# Structural Design of Suita Stadium

**Masahito OHNO**
Structural Engineer
Takenaka Corporation
Osaka, Japan
*Ohno.masahito@takenakalco.jp*

Masahito Ohno, born in 1976, obtained his master's degree at the Kyoto University, Kyoto, Japan in 2002.

## Summary

The Suita Stadium is a football-dedicated stadium with a seating capacity of 40,000 currently under construction in Suita, Osaka, Japan. Its large-span roof is characterized by the 3D (three-directional) mega truss structures and the seismic isolators supporting it from the top of the stand structure. In this paper, the structural design processes for the Suita Stadium are introduced featuring seismic response analysis, wind tunnel test and response analysis, and structural optimization.

**Keywords:** space structure, structural design, 3D truss structure, seismic isolation, seismic response analysis, wind tunnel test, wind response analysis, structural optimization

## 1. Summary of the Suita Stadium

This paper describes the structural design of the Suita Stadium, a large stadium characterized by the three-directional mega truss design (hereinafter referred to as "the 3D truss design") of its wide-span roof structure and the seismic isolation bearings that support it. Seismic isolation bearings are installed on top of a six-story high reinforced concrete (RC) structure specially designed to support the 3D truss design.

Fig. 1 Bird's eye view of the stadium building

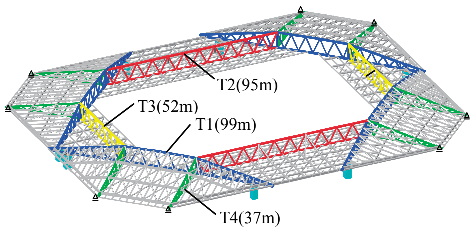
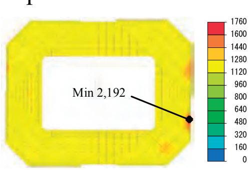


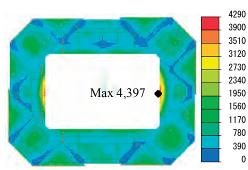

Fig. 2 Roof model

## 2. Seismic Response Analysis

The seismic response of the building was analyzed using two different models. One is a model that supports the determination of the vibration characteristics of the entire building. This is called the stand model. The other is a model of the roof structure. This is called the roof model (Fig. 2). Fig. 3 shows the distribution of the maximum acceleration arising in response to the input of Level-2 seismic motion in the X direction. The maximum acceleration is estimated to be around 1200 mm/sec$^2$ in most parts of the roof structure.




(1) Acceleration in the X direction (mm/sec$^2$)




(2) Acceleration in the Z direction (mm/sec$^2$)

Fig. 3 Distribution of the maximum response acceleration
(Level-2 seismic input in the X direction)

## 3. Wind Resistant Design

Wind tunnel test was performed to determine the design wind load. A linear static analysis was performed against the Level 2 (Very Rare) wind load, which was calculated through the wind pressure coefficient distribution multiplied by the basic design wind pressure.
The structure is to vibrate under strong wind in reality, however, such effects were not considered in the static analysis. Therefore, a linear dynamic analysis was carried out using the time history data of wind pressures (with conversion to the Level 2) from the wind tunnel test.
Fig. 4 shows the axial forces obtained by the linear static analysis. Fig. 5 shows the maximum and minimum forces observed in the linear dynamic response analysis. The maxima and minima were overlaid. The axial forces in Fig. 5 are generally smaller than those in Fig. 4, indicating the validity of the static design procedure.

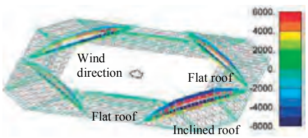



Fig. 4 Axial forces due to the design wind load(kN)

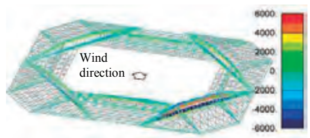



Fig. 5 Maximum and minimum axial forces during the linear dynamic response analysis(kN)

## 4. Application of Optimization Technique

In designing the roof structure, an in-house structural optimization program was used. The program is to find the optimum cross-sections of steel members that minimize the total mass of the structure.
The structural design was proceeded following the flowchart shown in Fig. 6.

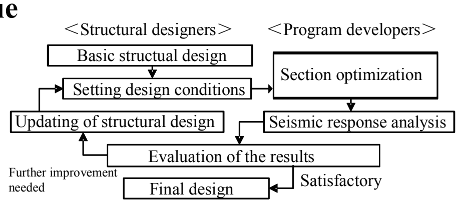
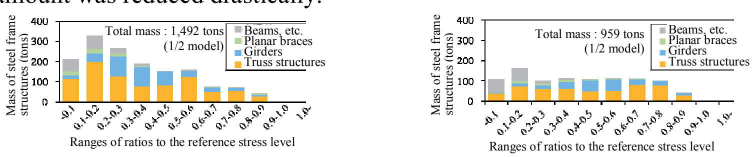



Fig. 6 Flow of structural design

In the course of structural design, a total of 19 cases of designs were studied, among which optimization were performed in the intermediate 17 cases (all but the first or last). Fig. 7 shows the histogram of structural mass, in the 15th case, with respect to the ranges of the maximum utility factors among all load combinations. Fig. 7(a) is the optimized result under 15 member groups. Fig. 7(b) shows the resulting histogram of the structural mass under 29 groups. Compared to Fig. 7(a), the overall distribution of the structural mass shifted toward higher values of utility factors, and the total mass amount was reduced drastically.




(a) Under 15 member groups (b) Under 29 member groups

Fig. 7 Histogram of structural mass w.r.t. utility factors (Case 15)

## 5. Concluding Remarks

In this paper, structural design processes for a large-scale football stadium in Japan were introduced. Since it is to be constructed in a country with higher risk of earthquake as well as typhoons, the design required detailed earthquake response analysis and wind tunnel test and analysis on top of the usual static design procedure. A sophisticated member sizing process using optimization technique was also adopted for a reasonable design.