Suitengu

水天宮

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Synopsis

This project marks the 200th anniversary of the founding of Suitengu Shrine, in the Edo period in what is now Tokyo. The entire site was completely renovated, including above- and belowground facilities in keeping with three major requirements from the shrine's management. First, the new shrine site should provide a safe and secure place for worshippers in the event of a major earthquake. Second, in light of the shrine's traditional role as a place to pray for safe childbirth, the site should provide a comfortable and relaxing waiting space for pregnant women. Third, the main shrine building should retain its traditional design. To meet these requirements, this project employed an aesthetic structural design that fully utilized the capabilities of concrete as well as a hybrid construction technique involving concrete and wood, resulting in a shrine building complex that is highly resistant to earthquakes and fire.

Structural Data

Building Scale: 1 basement floor, 6 above-ground floors, 1 attic floor
Construction Area: Approximately 2,000m^2
Total floor Area: Approximately 5,000m^2
Tower height: 24.14m
Owner: Suitengu
Designer: Takenaka Corporation
Contractor: Takenaka Corporation
Construction period: Jan. 2014 – Feb. 2016
Location: Nihonbashi, Chuo Ward, Tokyo

Fig.1 Exterior view

1. Introduction

Suitengu Shrine is a traditional Japanese shrine located in an urban area, and is often visited by people praying for safe delivery in childbirth.

2. Overview of Design

We created a new Suitengu Shrine design based on the concept of connecting the solemn historic shrine and the modern townscape as a rebuilt and familiar regional landmark from 200 years ago. (**Fig.1**) Therefore, we harmonized the traditional wooden design of the main building of the shrine, which made full use of *miyadaiku* (traditional shrine carpentry) techniques, and a modern design for buildings for waiting and gathering, which was an abstracted version of the design for *nagaya-mon* (gates) and *kura* (warehouses) of samurai residences.

3. Overview of Structural Design

(1) IIntegral Base Isolation System Extending Throughout the Shrine Grounds

Fig.2 shows the layout of the shrine. There is a parking area on the basement floor and the first floor. On the second floor and higher are three buildings placed to enclose the shrine grounds: the *shaden* (shrine pavilion), the *machiai* (waiting room), and the *sanshuden* (assembly hall). Corridors in all three directions between the buildings are also placed on the first floor.

To respond to the owner's strong desire to provide safety and peace of mind to the many worshippers, including expectant mothers, who will come to the shrine in the event of a major earthquake, an integral base isolation system was used, instead of simply providing base isolation for the shrine pavilion, meeting room and assembly hall on the second floor. Using this system, a base isolation floor was placed beneath the parking area, and all areas frequented by worshippers were base isolated (**Fig.3**). This reduced potential acceleration throughout the entire shrine grounds and improved earthquake resistance.

There is a self-parking structure and a backyard on the basement floor and first floor, covering the entire site. Above this are the three differently sized buildings comprising the shrine complex: shrine pavilion, meeting room, and assembly hall. For this reason, the center of gravity of the buildings is unevenly distributed in the planar direction, and the complex will be subjected to torsional force in the event of an earthquake. Accordingly, lead rubber bearings of various rigidities have been placed around the periphery of the buildings, as shown in **Fig.4**, positioning the center of gravity of the base isolation layer as close to the center of rigidity as possible to address this torsional force. Oil dampers were also placed around the periphery of the buildings to dampen both torsional vibration as well as horizontal motion.

The upper structure has a complex planar and elevation shape due to the characteristics of the building complex, and it was difficult to ensure balanced planar rigidity. Furthermore, it was also difficult to extend the base isolation primary natural period because of the low-rise, lightweight nature of the buildings. These issues were resolved using the high rigidity and high specific gravity of concrete to place earthquake-resisting walls to ensure rigidity, while at the same time using the considerable dead weight of these walls to extend the base isolation primary natural period.

(2) Superfine Octagonal Columns Made of Ultra-high-strength Concrete

As the shrine complex was constructed in an urban area, the site was limited in area. Therefore, to secure as large an area as possible for the waiting room and access ramp, superfine octagonal columns made of ultra-high strength concrete were developed. The reduction in seismic force achieved through the use of

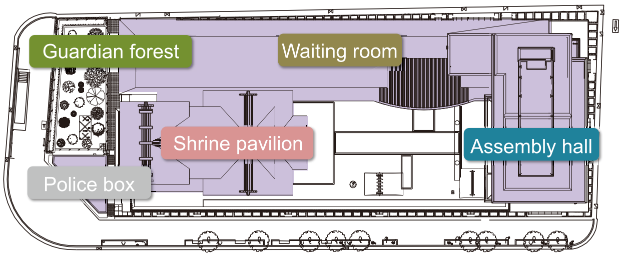

Fig.2 Shrine layout

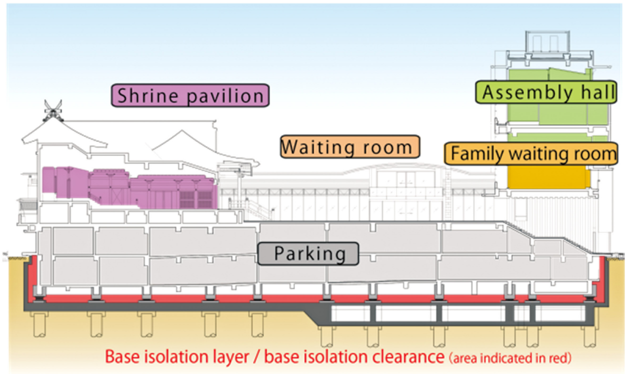

Fig.3 Integral base isolation system

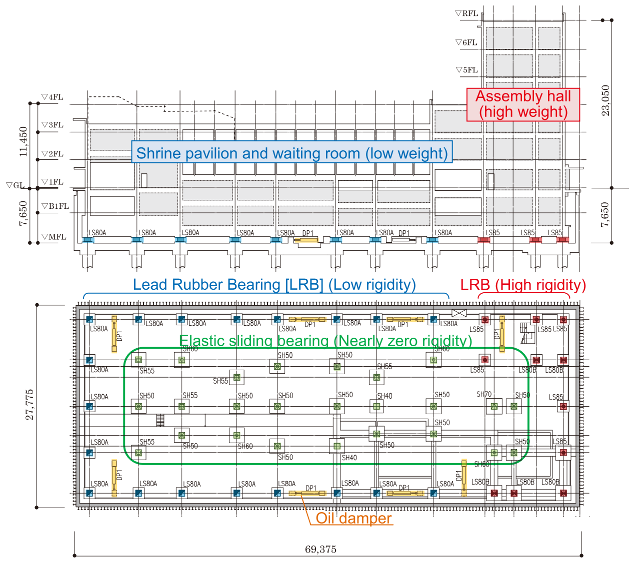

Fig.4 Framing elevation and base isolation plan

the base isolation system made it possible to increase the concrete strength to ultra-high strength (Fc120), enabling the diameter of the columns of the structural body to be reduced to 250mm, which is the minimum diameter allowed under the Building Standards Law for columns offering two-hour fire-resistance. The structural plan has the structure bear the primarily vertical load, while in the event of an earthquake the horizontal force is transmitted through the slab to the earthquake-resisting wall skeleton on both sides. In addition, exposed concrete finishing with wood grain pattern was used for the surface of the columns to create a design that achieves both slimness and the appearance of wooden columns, to match the aesthetic of a shrine pavilion. **Fig.5** shows the placement of the superfine columns, while **Fig.6** shows the interior of the waiting room and the access ramp. The result is an open space that lacks the oppressive feeling that may result from the use of large columns. The use of steel fibers is thought to be one effective means of increasing concrete strength. However, as the waiting room and ramp are areas in which children and expectant mothers can be expected to occasionally touch the columns, the fibers that would possibly protrude from the uneven cedar board tongue-and-groove formwork could lead to injury. Accordingly, experiments to check performance were conducted using synthetic fibers as the sole additive (**Fig.7** and **Fig.8**). The resulting high-strength concrete achieved structural load-carrying capacity and two-hour fire-resistance without using of steel fibers.

(3) Shrine Pavilion: A Fusion of Traditional Wooden Finishing and Reinforced Concrete Skeleton

The site is located in a fire zone, so the entire building complex, including the shrine pavilion, needed to be a fire-resistant structure. For this reason, an inner box structure was devised in order to add earthquake resistance and fire resistance using an enclosed concrete skeleton housed within aesthetic visible inner and outer sections created by traditional wooden roof truss and finishing (**Fig.9**). Concrete's ability to be freely poured in any shape meant it was possible to create a skeleton shape that would not obstruct the finishing or the equipment housed within. The shrine pavilion was designed using the proportions and measurements of the old Japanese measuring system, called *shakkanho*. As the span did not match that of the parking area below, the thickness of the slab beneath the shrine pavilion was increased to 500mm to enable transmission of the stress generated by the staggered column positions. Care was taken with the detail work as well. For example, out of consideration for differences in deformation characteristics resulting from the drying and aging of concrete and wood, brackets that are able to track deformation were used for the joints between the two materials, and a portion of the vertical load was applied to the wooden finishing to reduce the ability of gaps to occur as a result of shrinkage.

4. Overview of Response Analysis

(1) Design Input Ground Motion

Three types of design input ground motion were adopted with consideration given to the seismicity and site ground characteristics in the area of construction: "official-spectrum waves (waves matching the spectrum as defined in official ministry notices)", "simulated waves (a simulated Kanto earthquake)", and "observed waves (three standard waves from actual recorded earthquakes)". Moreover, two ground motion

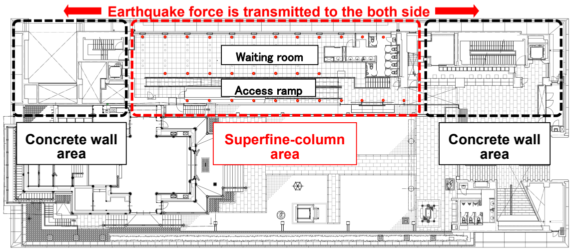

Fig.5 Superfine columns layout plan

Fig.6 Interior view of waiting room and ramp

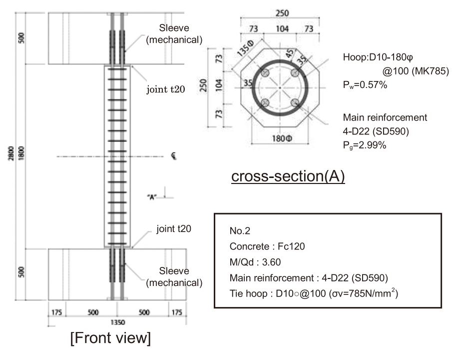

Fig.7 Test specimen summary

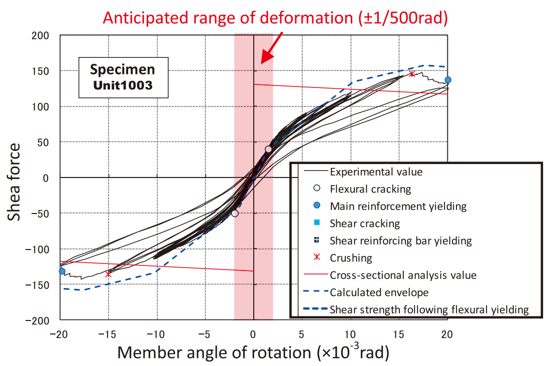

Fig.8 Load deformation curve

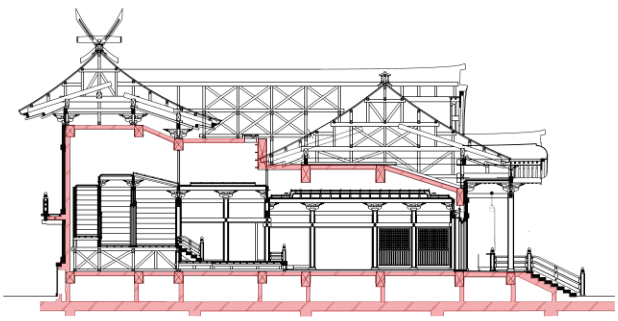

Fig.9 Shape of concrete skeleton

input levels were established: "Level 1 (occurs rarely)" and "Level 2 (occurs extremely rarely)". The official-spectrum wave (Kobe phase) is dominant (**Fig.10**).

(2) Response Analysis Model

Fig.11 shows the model used for earthquake response analysis. Mass was concentrated at the center of gravity on each slab, and an equivalent shear model with degrees of freedom in the X and Y directions was created. The configuration of the building complex was a triple tower configuration in which three buildings (shrine pavilion, waiting room, and assembly hall) were placed on the second floor slab level that formed the top of the parking area. For this reason, the model was created with the second floor to the basement floor as one bar and the upper floors as three bars. The waiting room and the assembly hall are connected on the third and fourth floor levels by slabs and beams, so connecting springs were placed between the mass points at the joints. In addition, the base isolation system was placed at the corresponding coordinate positions, and the topmost floor was modeled as a rigid floor, to evaluate the effect that the torsion of the base isolation layer would have on the building.

(3) Results of Response Analysis

Fig.12 shows the results of earthquake response analysis in the X direction in the event of a Level 2 earthquake. In each case, the response results satisfy the design target values. Moreover, the placement of many earthquake-resisting walls resulted in an extremely small value for story drift in the upper section (1/1000 or less). The maximum response acceleration for the 3rd floor and below—the areas that worshippers will primarily use—was kept around approximately 150cm/s^2. This is well below the target value of 200cm/s^2, reducing the danger of people and furniture being toppled, even in the event of a major earthquake.

5. Conclusion

Recently, disaster prevention measures in the renovation of shrines and temples have become a growing concern, and there has therefore been increasing need for state-of-the-art base isolation technologies. At the same time, as wooden architecture continues to be promoted, there has been increasing desire for traditional wooden construction, even in a fire protection district. Hopefully, this project, which involved a base isolation structure and a concrete–wood hybrid construction and which won the Award of the Japan Concrete Institute, can offer one potential solution to these architectural challenges.

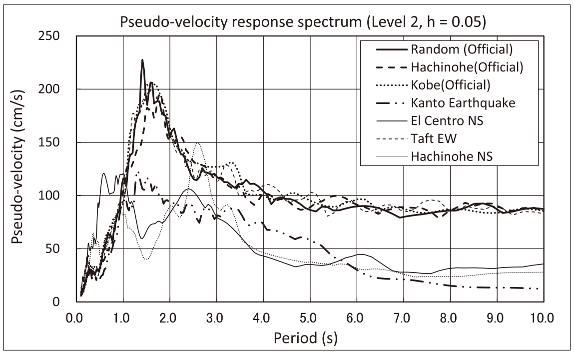

Fig.10 Pseudo-velocity response spectrum (Level 2)

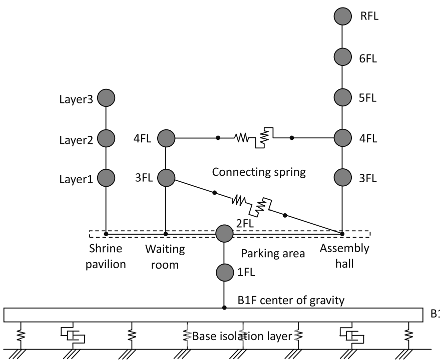

Fig.11 Response analysis model

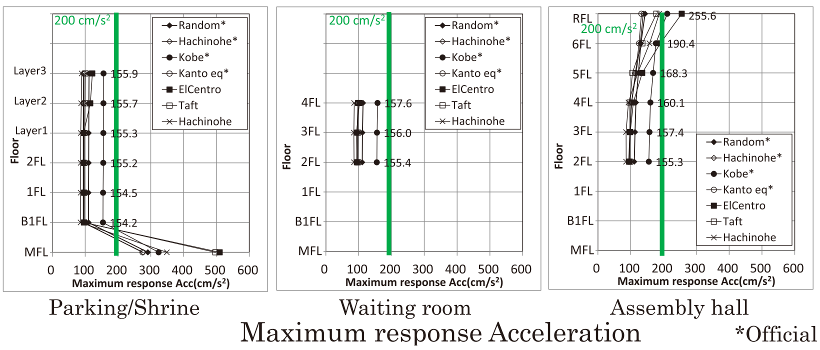

Fig.12 Results of response analysis (X direction, Level 2)

概　要

本計画は安産・子授け・水難除けなどのご利益で知られる東京日本橋の神社「水天宮」の江戸鎮座200年記念事業として境内を一新した御造替（ごぞうたい：建替工事）である。本建物の建設にあたり建築主から，大地震時に妊婦の方をはじめとする大勢の参拝者の方々に安全・安心を提供したい，妊婦の方の為の快適な待合空間を確保したい，社殿は伝統様式を尊重したデザインとしたいという 3 つの強い要望があった。本建物は，これら 3 つの強い要望をコンクリートならではの特性を活かした構造デザインにより実現した建物である。