Design of a Reinforced Concrete Double-skin Structure with Circular Window Openings — Waseda University Honjo Senior High School Gymnasium —

円形開口を有する鉄筋コンクリート造ダブルスキンの設計 — 早稲田大学本庄高等学院体育館 —

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Synopsis

This building was designed with a symbolic appearance consisting of large reinforced concrete walls (**Fig. 1**). On the outer periphery of the arena, equipment spaces and a running course were layered to form a reinforced concrete double-skin frame. Circular window openings were arranged in the large outer walls and inner walls for lighting and air conditioning, and the inner walls were also structurally designed as shear walls. To express the texture and strength of concrete, the outer and arena walls were constructed without crack-inducing joints in the concrete frame.

Fig. 1 External appearance of the gymnasium

Fig. 2 Circular window openings in the reinforced concrete double-skin wall

Building Data

Structure: Reinforced concrete structure, steel arena roof
Girder Span of Arena Roof: 43.0 m
Building Height: 18.5 m
Owner: Waseda University
Designer: Nikken Sekkei Ltd.
Contractor: Toda Corporation Ltd.
Construction Period: Jul. 2018 – Feb. 2020
Location: Honjo City, Saitama Prefecture, Japan

1. Development of the Layout of Circular Window Openings

The exterior reinforced concrete double-skin walls were designed with circular openings (**Fig. 2**), and the authors developed calculation software to study their layout in order to simulate the light and air conditioning iteratively. To realize the arena space without any blackout curtains, the software calculates the positions of the circular openings in the inner and outer walls such that no direct sunlight reaches the inside of the arena space (**Fig. 3**).

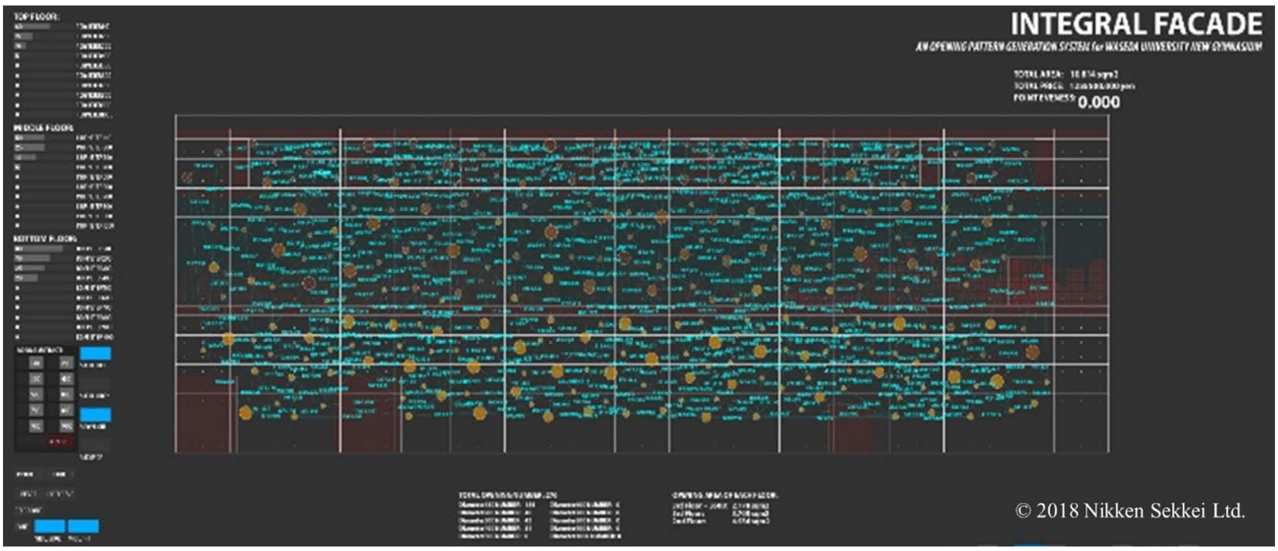

Fig. 3 Program for calculating the layout of the circular openings

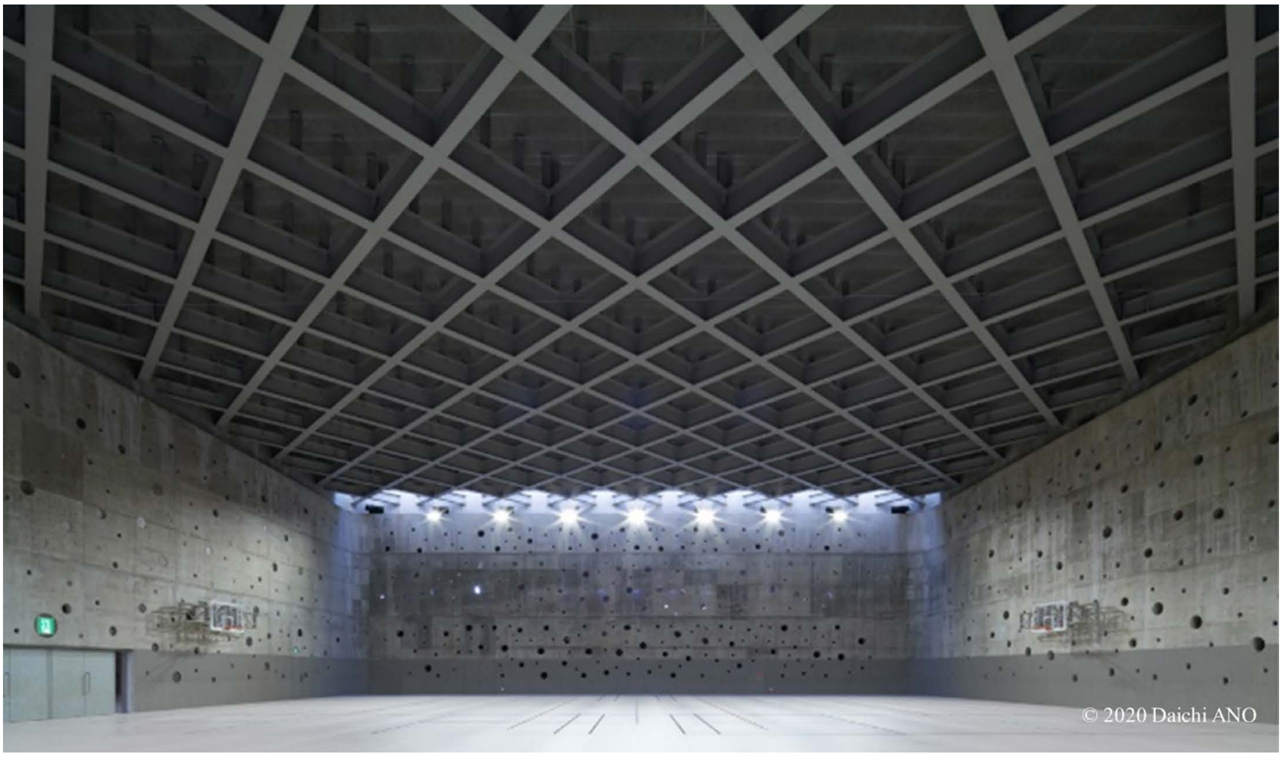

Fig. 4 Internal space of the arena

2. Roof with Diagonal Steel Frame

For the 40-m long-span roof structure of the arena, a lattice structure was chosen to span the surrounding shear walls. A diagonal lattice frame was designed to transfer the lateral load from the roof to the surrounding walls efficiently and to restrain the overturning of the double-skin walls (**Fig. 4**).

3. Concrete Double-skin Walls

The concrete double-skin walls that surround the arena were designed without crack-inducing joints to express a dynamic large wall surface. The inner walls were designed to serve as shear walls that resist the vertical and horizontal loads of the arena. Furthermore, by connecting the outer walls to the inner walls with the floor slabs of each layer, it became possible to form a Vierendeel frame, the interior of which was planned as a running course and equipment spaces (**Fig. 5**).

4. Design of Rooms on the First Floor

For the first floor of the building, to realize the appropriate span and ceiling height for each room, the authors planned the structural design differently depending on the purpose of the room.

In the lecture room and entrance hall, a slab-wall structure with haunches was used to secure the effective room heights and realize a space without exposing the beams and columns in the interior (**Fig. 6**). For the multi-purpose room, which requires a particularly large span and ceiling height, prestressed concrete beams were used as inverted beams. Also, to integrate structural and facility design, the spaces between the beams are used effectively as equipment enclosures for air conditioning and lighting (**Fig. 7**).

Fig. 5 Running course

Fig. 6 Lecture room

Fig. 7 Internal space of the multi-purpose room

5. Large Concrete Walls without Crack-inducing Joints and Their Construction

To achieve large concrete walls without crack-inducing joints, careful consideration was given in each phase of the design and construction. In the design phase, the authors planned to disperse the cracks by arranging reinforcing bars, and they calculated the predicted crack widths. Also, by not grounding the outer walls, it released them from the restraining force and helped to create an impressive appearance for the entire building as well as preventing concrete cracks. In the construction phase, the authors selected admixtures that matched the concrete properties of the local ready-mixed concrete plant, and they gave careful consideration to aspects such as the timing of concrete pouring based on the outside temperature and planning finely divided concrete pouring sections. In this way, the authors realized jointless exposed concrete.

For the construction of the circular openings, two construction methods were used in combination: (i) void formwork and (ii) removing the concrete cores after placing the walls. If all the openings had been constructed with void formwork, the formwork processing and erection would have been too complicated and the concrete pouring performance could have been adversely affected. Thus, it was instead decided to use core boring for the smaller openings after construction.

概　要

本建築物は，鉄筋コンクリート造長大壁面によって構成した体育館である。内外の壁面には採光のための大小さまざまな円形開口を設けており，力強い遺跡のようなファサードとした。外周部分は鉄筋コンクリート造のダブルスキンとしてフィーレンディール架構を構成し，この間はランニングコースや設備空間として計画している。主たる耐震要素でもある内壁にも，複数の円形開口を設けることで，外部からの自然光を調整し，また温湿度環境もコントロールして運動に集中できるよう建築，設備計画を統合した設計を行った。建物全体においても，コンクリート打放し仕上げなど，徹底したコンクリートによる建築表現を追求し，力強さを表現するために長大壁面にはひび割れ誘発目地は設けず，石灰石骨材使用や混和剤の技術的工夫で，ひび割れ抑制を行っている。