Atrium Roof Constructed with Structural Cables and Half Precast Slab — Nippon Rietec General Training Center —

構造ケーブルとハーフ PCa 床版を組み合わせたアトリウム屋根 — 日本リーテック総合研修センター —


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Synopsis

The Nippon Rietec General Training Center was constructed as the owner’s 10th anniversary project to be used for the development of technical staff. The owner requested a design concept that would advance its brand value and a mechanism to induce communication among trainees.

In response, the architect adopted “design for nurturing people” as the architectural concept and planned various communication lounges at the center of the facility along an atrium space known as the Learning Atrium. The authors adopted a cable-supported reinforced concrete (RC) slab for the roof of the atrium because cables symbolize the owner’s business (**Fig. 1**). The half-precast concave roof was constructed with full propping before the post-tensioning of the cables. When the post-tensioning load reached the specified load, the concave RC roof was lifted safely.

Structural Data

Building Area: 3,758.72 m^2
Total Floor Area: 8,074.11 m^2
Number of Stories: 1 basement level, 2 stories above ground
Maximum Height, Eaves Height: 13.93 m, 10.70 m
Cable Span: 15.0 m
Structure: Reinforced concrete
Owner: Nippon Rietec Co., Ltd.
Designer: Nikken Sekkei Ltd.
Contractor: Totetsu Kogyo Co., Ltd.
Construction Period: May 2017 – Mar. 2018
Location: Ibaraki Prefecture, Japan

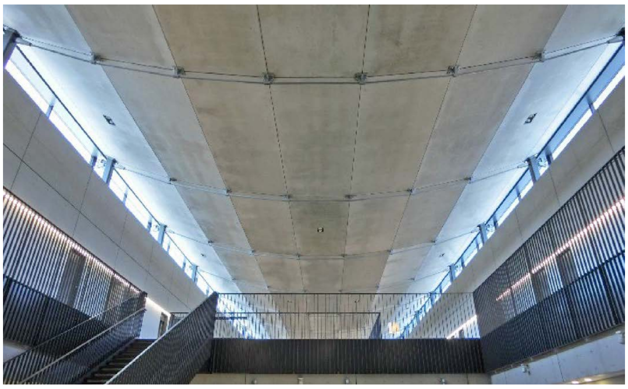

Fig. 1 Interior view of the atrium

1. Introduction

The owner, Nippon Rietec Co., Ltd., is a construction company with four businesses: railroad electrical facilities, road facilities, indoor/outdoor electrical facilities, and power transmission line facilities. This building is a training center to commemorate the 10th anniversary of the company’s founding. The training facility is aimed at providing not only classroom lectures but also practical training on electrical equipment work.

For the design of this training center, the owner requested three concepts: (1) to be a training center that serves as a platform where trainees build things on their own, (2) to include communication spaces for trainees, and (3) to be low-cost and have a short construction period. In the following report, the project is summarized.

Fig. 2 Building appearance at site entrance (photo by Harunori Noda [Gankohsha])

2. Design

(1) Architectural Design

At the center of the building is a three-story atrium that connects training rooms and accommodation rooms with lounges and other interactive spaces. The architect conceived a cable structure for the atrium roof because the owner handles cables in its business. The authors designed a half-precast slab with a cable suspension structure above the atrium, with a metal sheet providing the roof's waterproofing over the concave half-precast concrete slab.

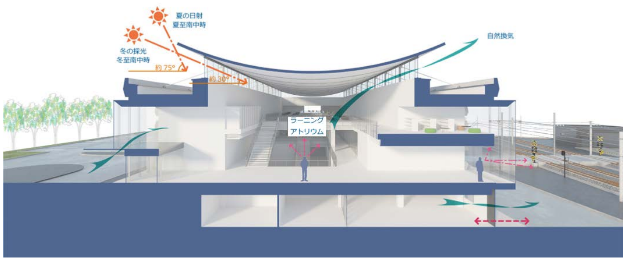

Fig. 3 Concept of atrium

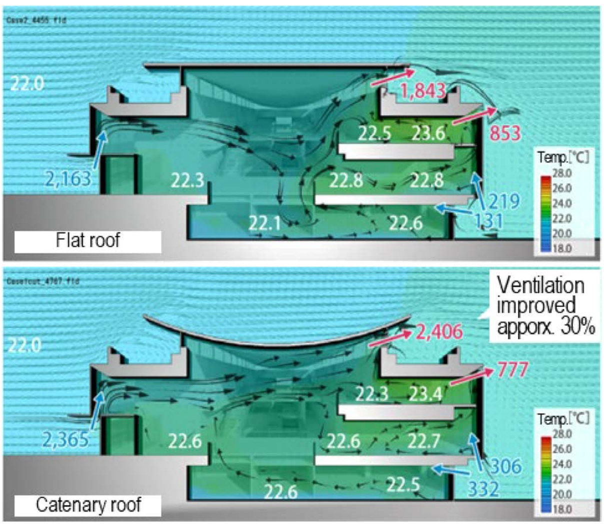

Fig. 4 Effect of roof shape on ventilation

The cable-suspension structure creates a catenary shape, and the concave roof functions successfully in providing high ventilation efficiency in the atrium. (**Figs. 3** and **4**). In addition, the clerestory between the concave roof and the walls below is effective in admitting natural light, as shown in the interior photo and the exterior photo (**Figs. 1** and **2**).

(2) Structural Cable Design

In the structural cable design, the authors' aim was that the cable tension force induced by the self-weight of the roof slab would be slightly below the long-term allowable tension. This condition ensures that the cable force remains above the lower limit of the linear range (about 10% of the failure load) when the roof is subject to wind uplift. Furthermore, the increased tension force due to vertical seismic loading should remain within the short-term allowable load (**Fig. 5**). The loading conditions of the roof is shown in **Fig. 6**. The authors selected the cable cross-section considering the aforementioned conditions.

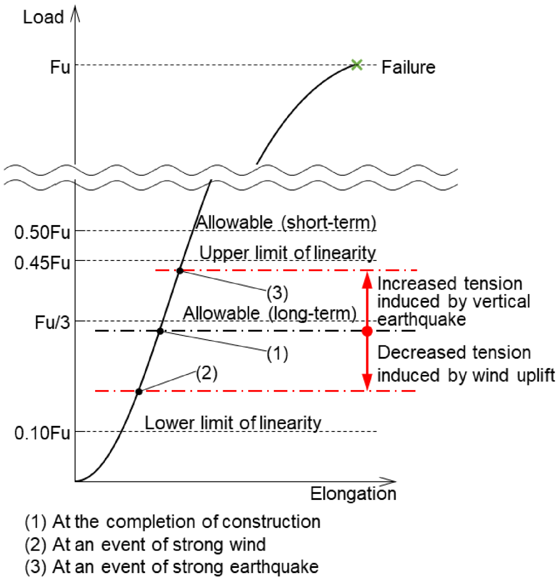

Fig. 5 Load–elongation model of cables

The architect's spatial image was that the cable ends would disappear toward the outside. Therefore, the authors started the study based on the one-cable system in a cable suspension bridge and studied the possibility of a saddle at the top of a cable support column utilized as the mullion of clerestory windows.

However, the architect requested that the size of the cable support columns be minimized and thus the authors abandoned the saddle in a column. This restriction led the authors to consider the redundancy of the one-cable system. Thus, in the final configuration, the cable support columns were the border, with outside tie bars and inside cables.

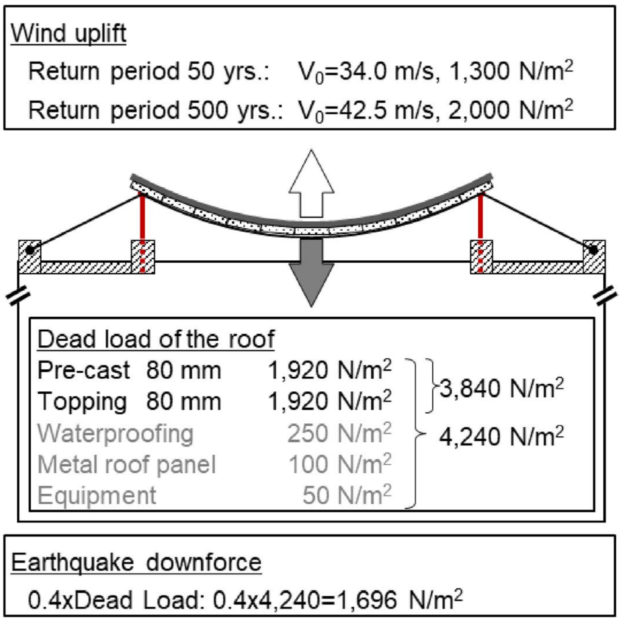

Fig. 6 Loading conditions of the roof

(3) Cable End Detail Development

The authors developed an integrated connection detail for an outer tie rod and an interior cable to realize the architect's spatial image. A threaded cast iron cable end is fixed on the pipe that penetrates the box column, and the pipe and the gusset plate for the outer tie rod are connected. The unbalanced force due to the differential angle between tie rod and cable is resisted by the flexural rigidity of the box column (**Figs. 7** and **8**). Seismic isolation was also employed because of the location's high earthquake risk.

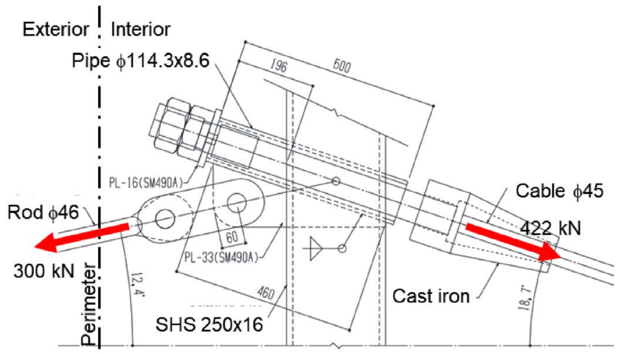

Fig. 7 Detail of the cable end and rod end

Fig. 8 Photo of cable fixing detail

(4) Lateral Resistance

As shown in **Fig. 9**, the lateral earthquake force of the roof is transferred as the flexural moment of the support columns to the main structural body.

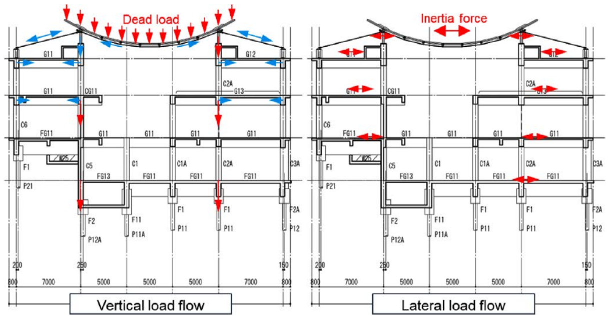

Fig. 9 Diagram of cable load transfer

(5) Cable Fastener Detail Development

The design philosophy was to minimize the risk of debris falling from the roof into the atrium throughout the design life. Considering the various tension forces induced by earthquake or wind loads, the authors developed the connection detail between the precast concrete and the cables as shown in **Figs. 10** and **11**. A clamp-type fastener is generally adopted to connect a cable to other elements, but such a fastener consists of many steel components such as plates, bolts, and nuts. Instead, the authors decided that the cables should sit in the fasteners without clamping, and the fastener length of 150 mm was decided by the pressure restriction on the cable (5 kg/mm^2). [1]

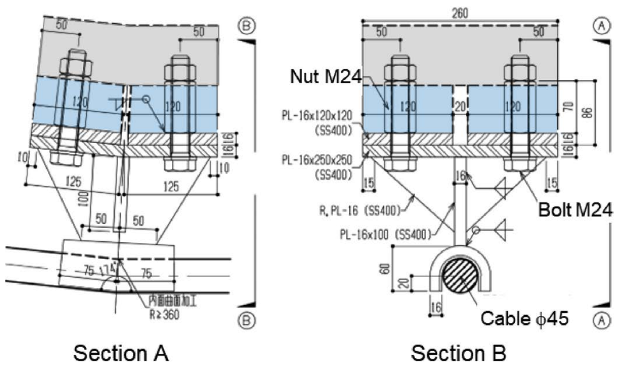

Fig. 10 Detail of precast panel fixing

Fig. 11 Photo of precast panel fixing detail

3. Construction

(1) Construction Sequence of the Roof

The half-precast concrete concave slab was constructed utilizing full propping. Prior to the concrete work, cables were set below the slab without stressing (**Fig. 12**), and each exterior rod was pre-tensioned to 125 kN prior to the tensioning of the cables.

After the full stressing of the cables up to 385 kN, the authors confirmed that the concave RC slab was lifted from the observed displacement using a high-precision displacement transducer, as shown in **Fig. 13**.

Fig. 12 Unstressed cable before tensioning work

Fig. 13 High-precision displacement transducer

(2) Cast-in-Situ Concrete of Exterior Walls

The exterior walls featuring ribbon windows were constructed with cast-in-place concrete (**Fig. 14**). Regarding the exterior walls, the owner was concerned about the ease of maintenance and stain resistance. Therefore, the contractor built mock-up walls on-site, and exposure tests were conducted to determine the appropriate shape of the concrete (**Fig. 15**). The supervisors and structural engineers also visited concrete plants to conduct a preliminary investigation with 74 queries, including the acceptance criteria of the aggregate surface water ratio. This type of quality control activity ensured fair-faced concrete quality.

Fig. 14 Ribbon windows (photo by Harunori Noda [Gankohsha])

Fig. 15 Mock-up of exterior wall concrete

4. Conclusion

The Nippon Rietec General Training Center featuring a cable-supported concrete roof and ribbon window exterior walls won the Award of the Japan Concrete Institute in 2020.

Reference

[1] Architectural Institute of Japan: *AIJ Recommendations for Design of Cable Structures*, June 1994 (old edition, in Japanese).

概　要

日本リーテック総合研修センターは，総合電気工事会社である事業者が，設立（合併）10周年目を記念して設立した研修所である。電気設備工事に関して座学だけでなく泊まり込みで実技研修を行う研修所として，事業者からの設計要求は，①事業者自らがつくり上げるプラットホームとしての研修所となること，②人を育てる交流空間を内包すること，③10周年の記念に開所するために短工期（工期10か月）かつ経済合理性を追求すること，の 3 点が挙げられた。これらの要求事項に対して，屋外実習エリアに沿って低層で平面的に長い建物とすることで短工期を実現できるようにした。その上で，内部に 3 層吹抜アトリウムを設けて諸室が交流空間でつながるようにし，アトリウム上部に事業者の事業を象徴するケーブルを構造に取り入れたハーフ PCa スラブ屋根を設けた。内部はほぼコンクリート打放し仕上げでスケルトンに近い内装とし，研修生が実習の一環として設備ボックスや照明器具などを取り付けられる仕組みとした。