Cantilever Structure with a Prestressed Concrete Multi-story Wall — KANDA HOLDINGS Headquarters —

PC 連層壁による跳出し架構 — カンダホールディングス本社 —


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Synopsis
This report describes a new headquarters project for a general logistics trading company. The client wanted a new compact base built in the center of Tokyo for convenient transportation access. The most important feature of this building is that a 6.8-m-long front portion is an over-hanging long-span cantilever structure. This cantilever part is supported by prestressed concrete (PC) multi-story walls at both sides. The aim was to create a parking space under the eave and maximize the floor areas of typical floors (**Fig. 1**).

Structural Data
Building Scale: 8 stories above ground
Construction Area: Approximately 334 m^2
Total floor Area: Approximately 2,157 m^2
Building Height: 33.2 m
Owner: KANDA HOLDINGS Co., Ltd.
Design and Engineering: Takenaka Corporation
Contractor: Takenaka Corporation
Construction Period: Jan. 2018 – Feb. 2019
Location: Kanda-Misakicho, Chiyoda Ward, Tokyo

1. Introduction
In this building, the client wanted improved energy efficiency and a better working environment in order to clearly indicate that their business is contributing to the natural environment. Also, the building was designed to maximize its total floor area while accommodating indispensable parking spaces, and constructed in the very narrow confined working area available in the center of Tokyo. The most reasonable solution to these problems was deemed to be a PC multi-story wall.

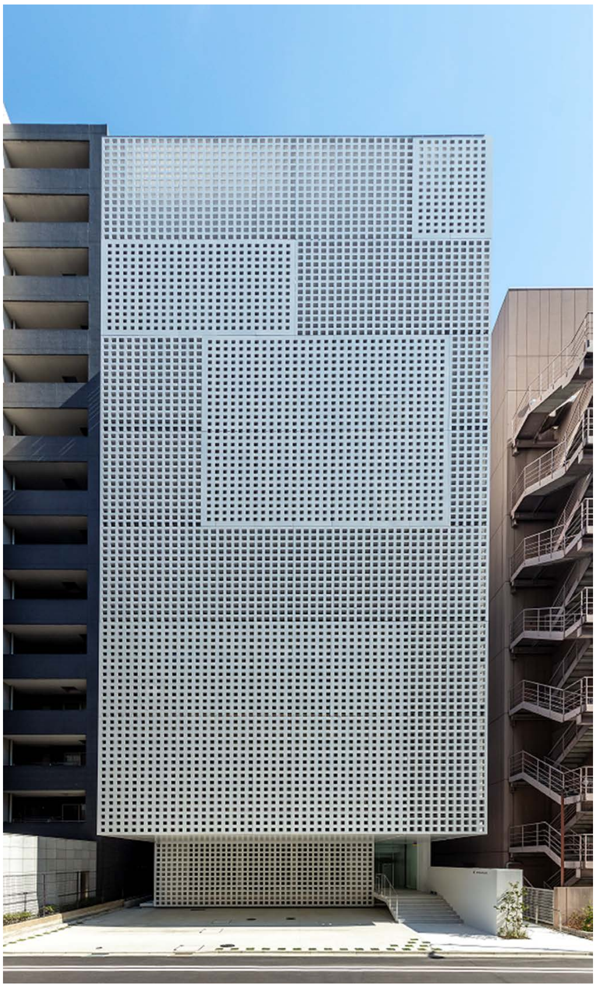


Fig. 1 Exterior view

2. Overview of the Building

This building is an 8-story office building on a narrow site in central Tokyo. The building was built to symbolize the company itself in the hope of becoming the face of company as the new headquarters.

The most important feature of the architectural plan is an intermediate area designed to reduce environmental impact and improve the working environment (**Fig. 2**). The intermediate area is a semi-exterior space with soft natural light and gentle breezes and is covered by a shading facade. All the workspaces including even small spaces such as meeting rooms are directly connected by the intermediate area (**Fig. 3**).

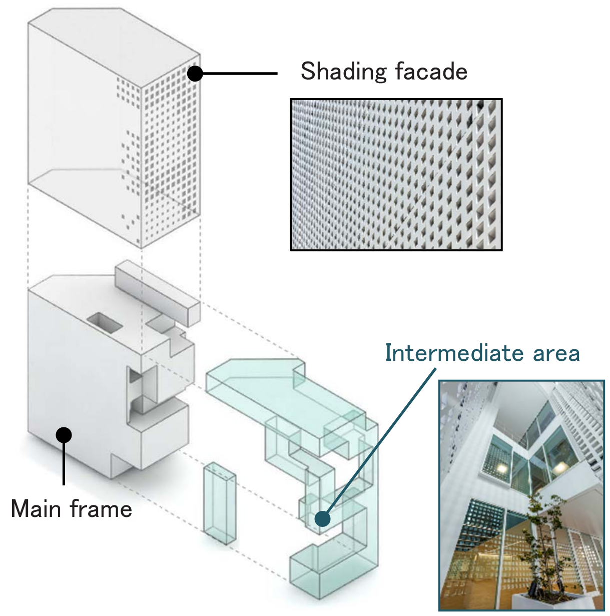


Fig. 2 Design diagram

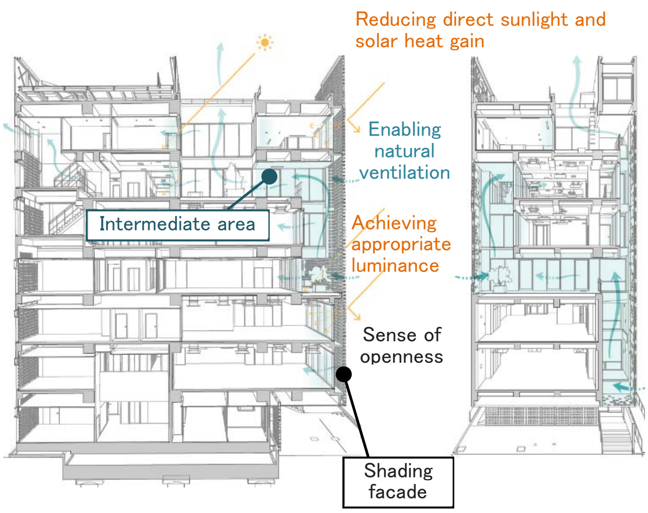


Fig. 3 Function of the intermediate area

3. Overview of Structural Design

(1) Structural Planning of the Entire Building

The building has a unique structure in which approximately 50% of the floor area is a cantilevered structure. The structure is a rigid-frame structure with bearing walls in both the X and Y directions, with column spans ranging from 3.2 to 10.0 m in the X direction and from 2.85 to 7.2 m in the Y direction. High-strength concrete with a design compressive strength of 42 to 48 N/mm^2 was mainly used for the columns, beams, and walls in consideration of crack suppression in addition to the stresses of the upper structure. **Fig. 4** shows a floor plan of a typical floor, and **Fig. 5** shows a representative framing elevation in the Y direction.

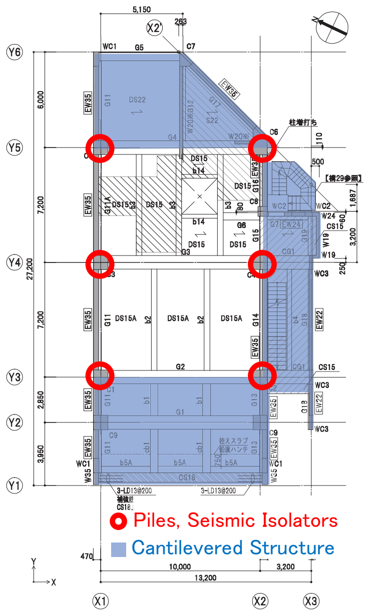


Fig. 4 Typical floor plan

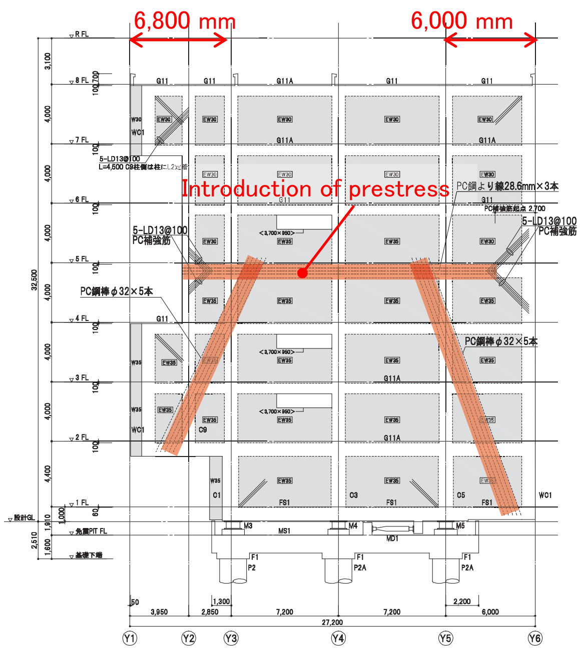


Fig. 5 Framing elevation

To realize the design concept, the superstructure has a large 6.8-m span overhang on the west side (front) of the building to maximize the floor area. Although a steel frame would typically be adopted because of the long-span cantilever structure, a reinforced concrete frame with rigidity and weight was adopted to enhance the seismic isolation effect. In addition to the 6.8-m-long projecting structure on the west side (front) of the building, a 6.0-m-long projecting structure was also adopted on the east side (rear) of the building in consideration of long-term weight balance. The east–west overhang is supported by a 300–350-mm-thick continuous wall, which is prestressed to prevent cracking.

(2) PC Multi-story Wall

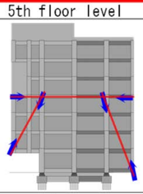
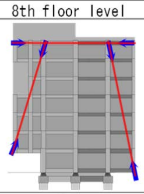
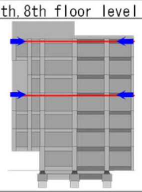
The long-span cantilever structure is prestressed in a direction that cancels long-term stresses in order to suppress cracking due to shear deformation in the cantilever sections.

Three options for the location of the prestressing were compared in the early planning stage (**Table-1**). Based on a comprehensive evaluation of deformation, stress, cost, and workability, it was decided to apply the prestressing force at the fifth floor level.

The prestressing force was given to as many PC steel bars that could be accommodated in the frame, and the stress due to prestressing did not exceed the long-term wall-borne shear force. As a result of the stress analysis and the investigation of the wall layout, it was decided to install five ∅32 PC steel bars inside the wall and three 28.6-mm PC steel strands in the large beam on the fifth floor to provide prestressing forces of approximately 2,500 kN in the diagonal direction and 1,650 kN in the horizontal direction (**Fig. 6**).

The design criterion for the cantilever continuous wall was set to below the shear crack strength for the design stress considering the vertical motion response during earthquakes in order to prevent the increase of long-term deflection due to cracking. The results of finite element analysis of shear stress and vertical deformation are shown in **Figs. 7** and **8**. By introducing prestressing, the long-term stress is reduced by about 50% and the elastic deflection is reduced by about 30%, satisfying the design criteria for the stresses considering vertical movement during earthquakes.

Table-1 Comparison of prestress introduction position

	5th floor level	8th floor level	5th, 8th floor level
Diagram			
Deformation	++	++	+
Stress	++	++	+
Cost	++	+	++
Workability	++	+	+++
Overall	++	+	+

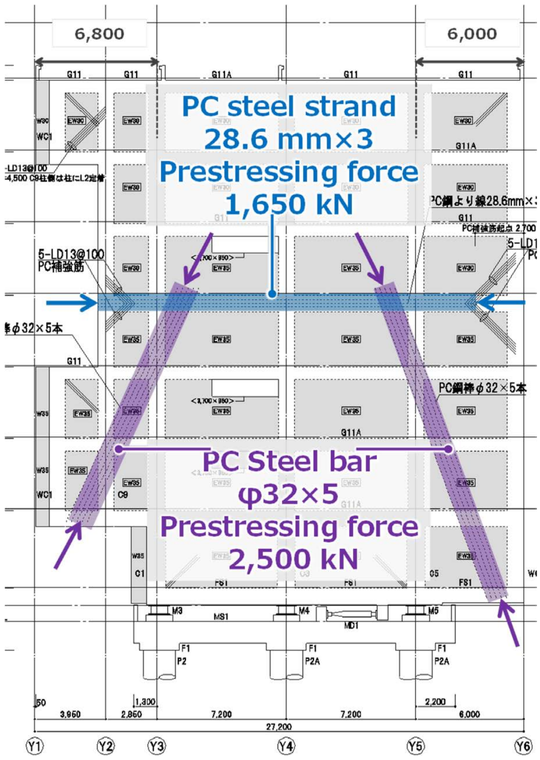


Fig. 6 Setting prestressing force

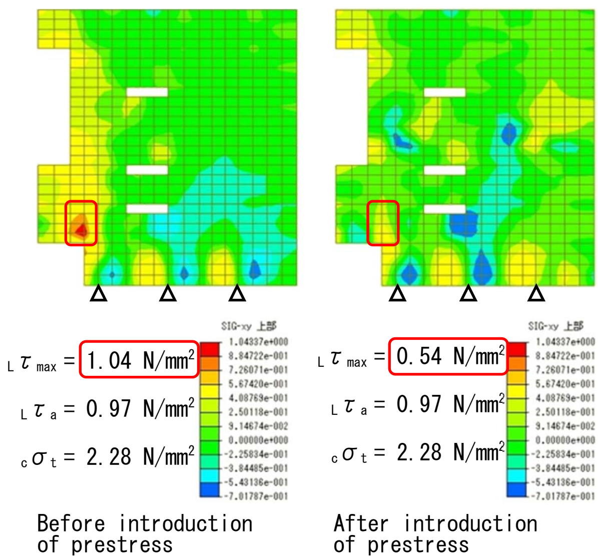


Fig. 7 Long-term stress diagram (N/mm^2)

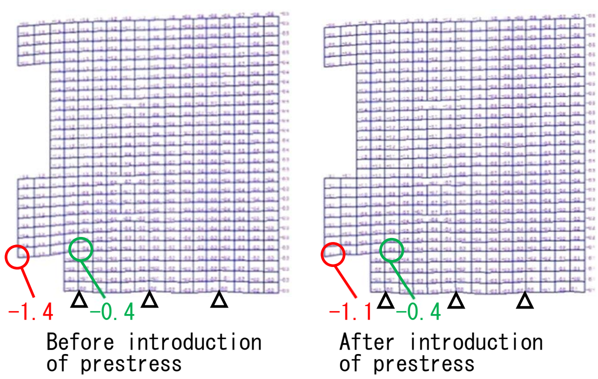


Fig. 8 Long-term deformation diagram (mm)

The minimum wall thickness was tentatively determined based on the dimensions of the PC steel bars and reinforcements therein. Then the final thickness was determined considering the configuration of reinforcements in the beams and columns as shown in **Fig. 9**. Following the aforementioned study, the wall thickness was set to 350 mm and the beam dimensions were set to 500–550 mm × 900 mm. Building information modeling (BIM) was also used in the detailed design to check the configuration of the reinforcements visually (**Fig. 10**).

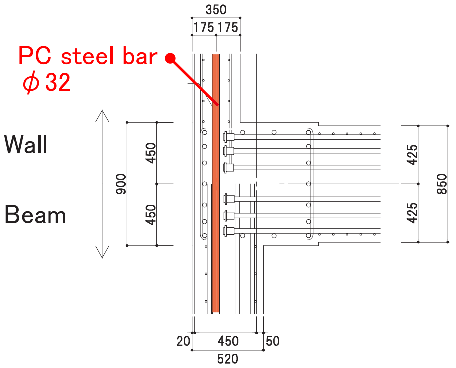


Fig. 9 Detail drawing of PC steel bar

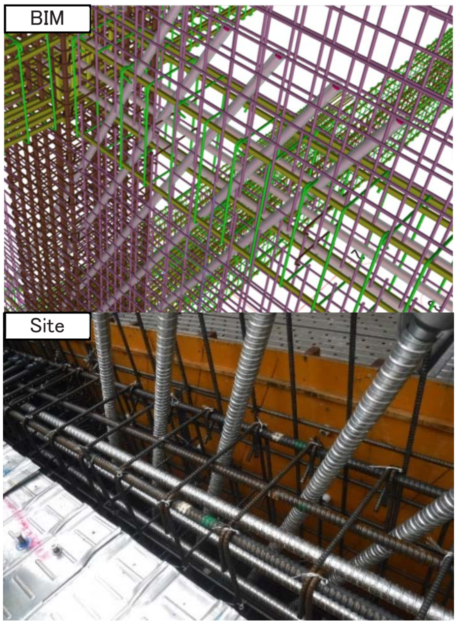


Fig. 10 BIM utilization

4. Conclusion

The resulting PC multi-story wall utilizes floor areas efficiently at the narrow construction site located in the center of Tokyo. It also produces excellent environmental conditions for employees in this building (**Fig. 11**). Various studies of structural engineering and construction methods through close communications with construction team based on the schematic design realized a high-quality reinforced concrete structure and an architecturally unique building.

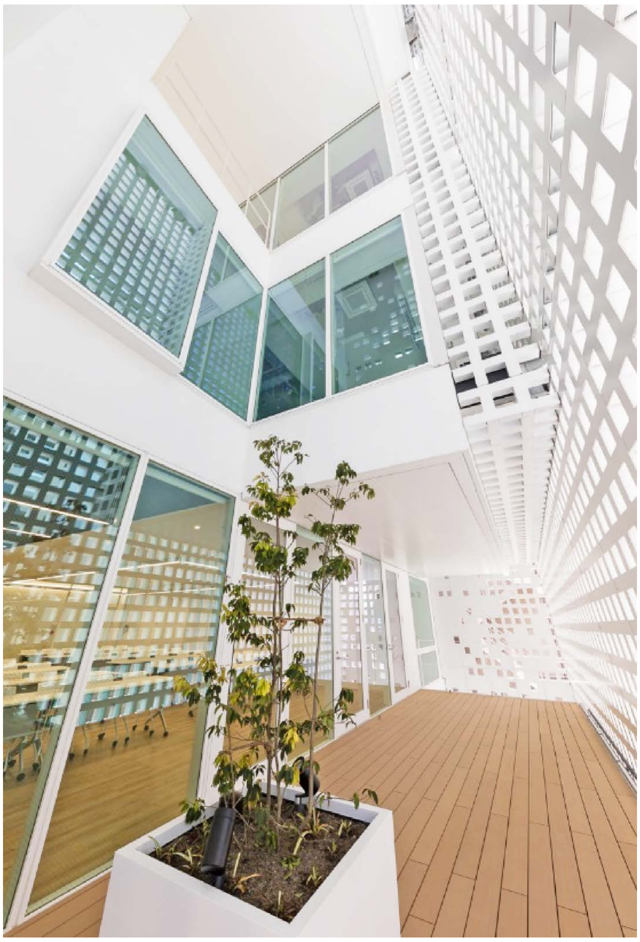


Fig. 11 Interior view

概　要

本建物は，床面積の約50%が跳出し架構により構成される特徴的な構造をした総合物流商社の本社オフィスビルである。とくに建物前面は，周辺環境と調和した軒下空間の創出と附置義務駐車場の確保および上階フロア床面積の最大化という機能的要求から，6.8m の跳出し架構が求められた。この課題に対して，プレストレストコンクリート連層壁により跳出し架構を支持することで，要求された機能を確保するとともに，フロア床面積を最大化することで創出した空間を，外部環境負荷の低減と組織間のスムーズな交流を誘発する連続した半外部空間（中間領域）として活用し，高い環境性能と執務空間の快適性を持つ新本社を実現することができた。