8** shows an example of erecting the PCa wall.

5. Conclusion

In translating the given design concept for the building into reality, the creative structural plan was carried out by making the most of concrete technology such as PCaPC components and the wall tube structure. Also, the design was made successfully compatible with environmental technology.



(a) Erecting PCa wall panels (b) Installing ST floor slabs

Fig. 8 Erecting the wall

概　要

本建物は，東京都心部に計画された地上16階の超高層都市型データセンターである。都心部の限られた敷地おいて建築面積を最小化しつつ高層化することにより床面積を確保する建築計画に対して，PCaPC 造と基礎免震構造と組合わせる構造計画とした。これにより，超高層でアスペクト比が大きな建物でありながら高い免震効果を発揮し，耐震安全性を確保しつつ床応答加速度の低減を実現している。架構形式は，大きな設備開口の必要な 5 階以下を耐震壁付ラーメン構造， 6 階以上は開口を最小限とした壁式チューブ構造とし，柱形のないフラットな空間とすることでサーバラック数の最大化に貢献している。また，コンクリートの外壁に，アルミルーバーや壁面緑化を組合せることで，環境に配慮しつつ軽快で先進的な外観デザインとなっている。