Structural Design for a Stadium Inspired by Traditional Wooden Frames Using Precast Members
— Mie Prefectural Stadium —

プレキャスト部材を用いた伝統的な木組みをイメージさせるスタジアムの構造設計
— 三重交通 G スポーツの杜 伊勢 陸上競技場 —

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Synopsis

This paper provides an overview of the structural design of the Mie Prefectural Stadium located in the Jingu Forest in Ise. The beauty of this stadium is its simple structure that evokes a traditional wooden structure by making full use of modern technology, such as prestressed concrete beams with precast concrete members and a hanging roof structure using tension rods.

Structural Data

Structure: Precast prestressed concrete and steel
Number of Stories: 4
Basic Span: 10.1 m (X-dir.), 9 m and 14.2 m (Y-dir.)
Total Floor Area: 13 547 m^2
Height: 27.80 m
Owner: Mie Prefectural Government
Designers: Yasui Architects & Engineers, Inc.
Constructor: Shimizu/Horisaki/Ito joint venture
Construction Period: Mar. 2016 – Oct. 2017
Location: Mie Prefecture, Japan

Fig. 1 Location

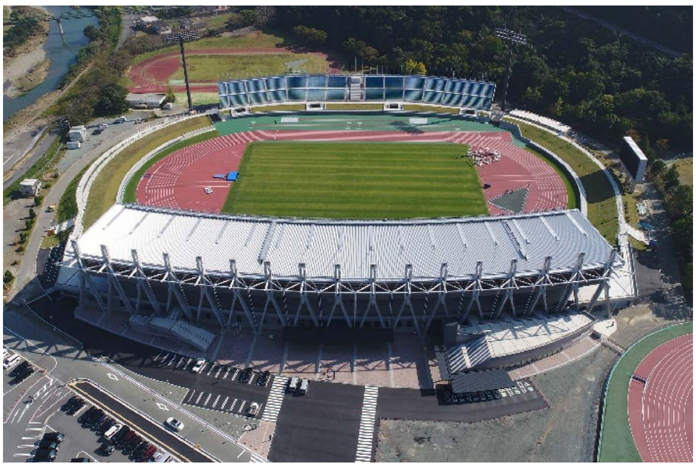

Fig. 2 Bird's-eye view

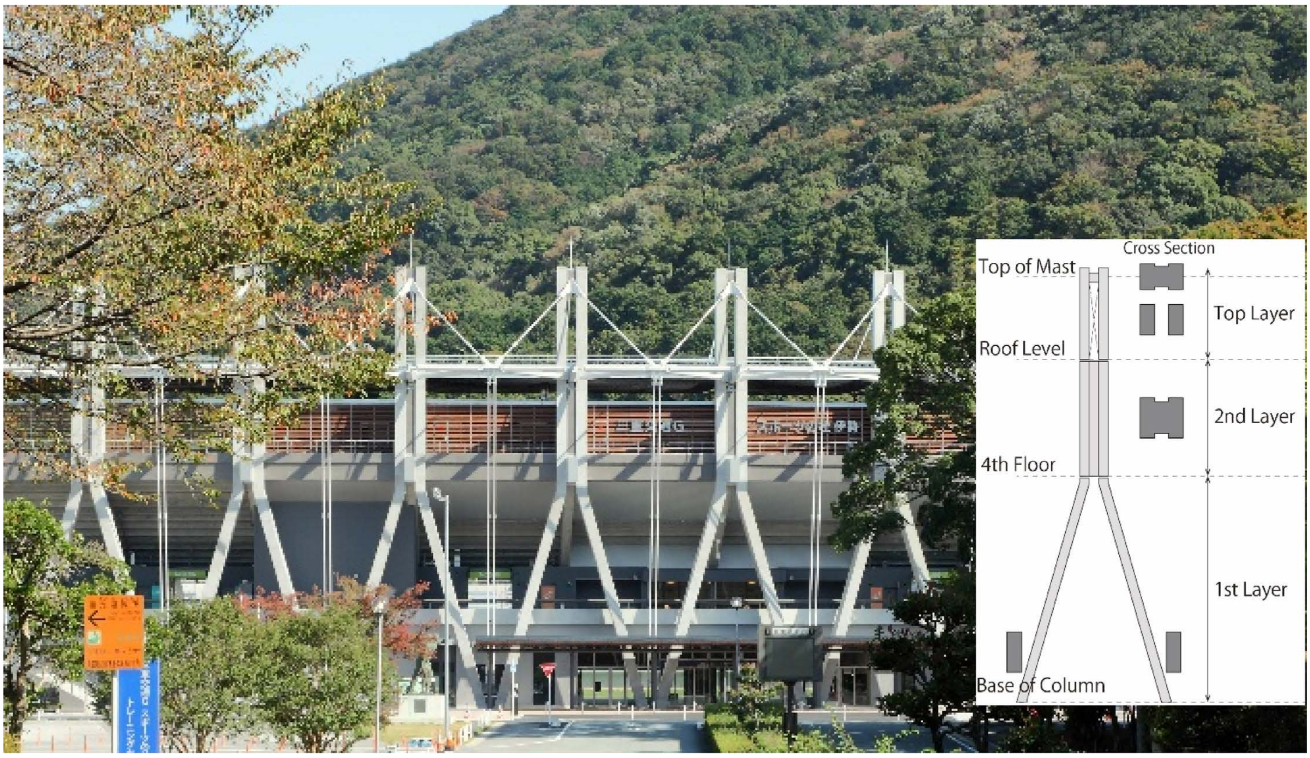

Fig. 3 Outside view and cross section of assembled columns

1. Introduction

The stadium was built in Isuzu Park adjacent to Jingu Forest in Ise City, Mie Prefecture (**Fig. 1**). The main concept of the stadium is a stadium in a forest suitable for Ise and connected to Naikū of Ise Jingu (**Fig. 2**). Naikū is the most venerable sanctuary in Japan, and Amaterasu Ōmikami, an ancient god in Japan has been revered there as a guardian for about 2000 years.

2. Design

(1) Planning of Stadium

Spectators can view the players warming up in the adjacent sub-stadium from the approach terrace, and the concourse behind the main stand connects to the side and back stands allows walking around the second floor to enjoy various activities (refer to **Fig. 5**).

The main structure uses precast linear members, and this frame design evokes the image of a traditional wooden structure. In addition, a hanging roof structure was adopted to create a lightweight flat roof that is low in height, reduces the volume of the structure, and is in harmony with the mountain landscape in the background (**Fig. 3**).

(2) Structural Planning

The structural design of the stadium was proceeded with the aim to achieve the following goals: a large roof that spreads gradually, a structure reminiscent of traditional construction methods in Ise, and appropriate management of construction costs.

From the front approach, one can observe the greenery of the park in the foreground and the beautiful mountain greenery in the distance. A hanging roof structure using tension rods was adopted to blend in the 25 m overhanging roof with the surrounding scenery. This was achieved by composing the structure mainly with axial members having smaller cross-sectional dimensions (**Fig. 4**).

Fig. 5 shows the floor plan and structure type.

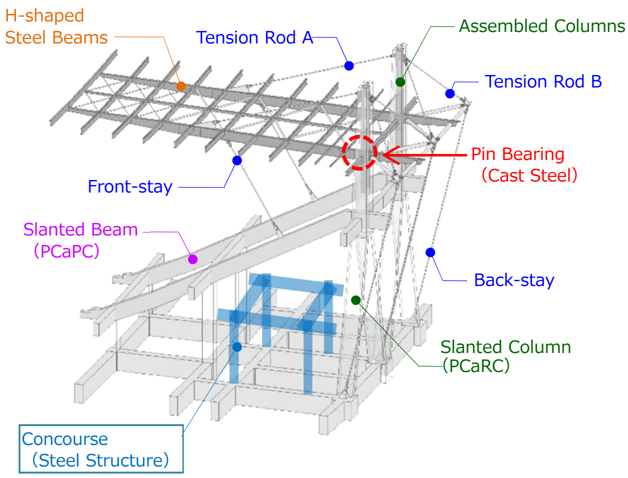

Fig. 4 Basic structural concept

(3) Roof Structure

Back-stays (tension rods 2-∅90 mm) to support the large roof extend vertically from the bases of the slanted columns and extend diagonally toward the mast tops at roof level. This is effective for preventing the tension rods from acting as braces during an earthquake

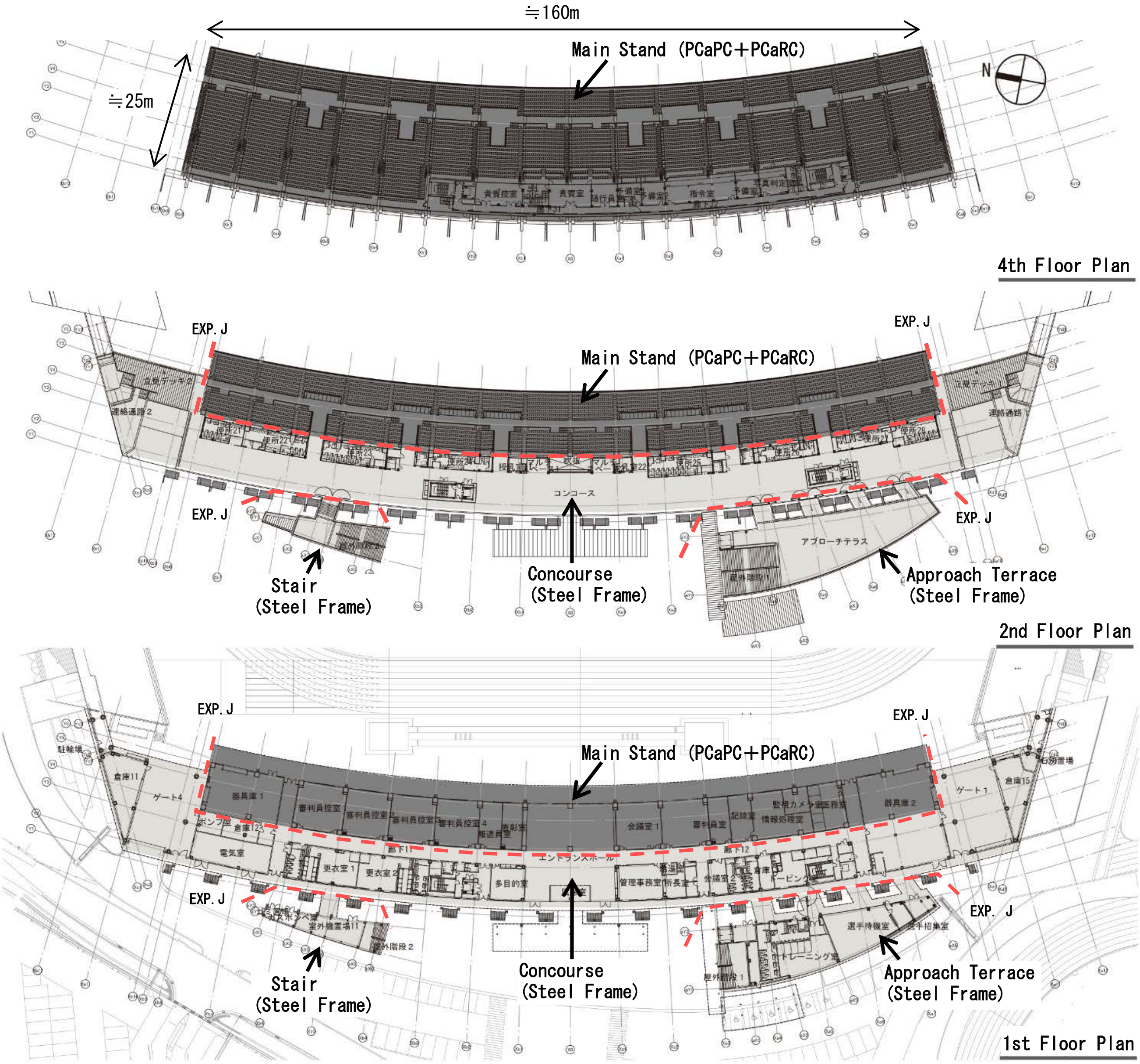

Fig. 5 Floor plan

and causing unexpected damage.

The front-stays—which resist blow-up in strong winds—were installed inside the spectator seats for structural rationality. At that time, while confirming the spectator's line of sight was not blocked by using building information modeling (BIM), the positions of the front-stays were decided with the consent of the building owner (**Fig. 6**).

By introducing prestressing force, the tension rods are expected to stabilize the large roof and cancel out the base moments of the cantilever columns (assembled columns) in the second layer. The initial prestressing force was set to a value that satisfies the following two requirements: the level of the roof surface matches the design value when tension is introduced, and the front-stays remain in tension during strong winds (downwash).

(4) Structural Planning of Main Stand

The span in the longitudinal direction is 10 m, and precast reinforced concrete (PCaRC) beams are used. In the span direction, the authors realized a frame with a maximum span of 14.2 m by using post-tensioned precast prestressed concrete (PCaPC) beams. The stepped floor—which occupies the majority of the stand—makes two steps in one piece with PCaPC, thereby minimizing the portions of cast-in-place concrete.

(5) Joints between Reinforced Concrete and Steel Elements

The steel beams on the roof surface and the assembled columns intersect three-dimensionally, creating joints that evoke the image of *nuki*, a traditional Japanese joinery technique.

In the first layer, two slanted columns form a triangle,

and they become a pair of parallel columns in the second and top layers. This pair of columns is bundled in the second layer, and a pin bearing is installed to join the H-shaped steel beams on the roof surface through the columns (**Fig. 7**). At the mast top, the pair of columns is bundled again and a steel element is embedded in the reinforced concrete portion, thereby simplifying the joint where the tension rods are attached from three directions.
In the joints where multiple members gather, the joint details and its constructability were confirmed by BIM (**Fig. 8**).

(6) Seismic Design and Ensuring Safety

This building has a low degree of indeterminacy and is balanced by an axial force system; thus, it is designed to be elastic against loads assuming a large earthquake, with fail-safe for increased safety. In addition, even if the prestressing force of some tension rods were to be lost for some reason, it is designed so that the large roof can be maintained, thereby ensuring sufficient safety.

(7) Cost Control

In the preliminary design, construction costs were estimated at several stages for cost control. Based on this rough estimation, precasting the entire frames of the stand would cause a budget deficit, so a steel frame structure for the concourse section was adopted, which is independent within the stand frames. As a result, the stands—which can be said to be the skeleton of the stadium— are designed as reinforced concrete structures, and the concourse that extends indoors and outdoors, the deck with standing room, and the approach terrace are designed as steel structures.

Fig. 6 Outside view: southeast side

In the conventional stadium construction, short columns due to slanted beams often cause structural weakness and other problems. In this stadium, above mentioned problems were solved by adopting different structural types in the right places.

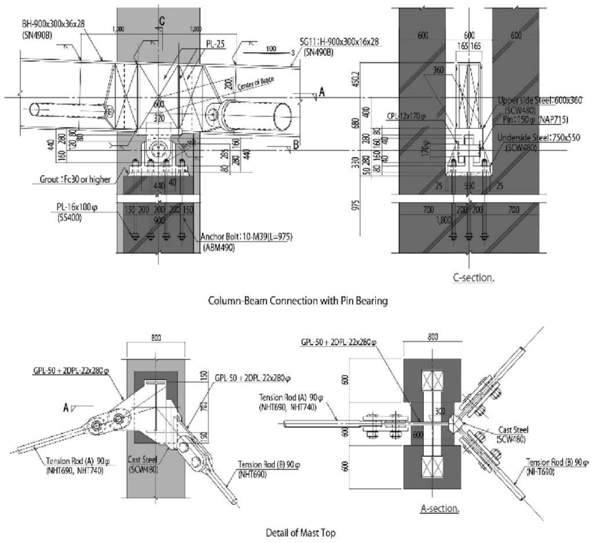

Fig. 7 Joint of reinforced concrete and steel elements

Fig. 8 Assembled columns with back-stays

概　要

本建物は，三重県伊勢市に位置し，神宮の森に隣接する「五十鈴公園」内に建つ。“「伊勢」に呼応した競技場”を実現するため，プレストレストコンクリート梁を含めたPCa部材やテンションロッドを用いた吊り屋根構造などの現代の技術を用いて「伝統工法」を連想することのできる建物とした。木組みのような構造体をそのまま外観デザインとし，自然景観との調和や地域性の表現という課題に対する解とした。軸力系の部材でバランスを保つ構造形式のため，一部のテンションロッドで初期張力が消失しても屋根を維持できる設計とし，大地震時を想定した外力に対して弾性設計を行うなど，十分な安全性を確保した。