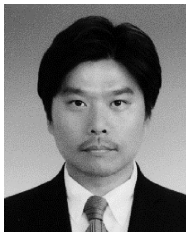
Gymnasium in the Inverted-cone Shape Using Precast Concrete Walls — Yamato Forum at Haneda Chronogate —

プレキャストコンクリートを用いた逆円錐形状の体育館の設計 — 羽田クロノゲート「ヤマトフォーラム」—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Synopsis

The Forum building (**Fig.1**) is a gymnasium that forms part of a planned community-contribution complex open to local residents at a next-generation logistics terminal called the Haneda Chronogate (**Fig.2**). It has a unique external appearance consisting of circular planes and an inverted-cone elevation surface. Faced with the challenge, we adopted the compression method for precast concrete materials as a structural solution. To construct the Forum, we devised and applied the "uplift" method, in which the precast walls' own weight was used to lift the steel roof, which was pre-assembled at ground level. This paper gives a detailed overview of this structural design.

Structural Data

Structure: PCaPC + S (precast/prestressed concrete and steel)
Total Floor Area: 1,880m²
Floors: 2, above ground
Maximum Height: 13.48m
Diameter: Roughly 60m
Owner: Yamato Transport Co., Ltd./Yamato Group
Designer: Nikken Sekkei Ltd.
Contractor: Kajima Corporation
Construction Period: Dec. 2010 – Sep. 2013
Location: Haneda, Ōta ward, Tokyo

Fig.1 Interior of Yamato Forum

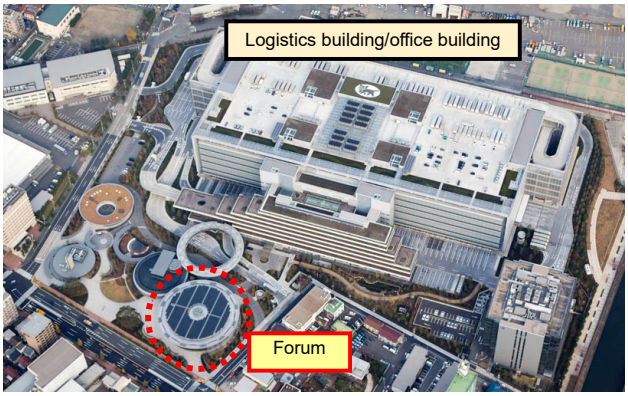


Fig.2 Panoramic view of Haneda Chronogate

1. Introduction

The Haneda Chronogate, a next-generation logistics terminal of the Yamato Group, was built in Haneda in Tokyo's Ōta ward. Close to a highway interchange and an airport, it is favorably located as a logistics site, but there are residential areas nearby. Since the planning stage, the building's owner has expressed a desire to turn this into "a logistics facility open to the local community." To the south, the plan includes an area adjacent to residential neighborhoods—the "Wa no Sato"—that will be open to residents and is intended to contribute to the local community by offering, among other amenities, a gymnasium, a café, and a parcel-delivery service counter.

Yamato Forum is one of the facilities planned within Wa no Sato. All facilities are structured on circular planes, and the elevation surface is shaped as a reversed cone, creating a unique external appearance.

2. Design

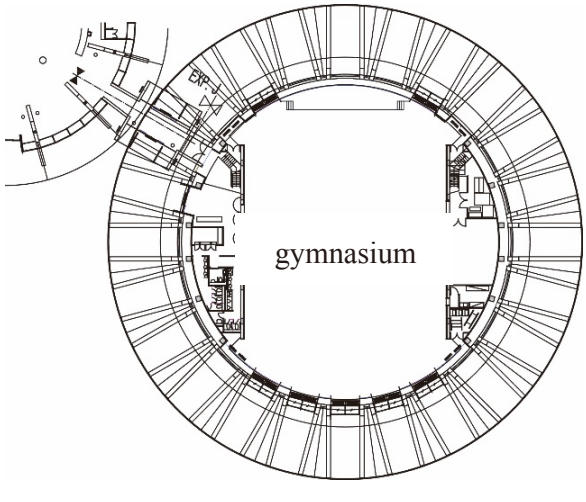
(1) Aesthetic Design and Competition

The use of circular planes differentiates from the four-sided buildings located to the rear, such as the logistics building and the office building, and harmonizes the buildings with the landscape through the smoothness of curved surfaces, reminiscent of a village forest. We also reasoned that the distinctive exterior would function as a local landmark (**Fig.3**).

(2) Structural Design

While considering the structure's type, we also considered its construction method. A reversed-cone-shaped wall was built of 24 precast (PCa) walls. Weighing roughly 90t, each wall was extremely heavy. Given the transportation and lifting constraints, we adopted a construction method whereby each plate was divided into three smaller ones that were then assembled into one on site by post-tensioning.

On the other hand, we thought that the roof's steel frame should, as far as possible, be tentatively assembled close to a stable ground surface and lifted up, rather than installing a heavy steel frame on top of an unstable upper bent. This was because we thought it would be very difficult to secure bents that would protrude more in a reversed cone's upper portion than at its base, and because an extremely high level of precision in construction would be required from an aesthetic perspective because the architects wanted the structure's hoop-type beam strings to show (**Fig.4**).



1F ground plan

Elevation

Fig.3 Plan and elevation of Yamato Forum

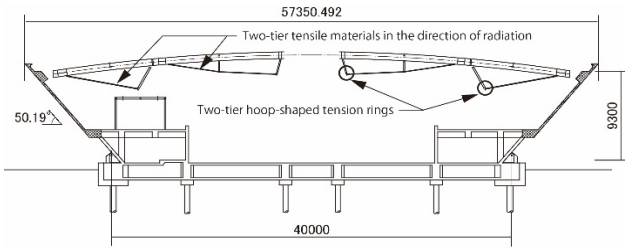


Fig.4 Section of Yamato Forum

3. Construction

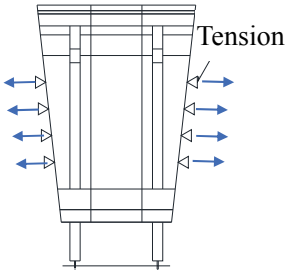
(1) Construction of Dome by PCa Wall

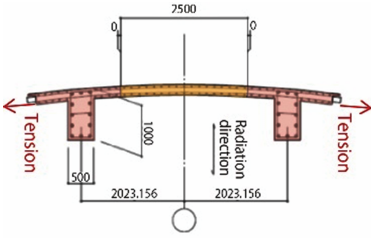
We planned an "uplift" method (**Fig.5**) whereby the steel roof was lifted by using the precast wall's own weight. This construction method entailed installing the hoop-type tension rings' post-constructed portion and closing the rings after having lifted the roof to the prescribed position, simultaneously compressing the PCa wall through pre-stress to close the lower structure as well. We thought that this construction method would be rational from a process standpoint as well because it allows work to be conducted simultaneously at two levels—the roof and the interior—immediately after completing the framework.

(2) Construction of Uplifting Work

The flow of construction is shown in **Fig.5**. Half of the 24 PCa walls (12 pieces) were set in advance at a near-vertical angle (70°). These were then linked to the roof's steel frame and assembled tentatively in a collapsed fashion. The method then entails bringing down the panels from this position, making the roof's steel frame stand out ("uplifting" it), and moving the steel frame in unison until the prescribed height to create the final shape. Dynamic lift-off employs the PCa walls' own weight. Uplifting work was controlled by simultaneously moving a horizontal jack installed in the panels' horizontally displaced portion and six jacks installed on the vent props.

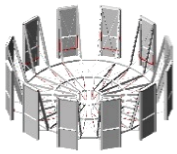
Step 1 PCa wall compression



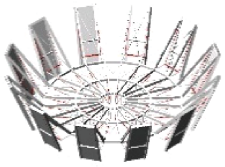


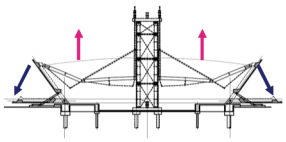
- After being brought to the site, the PCa walls, divided into three parts, are reassembled into one. This is done by tensioning a 300-pitch, 1–⌀15.2 prestressed concrete (PC) steel wire through the wall portion, and then by integrating the main reinforcement of the roof beams and two-level beams.
- While the roof is dome-shaped, combining parallel poles and parallel chord members allows for deformation in the height direction.

Step 2 Tentative assembly

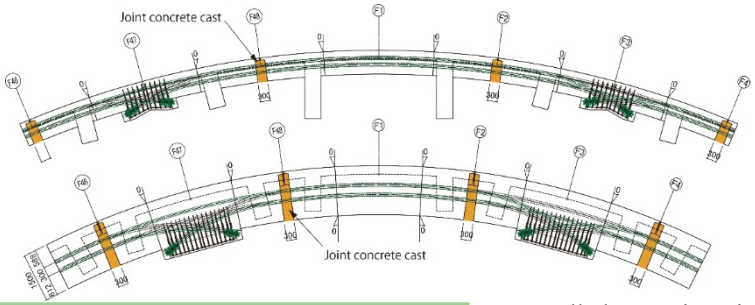


Step 3 Begin uplifting

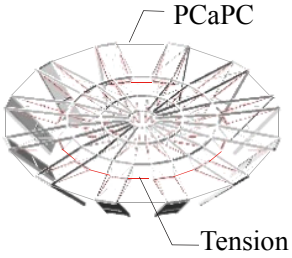


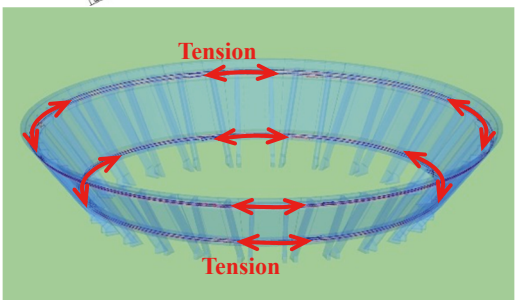


- The structure is resistant to horizontal forces exerted during the work thanks to the internal rigidity of the PCa walls and the roof's steel frame.
- Create a central vent in the oculus, and use vertical jacks to raise the roof's steel frame.

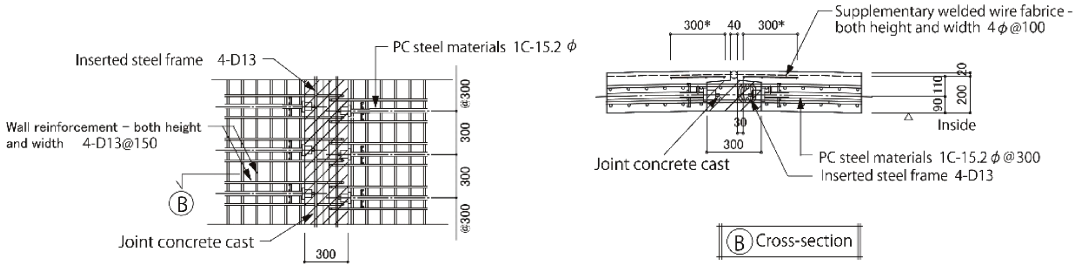


Step 4 Complete uplifting





- Install the tension ring's post-constructed portion, then pre-stress the PCa walls were jointed by post-tension and close the lower portion.
- Roof and indoor works can be carried out simultaneously after completing the framework.

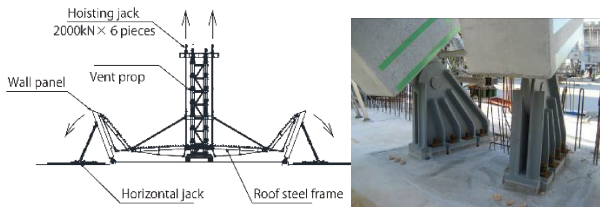


Detailed image of wall portion junctions

Fig.5 Overview of the uplift construction method and works procedures

4. Management during Works and Results

The uplift construction method involves dynamic changes of structural shapes. The work was carried out carefully while measuring the stress on materials and their coordinates, and matching the data against calculated values at each construction stage. The main measurement items were the tensile strength of the tension rings and the counterforce and displacement during uplifting. The work was completed with tension on cables fluctuating within the calculated range and showing no variations (**Figs.7** and **8**). The horizontal and vertical displacements of the roof after jacking down were roughly as calculated (**Fig.9**). This massive space emerged in an extremely quick timeframe of just 8 hrs from the start (**Fig.10**).



Overview of the uplift method

Leg hinge

Hoisting jack

Horizontal jack

Fig.6 Overview of the uplift method

5. Conclusion

Faced with the challenge of designing large-span architecture with a unique external characteristic of an inverted-cone wall, we successfully used a post-tensioning with precast concrete materials. The project also led to the development and implementation of the uplift construction method, in which walls' own weight was used to lift the steel-frame roof. Based on our measurements, we believe that we were able to successfully complete the work according to plan. We also obtained the results we had hoped for in terms of reducing work in elevated places and simplifying the internal scaffolds.

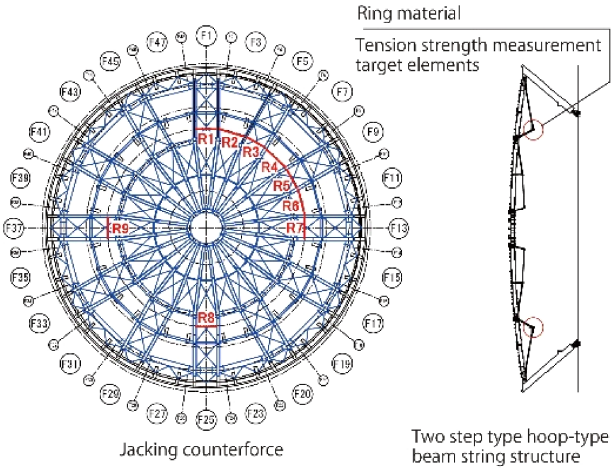


Fig.7 Positions where ring tensile strength was measured

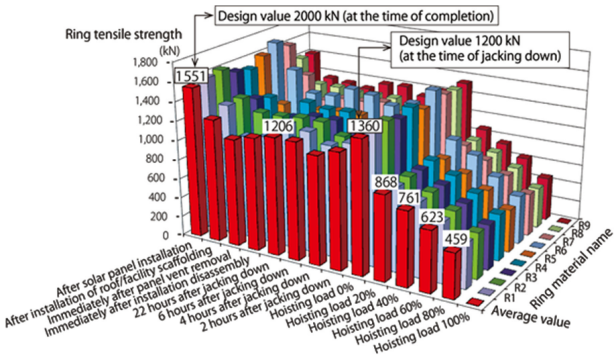
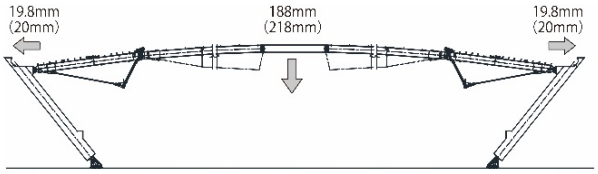


Fig.8 Changes in ring tensile strength



The above values were measured 6.0 hours after jacking
Figures in parentheses are design values.

Fig.9 Displacement after jacking down

Fig.10 After uplifting (completion after 8 hrs of uplifting)

概　要

フォーラム棟は，次世代型物流ターミナル「羽田クロノゲート」に計画された地域住民が自由に使うことのできる地域貢献施設の内の体育館である。円形平面で，立面は逆円錐形という類例の少ない外観を有している。この課題に対し，我々はプレキャスト部材の圧着工法を中心に構造的な解決を図った。さらにフォーラム棟の施工では，壁面のプレキャスト壁の自重を使って地組した鉄骨屋根を持ち上げる「アップリフト構法」を考案し，実施した。