Football Stadium using Precast Prestressed Concrete Structure
— Suita City Football Stadium —

プレキャストプレストレストコンクリート構造を用いたサッカー専用スタジアム
— 市立吹田サッカースタジアム —


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Synopsis

A major challenge facing the construction industry in Japan is how to improve productivity to compensate for the decreasing number of workers. When constructing this stadium, it was vital to build the concrete structures of the stands efficiently and quickly. In the early design phase, the designers and worksite office personnel held discussions and decided to use various precast (PCa) construction techniques. This paper provides an overview of the structural design of the stands and describes a construction system based on the extensive use of PCa concrete elements that the authors used to shorten the construction period and reduce the required number of workers.

Structural Data

Structure: Reinforced concrete (including some use of partially prestressed concrete)
Roof Structure: Steel frame construction
Structure Type: Oil-damper protected frame structure combined with seismically isolated roof structure
Foundation Type: Pile foundation
Covered Area: 24,717.59 m^2
Administrator: Gamba Osaka
Design and Construction: Takenaka Corporation
Construction Period: Dec. 2013 – Sep. 2015
Location: Suita City, Osaka Prefecture, Japan

Fig.1 Completed stadium

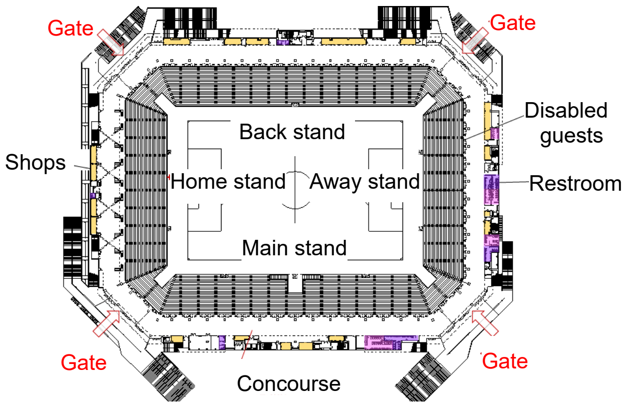

Fig.2 Third-floor plan

1. Structural Planning

(1) Structural Planning for the Stands

The authors decided to make the stands of reinforced concrete (RC). This was done to give rigidity to the structure to prevent vibrations due to many people walking or jumping up and down in unison when cheering for the players. The authors also planned to use partially prestressed concrete (PPC) beams to reduce the beam profile areas and prevent cracking. A pure frame structure was employed, with protection provided by 51 energy-absorbing oil dampers.

The concrete strength was engineered for each specific requirement. The authors ensured specified concrete strength of 45MPa for columns and beams, 24N/mm^2 for floor slabs, 100N/mm^2 for certain columns supporting the roof, and 200N/mm^2 for some columns (mentioned later) supporting the home stand.

(2) Planning the Structure of the Concourse and Lower Stands

Fig.3 is a framing elevation showing the use of PPC beams and the extensive use of PCa concrete elements. Along the concourses, columns support spans of 10.75m with 4.05m cantilever beams. PPC beams (600mm × 1,000mm) were used to handle these loads. Most of the floor consists of perforated prestressed concrete slabs that are either 175mm or 200mm thick. The stadium was thus given a simple structure based on columns and beams.

The structure of the lower stand, extending from the third-floor concourse to the front row of chairs in each stand, has columns that support spans of 8.55m or less, topped by RC beams (600mm × 1,000mm). PCa steps were placed directly on stepped beam structures without using floor slabs.

(3) Planning the Upper Stand Structure

The structure of the upper stand includes a floor inclined at 35° with an outward cantilever of 4.925m at the normal sections and 7.480m at the corners. The authors decided to use PPC beams in the normal sections because the beams bear the load of the outer wall, subjecting them to large bending moments. Because fabrication and transportation difficulties made it infeasible to prepare them as unitary PCa beams, the authors planned to divide the entire geometry into independent parts in a manner that would not affect the overall structural performance appreciably and to form each beam by prepressing multiple PCa concrete beams. **Fig.5** shows the upper-stand structure PPC beam connection diagram (for normal sections). The beams have a cross section of 600mm × 1,250mm in the normal sections and 800mm × 2,200mm maximum at the corners.

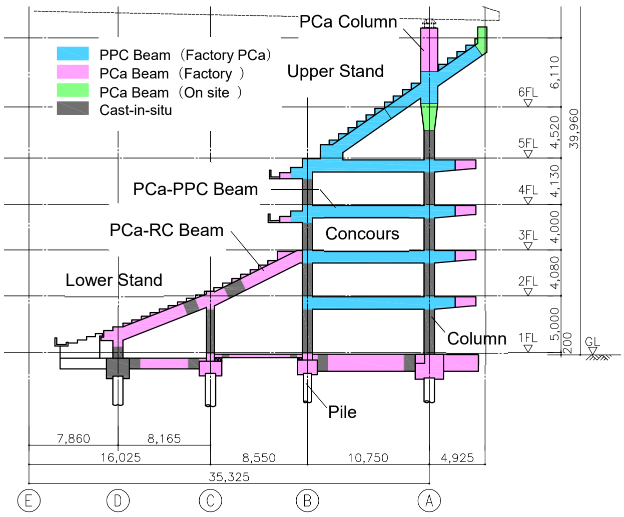

Fig.3 Framing elevation (showing the use of PPC beams and PCa concrete elements)

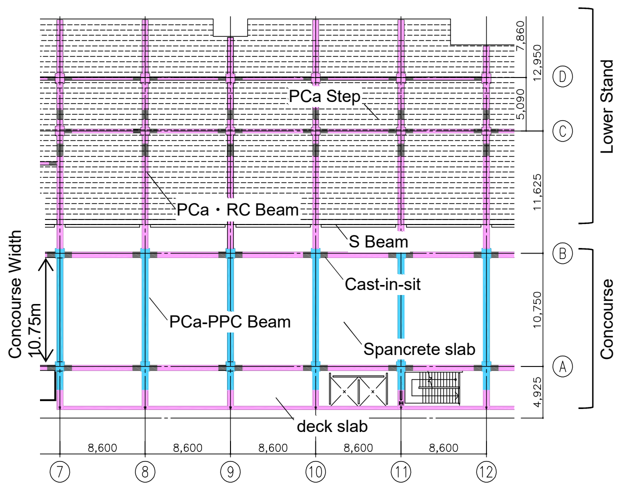

Fig.4 Third-floor framing plan construction

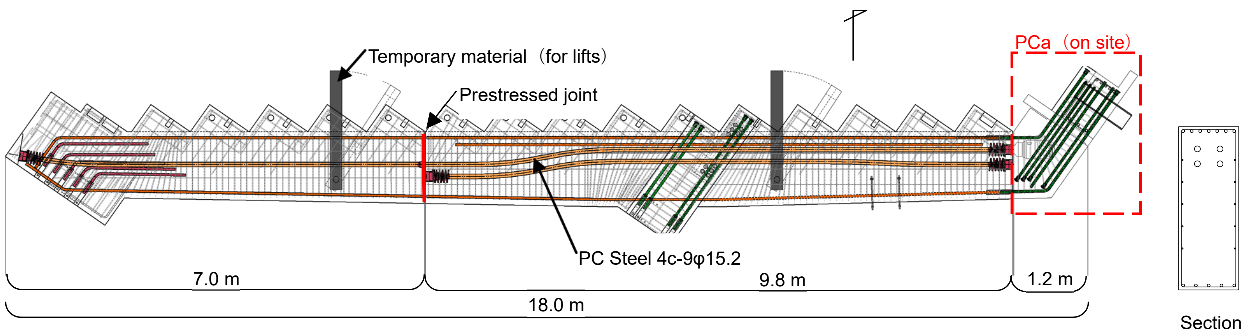

Fig.5 Connection diagram of upper-stand structure PPC beam

2. Roof Structure

To achieve a span that was both long and light, the authors used a single-truss steel-frame structure for the roof and supported it with seismic isolation devices placed immediately below the roof. These devices comprise laminated rubber bearings with excellent attenuation characteristics, together with direct-acting rolling bearings.

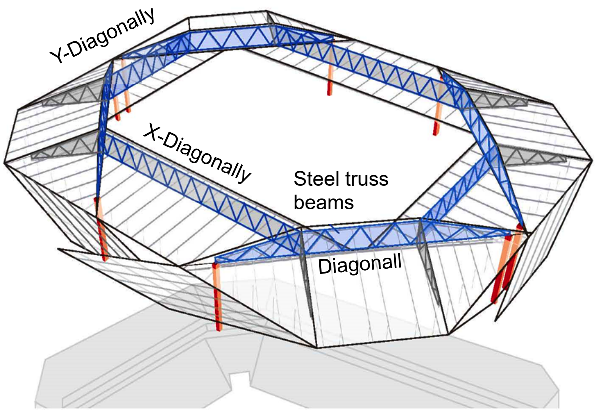

Fig.6 Roof structure

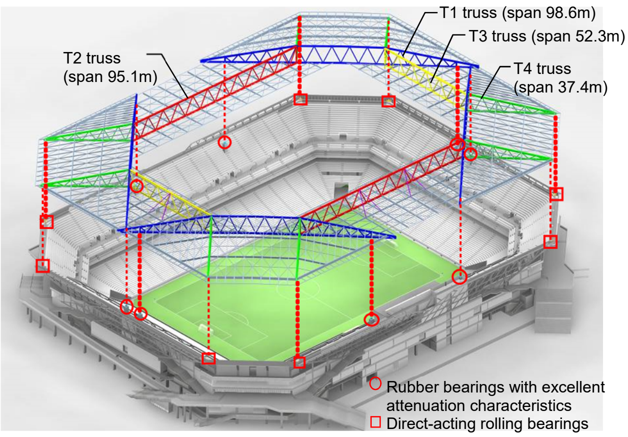

Fig.7 Roof isolation system

Fig.8 High-damping laminated rubber bearing

3. High-strength Slim Columns

Fig.9 shows a framing elevation of the home stand, showing the elements of the high-strength slim columns. The home stand has a wide area for spectators in the lower stand and therefore has a sectional plan that differs from those of the other stands, characterized by the use of diagonal columns above the third-floor concourse. These 10 diagonal columns are configured as slim columns (350mm square) of high-strength concrete with a specified concrete strength of 200MPa. They help to relieve the visual impression of oppression from the structure above the concourse (**Fig.10**).

The high-strength concrete contains steel fibers (produced by Bekaert; 30mm long and 0.62mm in diameter) that improve the plastic deformability of the columns by preventing separation of the covering concrete. Using main-reinforcement rebar of SD685 grade and with shear reinforcement, rebar of SD785 grade (weld-closed type) were fabricated as PCa modules at a special factory officially accredited for such procedures.

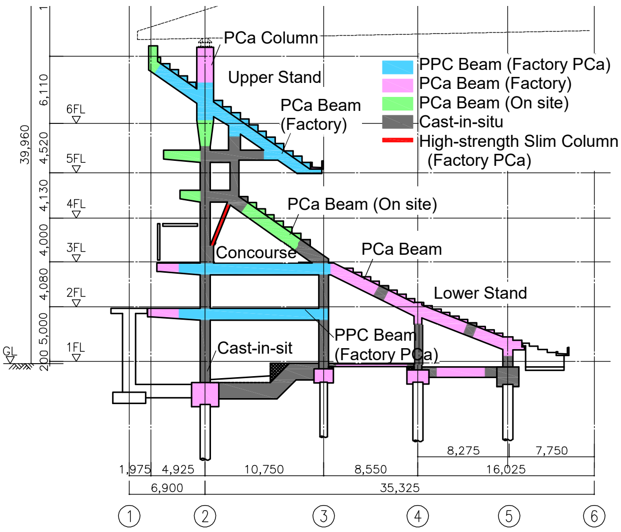

Fig.9 Home-stand framing elevation (showing the high-strength slim columns)

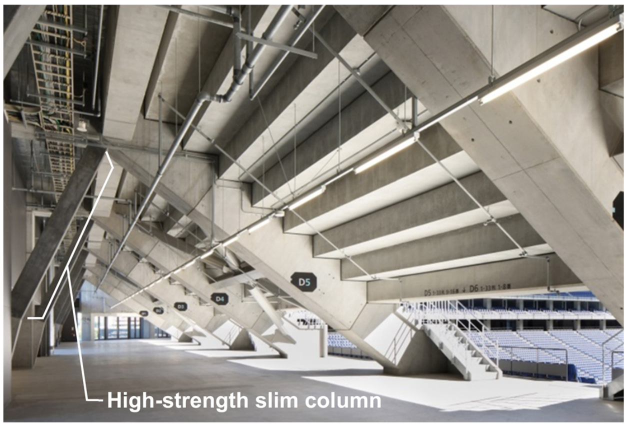

Fig.10 Home-stand third-floor concourse

Fig.11 State of foundation work

Fig.12 Precast system (for floor main beam)

Fig.13 Precast system (for upper-level stand beam)

4. Construction System using Precast Concrete Elements

Fig.11 shows scenes during construction of the foundations. **Fig.12** and **13** show scenes during construction of the concourses and the structures of the lower and upper stands.

5. Conclusion

To construct the largest football stadium in western Japan, with a capacity of 40,000 people, the authors used a new construction system based on the extensive use of PCa concrete elements. This technique improved the productivity of on-site construction sufficiently to allow the stadium to be completed in 22 months, far quicker than usual for a stadium of this size. The construction system described herein is expected to contribute to the development of such concrete architecture in general, addressing the increasing need to improve the efficiency of on-site construction efforts.

References

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概　要

市立吹田サッカースタジアムは，40,000人を収容する西日本最大のサッカー専用スタジアムである。本スタジアムの建設では，全体工期の短縮と現場での作業量削減のために，工場およびサイトで製作した多くのプレキャストコンクリート部材を活用した。

スタンドのコンコース部分には，梁と柱梁接合部を一体化した工場製作のプレキャストプレストレストコンクリート梁を採用した。また，上段席部分にもプレストレストコンクリート梁を採用し，圧着接合を採用することで高所でのコンクリート打設をなくした。ホームスタンドの柱にはコンクリート強度200N/mm^{2}の超高強度コンクリートを適用して断面寸法を小径化し，開放的な空間を実現させた。

施工における大きな特徴の一つが，基礎構造においてもプレキャスト工法を採用したことである。大部分の基礎と基礎梁をプレキャスト化することで，基礎工事の大幅な短縮が可能となった。