Space Design Realized by the Using Grid of Prestressed Concrete Plate — Gymnasium in Tanabe Sports Park —

プレートグリッドを用いて実現した空間設計 — 田辺スポーツパーク　体育館 —


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Keywords: diagonal lattice, sports space, interdependency structure
DOI: 10.11474/JPCI.NR.2018.55

Synopsis

Roof structure that covers a large space, such as a gymnasium, is commonly constructed using a lightweight material, such as steel or wood. However, in this gymnasium, we decided to use precast-concrete (PCa) columns and beams, so that their effectiveness as a structural frame was proved in not only structural rationality and workability but also architectural design.

Structural Data

Structure: Reinforced concrete (RC), partially precast reinforced concrete (PCaRC), precast prestressed concrete (PCaPC), steel frame
Construction area: 5,619.13m^2
Total floor area: 7,964.24m^2
Number of floors: two floors above ground, underground one floor
Height: 19.03m
Owner: Tanabe City
Designer: Ishimoto Architectural & Engineering Firm, Inc.
Constractor: Tanaka, Toho, and Uraji Joint Venture
Construction Period: December 2012 to May 2014
Location: Wakayama Prefecture, Japan

1. Introduction

Kumano has been considered a sacred site associated with nature worship since prehistoric times. People took some days walking down the mountain road called Kumano Kodo, aiming at the Kumano Hongu Taisya (**Fig.1**). Tanabe City, known as the gateway to the world heritage now, is a scenic land located on the coastline of Wakayama Prefecture and has prospered as a key hub of traffic for over 1200 years. On the other hand, a big earthquake predicted would occur shortly in this area.

Fig.1 Kumano Hongu Taisya and Kumano Kodo (In Tanabe City)

In Tanabe City, a comprehensive sports center "Tanabe Sports Park" was developed in 2015 (**Fig.2**). This work is a gymnasium in this park.

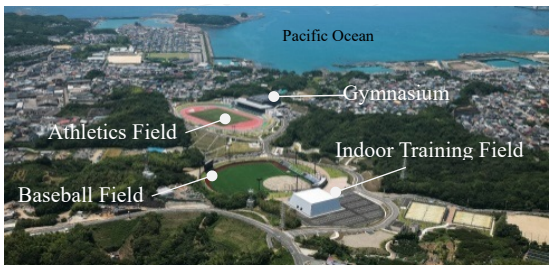

Fig.2 Panoramic View of Tanabe Sports Park

2. Design

(1) Design Concept

We aimed at a gymnasium arena symbolizing both the historical features of this area and seismic resistance. Therefore we adopted a structural design, which makes people conjure up the image of Kumano Kodo or Kumano Hongu Taisya, with reinforced seismic capacity.

(2) Architectural Design

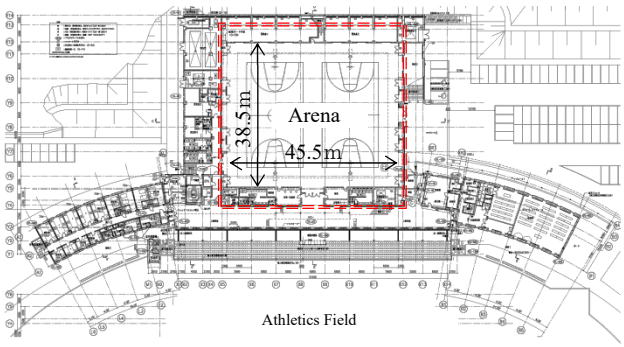

Fig.3 First Floor Plan

The arena, the center of the gymnasium building, has a shape of regular quadrangular pyramid surrounded by inclined walls with a base side of 48.1m and a top side of 39.0m (**Fig.3** and **4**). In addition, rib-shaped column beams, functioning as an interior design in themselves, were used to improve seismic resistance. The former is a metaphor for the roof of Kumano Hongu Taisya, and the latter is a metaphor for the trees of Kumano Kodo.

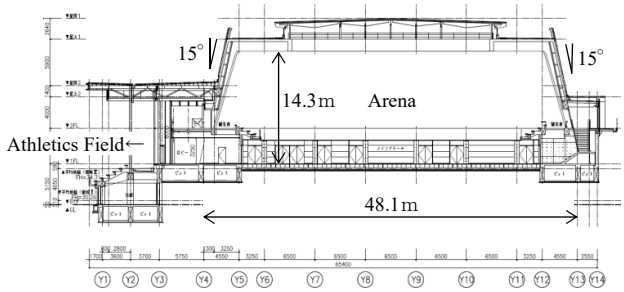

Fig.4 Section of the Gymnasium Building

(3) Structural Design

A structural system that can rationally construct large space surrounded by inclined RC walls was adopted. PC diagonal lattice frames were bridged 45 degrees to the plane and each frame was arranged to balance the thrust force caused by the inclination of the wall (**Fig.5**). In addition, the lattice beams and columns consisting of thin plate-like members, named "Grid Plates," were used, although plate-like member structure is usual in wooden construction. Using this reinforced grid plates, which are PCa columns and beams and have the flexibility of stress adjustment, has significantly contributed to slimness and sophisticated space design. The intersection of PCa columns and beams was connected smoothly with R shape for conveying large stresses generated at intersections and creating inner space like being in the woods. Using a structural framework as a substitute for the ceiling dramatically reduces the risk of ceiling fall during a major earthquake. The central part of the roof made of steel to save weight and be useful for flue gas and daylighting. As for the steel frame roof members, thin plate-like members were used to harmonize with "Grid Plates."

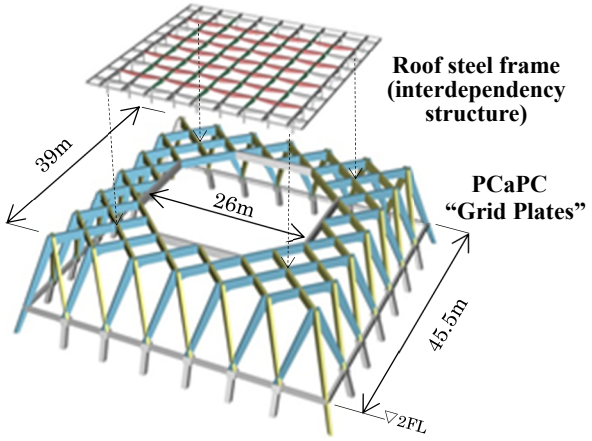

Fig.5 Arena Framing Image

(4) Seismic Design

RC walls were arranged in a well-balanced manner to maintain high strength even in case of a major earthquake. Furthermore, since this arena becomes a local evacuation facility at the time of a disaster, it was designed to have 25% more seismic resistance than ordinary buildings.

(5) PCa Member Design

The thickness of the members was thin as much as possible to be suitable for "Grid Plates." DYWIDAG method was adopted for prestress introduction of beams. Post-tension method was also adopted to place PC steel strand wires with a diameter of 15.2mm (SWPR 7 BL). Detailed investigation about tension fixing the part, cable wiring, and material splitting position made it possible to reduce the primary member thickness to 300mm. The arrangement/non-

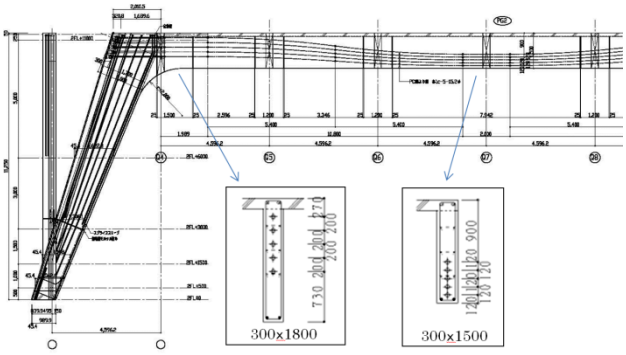

Fig.6 PC Connection/ Tendon Profile

arrangement of the PC cable was selected depending on the stress so that the cable anchorage did not appear on the center side. The precast concrete column bases were made as cast-in-place concrete.
The PC tendon profile is shown in **Fig.6**.

3. Construction

(1) Construction of PCa Member

Shape and arrangement of members are shown in **Fig.7**. The members consist of eight kinds of beams and four types of columns. Several models were made (**Fig.8**) and the problems related to the three-dimensional intersecting parts and inclined columns were multilaterally investigated using them. Particularly about the column bases where the reinforcing bars arranged complicatedly, their position was examined in detail using 3DCAD to reflect it in production.

(2) Construction of PCa

The panoramic view of PC construction is shown in **Fig.9**. In the range of 963mm from the column bases, concrete was cast on site (**Fig.10**). Splice sleeves connected the main reinforcement standing up from the bottom and the main reinforcement driven into the PCa columns (**Fig.11**). The joining of column capital members and column base members was very precisely carried out (**Fig.12**).

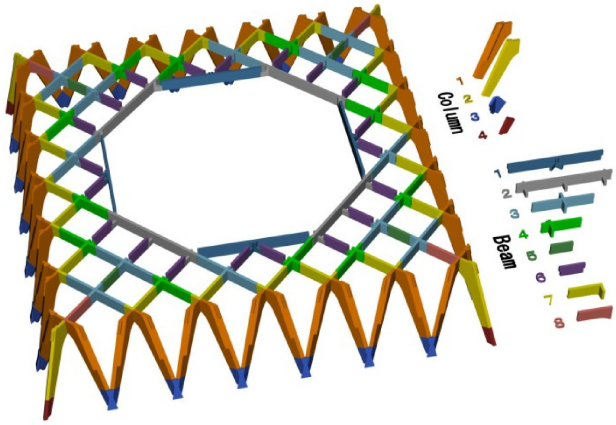

Fig.7 PCa Member Arrangement and Shape Diagram

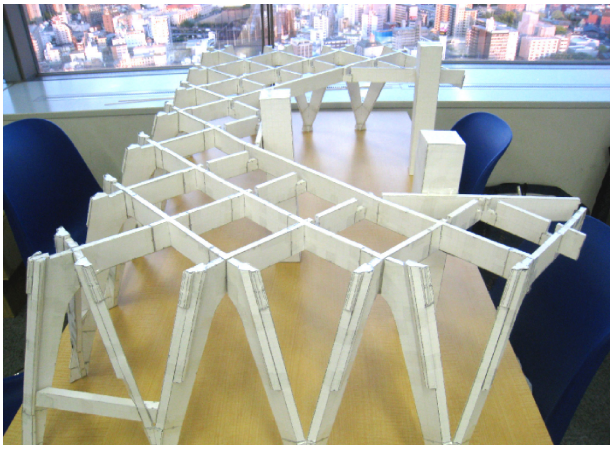

Fig.8 Model for Investigation

Fig.9 Panoramic View of PC Construction

Fig.10 Construction of Columns

Fig.11 Column Members Erection Completed

Fig.12 Member Crossing Parts

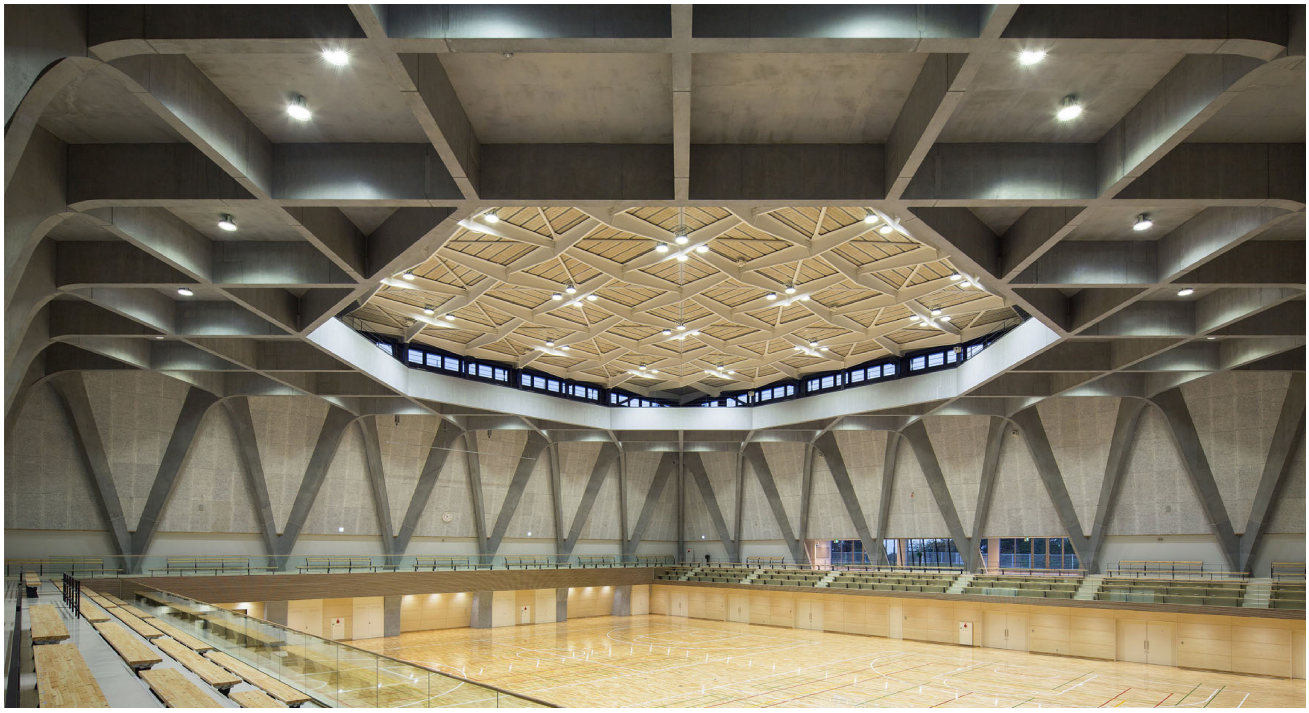

Fig.13 Arena Inside

Fig.14 Grid Plates

Fig.15 Exterior of Gymnasium Building

4. Conclusion

The exterior of the gymnasium building is symmetrical and symbolic (**Fig.15**). Standing inside the arena, you can feel as if you are surrounded by the trees of the Kumano Kodo and feel the soft light from the high-side light like sunbeams streaming through leaves, shining the interior gently (**Fig.13** and **14**). By this work, the effectiveness of "Grid Plates," framing construction method, was demonstrated in not only structural rationality and workability but also architectural design.

概　要

体育館棟の中心となるアリーナは，田辺にある熊野大社の屋根のメタファーとして，正四角すい台形状を設計コンセプトとし，外壁は垂直に対して15度の傾斜を持っている。本作品では上記のコンセプトを実現するためにRCおよびPCa部材を構造躯体として積極的に用いることにより，施工性，意匠性並びに耐震性に優れた魅力のあるPCaPC架構による大空間設計の一手法を実践した。

体育館の平面に対して45度の方向に，PCaRCの柱とPCaPCの梁からなる幅の薄い門型ラーメン架構を格子状に配置することにより，「プレートグリッド」を形成し，アリーナの大空間を構成している。

今後の大空間構造におけるPCaPC架構の可能性を提案し，また大空間構造物において，しばしば問題となる大地震時の天井落下の危険性を，構造躯体そのものを天井とすることにより大幅に低減している。