Structural Design Achieving Floating Artificial Ground and Attractive Office Space — Nichia Suwa Technology Center —

浮遊する人工大地と魅力的な執務空間を実現する構造デザイン — 日亜化学工業諏訪技術センター —

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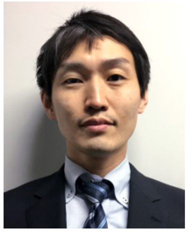 ****

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Keywords: PCaPC beam, hybrid structure, long span, labor saving
DOI: 10.11474/JPCI.NR.2018.31

Synopsis

Nichia Suwa Technology Center has an open office space that commands panoramic views of Lake Suwa. A dynamic and flexible structural frame floating in the air with a 28.8-m span and 6.4-m overhangs was constructed by applying the Gerber beam concept to a hybrid framing of precast prestressed concrete (PCaPC) and steel. The authors increased the percentage of PCa concrete in the members with the aims of saving labor in framework construction in a cold region and improving quality by ensuring accuracy.

Structural Data

Structural Type: PCaPC structure, reinforced concrete (partially PCa) structure, and steel structure
Scale: 2 floors above ground, 1 basement floor, and 1 penthouse floor
Building Height: 15m
Building Area: 2,625.44m^2
Gross Floor Area: 4,002.8m^2
Owner: Nichia Corporation
Designer: Osaka Main Office, Takenaka Corporation
Contractor: Tokyo Main Office, Takenaka Corporation
Construction Period: Jan. 2016 – Nov. 2016
Location: Suwa County, Nagano Prefecture, Japan

1. Introduction

This building is a technology center with an open office space that commands panoramic views of Lake Suwa. The whole office appears to float on the artificial ground constructed of a structural frame system, by which the authors have achieved a façade design that highlights the image of an advanced company while taking the surrounding abundant natural environment into the interior space (**Fig.1**).

Fig.1 Full view of building

2. Design

The design concepts in the architectural planning phase were “creating a favorable research environment” and “enhancing intelligent productivity.” The aim was a symbolic work that would afford the company recognition in the surrounding areas (**Figs. 2** and **3**).

3. Structural Planning

To match the architectural plan, the authors applied a combination of different types of structures so that

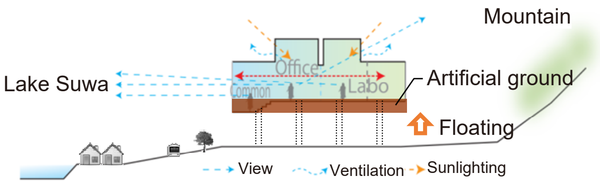

Fig.2 Concept diagram

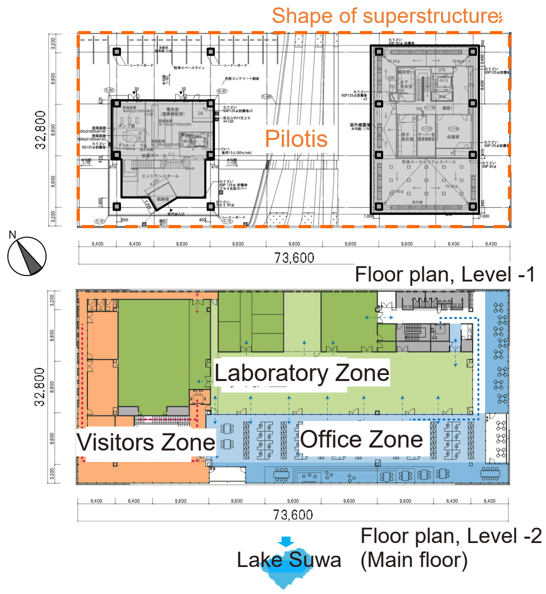

Fig.3 Plan of each floor

the right structures might be used in the right places. The substructure is made of reinforced concrete (RC) while the superstructure is made of steel. Some parts of the RC structure have a PCa structure and a PCaPC structure in combination depending on the span (**Fig.4**). Since only the minimum areas are used for the building uses on the first basement and first (ground) level floors, they comprise two cores, one in the east and the other in the west. Each core has a pure rigid-frame structure consisting of eight PCaRC columns and PCaPC girders, thereby minimizing the number of structural members and ensuring all of flexibility, bearing capacity and stiffness. Using PCa columns and PCaPC girders simultaneously resolved two major issues, namely snow accumulation and a shortage of

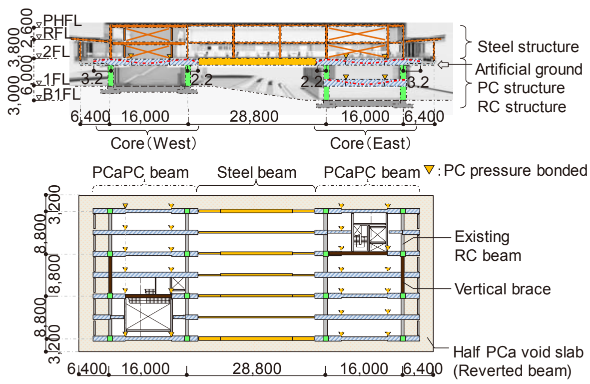

Fig.4 Building section (upper) and Floor framing plan, Level 2 (lower)

construction workers. The second-level floor comprises a steel rigid-frame structure with braces to achieve an open space. The aim was to minimize the member sections and reduce the load on the substructure.

(1) Construction of Artificial Ground

The artificial ground constructed at the second-floor level is a structure that can support the superstructure stably. It also gives the impression of floating by showing a dynamic framework with a 28.8m distance (on-center) between the columns in the east and west cores and 6.4m overhangs from the east and west cores (**Fig.5**).

The 28.8m span was achieved by pin-joining the steel beams to the PCaPC beams hanging over 2.2m from the cores and turning them into Gerber beams (**Fig.6**). The light-weight steel beams minimized the structure section, and PCaPC beams at the ends increased the stiffness, thereby enhancing the habitability of the office. The maximum height of the steel beams was 1,800mm considering the habitability of the upper habitable rooms. The maximum section of the PCaPC beams is 850mm by 1,500mm, and the specified concrete strength is 60MPa. The PCa members for integrated column–beam joints were fabricated in a

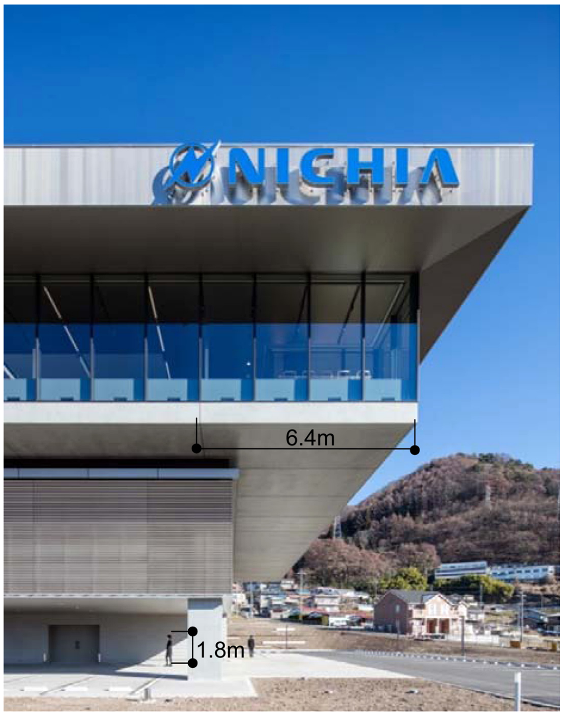

Fig.5 View looking up at 6.4 m overhang

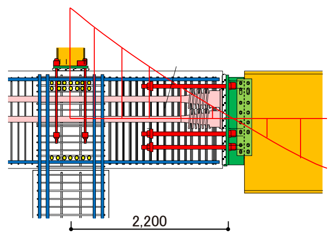

Fig.6 Joint between PCaPC beam and steel beam

factory and then erected and tensioned on site.

A 6.4m overhang was constructed by integrating a half PCa void slab into a 3.2m overhanging PCaPC beam in a reversed beam style. This style facilitated the design of an exposed slab on the underside of the slab, an under-floor air-conditioning system on its top side, and a structural design that looks like a 6.4m overhanging slab.

Combining these Gerber beams, PCaPC beams, and large-scale overhangs helped balance the long-term stressed condition of the artificial ground, leading to construction of stable ground (**Fig.7**).

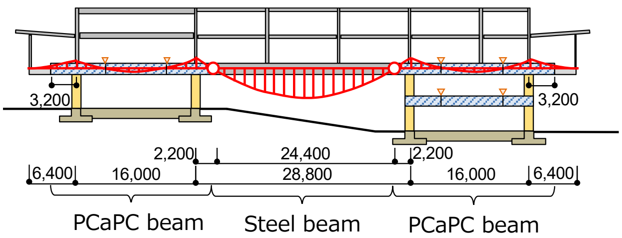

Fig.7 Long-term stresses on artificial ground

(2) Construction of Open Office Space

The office space above the artificial ground was made an open space with a uniform column diameter of 139.8mm by applying all the horizontal forces to the vertical braces (**Fig.8**). The vertical braces are concentrated, well balanced, and aligned with the core positions of the substructure, thereby minimizing the sections of the horizontal brace members that ensure the roof stiffness. Moreover, the authors used a combination of a pure rigid-frame RC substructure and a steel superstructure with braces to balance the story stiffness ratios of the whole building.

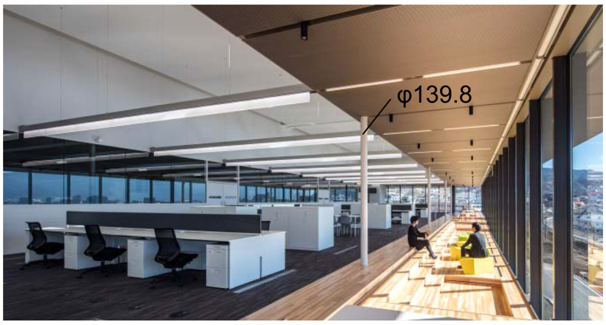

Fig.8 Office interior

4. Construction

(1) Fabrication of PCa Members

Because the project site is in a cold region, as many RC members as possible were precast to improve their workability. **Fig.9** shows the shapes and layout of the members and **Table-1** lists their quantities.

The PCa column members were designed to have projections in the east and in the west (**Fig.10**). Therefore, concrete was cast only in the north direction. The PCaPC beam members were designed so that their column–beam joints might be integrated. As many members as possible were made in the same shape, thereby enabling the same forms to be used for fabrication. For the PCa floor members, the cantilever floor members at the corners are large, measuring 6.4m by 3.2m, and two sides at the end of each overhang have rises. Special fixtures were used for form removal to prevent the members from being inclined. The same fixtures were used when erecting the members (**Fig.11**).

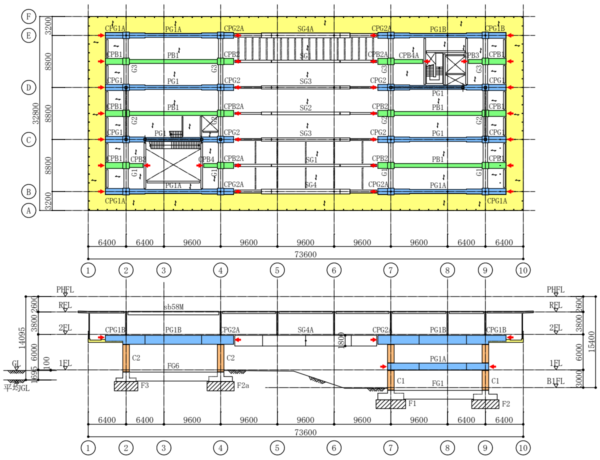

Fig.9 Layout of members

Table-1 Layout of members

Floor level - Work area	Member	Qty. (pieces)	Member weight (t)	Gross weight (t)
B1F - East	Column	8	7.75-10.04	63.96
1F - West	Column	8	14.16-15.05	115.71
1F - East	Column	8	9.52-10.16	78.72
1F - East	Girder	12	9.91-20.05	162.42
2F - West	Girder	12	15.80-24.13	236.26
2F - West	Beam	8	13.70-19.34	130.22
2F - East	Girder	12	15.80-24.13	236.26
2F - East	Beam	9	4.6-19.34	135.55
2F - East	Slab	11	5.06-8.51	63.22
2F - West	Slab	11	5.14-8.51	68.63
2F - South	Slab	12	4.73-6.27	60.21
2F - North	Slab	12	4.73-6.27	59.89

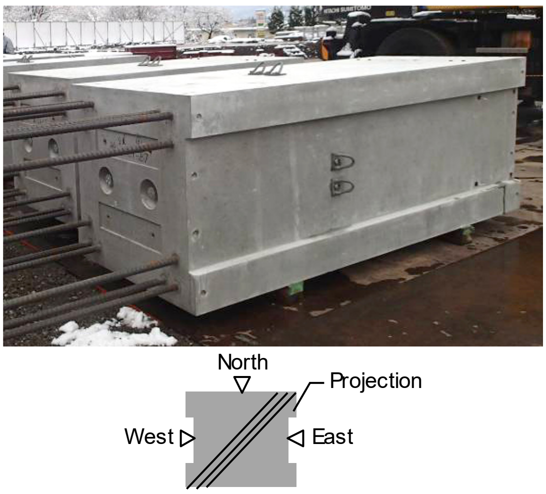

Fig.10 Shape of column menber projection

Fig.11 Fitting used to hoist PCa floor member

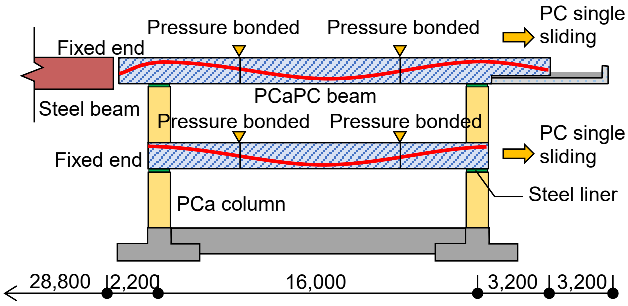

Fig.12 Framing structure of PCa columns and PCaPC beams

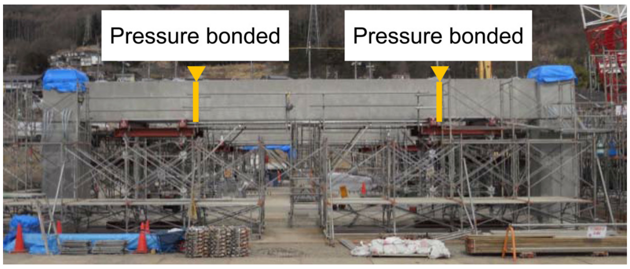

Fig.13 Installation of PCa columns and PCaPC beams

(2) Erection and Tensioning of PCaPC Beams

Because the withstand load of the carry-in route was 25t, the following erection program was incorporated in the design phase: splitting the PCaPC beams into three, carrying them on site, and then pressure-bonding the split members on site. The PCaPC beam members split into three were supported by timbering for installation. The PC cables were tensioned prior to injecting the joint mortar into the column capitals so that prestressing might not cause statically indeterminate stress. Because the authors were able to predict that the column capitals would move 3.3mm inside due to the deformation caused by prestressing, the capitals were shifted 3mm outside prior to installation.

Steel liners were used at the joints between the PCa column capitals and the lower surfaces of the PCaPC beams, thereby reducing friction and ultimately preventing constraint of the deformation caused by prestressing. The authors also took care so that the timbering supports installed at the joints of the PCaPC beams might not constrain the deformation caused by prestressing during tensioning work. The tensioned members were therefore erected as accurately as ±5mm or less.

Because the tensioning work took place prior to the floor installation, the stress conditions differed greatly between the loads in the construction phase and in the design phase. The authors considered a tensioning sequence that would not induce excessive tensile stress at the pressure-bonded joints (**Figs.12** and **13**).

5. Conclusion

Nichia Suwa Technology Center has a dynamic and flexible structural framework that appears to float in the air. Its 28.8m span and 6.4m overhangs were achieved by using a hybrid structure that combines the features of both PC and steel structures.

For the construction, the authors increased the percentage of PCa members and were thereby able both to save labor in structural work in a cold region and to improve quality by ensuring accuracy. The building was also well received by its owner, who noted that it provides a good research environment, taking in the surrounding abundant natural environment.

Consequently, the authors have realized the architectural plan that was aimed at a symbolic work that would suit two purposes: an open office space commanding panoramic views of Lake Suwa, and a building that could establish the company in the surrounding areas. This project won the JPCI (Japan Prestressed Concrete Institute) Awards for Outstanding Structures and the JSCA (Japan Structural Consultants Association) Kansai Structural Design Presentation 2017 Award of Excellence.

概　要

日亜化学工業諏訪技術センターは，諏訪湖を一望できる魅力的な執務空間を有する技術センターである。

構造躯体で構築した人工大地により執務室を浮遊させることで，周囲の豊かな自然環境を室内に取り入れると同時に，先進的な企業イメージをアピールする外観デザインとしている。

メインの執務空間を支える人工大地は，PCaPC 造と S 造を適材適所に組合わせることで，居住性と安全性の確保に加え，28.8m ロングスパンや6.4m 跳出しといったダイナミックな架構を実現し，空中に浮かせた。さらに，構造部材の数と断面を最小限とすることで，フレキシブルな空間を実現した。

施工面においては，躯体の PCa 化率を高めることで現場作業を削減し，寒冷地での施工効率・品質の向上と，省人化による労務職不足の克服を同時に実現した。