Tsunami Evacuation Facility with Wide Atrium Made Using Fin Arches — Okata Port Passenger Terminal / Tsunami Evacuation Facility —

RC フィンアーチによる開放的な待合空間を有する津波避難施設 — 岡田港船客待合所・津波避難施設 —


* Takunori OZAWA: Nikken Sekkei Ltd.
小澤　拓典：（株）日建設計
** Satoru FUKAI: Nikken Sekkei Ltd.
深井　悟：（株）日建設計
Contact: ozawa.takunori@nikken.jp
Keywords: tsunami evacuation facility, arch in plan, wide atrium
DOI: 10.11474/JPCI.NR.2022.49

Synopsis

A new passenger terminal at the main port of Izu Oshima was planned as a facility complex that also functions as a tsunami evacuation tower (**Figs. 1** and **2**). The building was designed to ensure safety with redundancy against extremely large tsunami loads, and to serve as an island gateway and open waiting area for boat passengers, as well as a bustling community center.

To realize an open waiting area with an atrium functioning as a tsunami evacuation tower, reinforced concrete fins that form arches in plan (hereinafter referred to as RC fin arches) were installed around the perimeter of the front façade to transmit tsunami wave forces acting on the exterior walls to the shear walls of the core, which are the main resisting elements. The RC fin arches protect the columns from tsunamis, while the protruding floor slabs prevent tsunami debris from directly impacting the main structure of the building. In addition to these functions, the RC fin arches also contribute to the building's distinctive appearance.

Structural Data

Location: Okata, Oshima-machi, Tokyo
Site Area: 46,786.17 m^2
Building Area: 1,094.87 m^2
Total Floor Area: 2,606.79 m^2
Number of Stories: 5 stories above ground
Maximum Height: 24.65 m
Structure: reinforced concrete structure
Owner: Tokyo Metropolitan Government
Designer: Nikken Sekkei Ltd.
Contractor: Penta-Ocean Construction Co. Ltd.
Construction Period: Nov. 2016 – Oct. 2018

Fig. 1 Okata Port Passenger Terminal / Tsunami Evacuation Facility (appearance)

Fig. 2 Okata Port Passenger Terminal / Tsunami Evacuation Facility (site view)

1. Introduction

A new passenger port terminal—which serves as the entrance to Izu Oshima—was planned as a facility complex that also serves as an evacuation tower against tsunamis. As an entrance to the island and the hub of the local community, it is important for the passenger terminal to be an open, lively, and comfortable place for people to spend time. By contrast, tsunami evacuation towers are often robust and closed buildings because of the need to be safe from tsunamis and receive people evacuating in an emergency. The authors considered how to balance these two seemingly contradictory functions.

2. Architectural Scheme

Figure 3 shows a plan view and **Fig. 4** shows a cross-sectional view. The first three floors are used as a waiting area for boat passengers and as an exchange area for the town of Oshima. The fourth floor is used as a rooftop evacuation space from tsunamis. A large atrium facing the glass façade in the center of the first to the third floors was designed to create a lively atmosphere (**Fig. 5**).

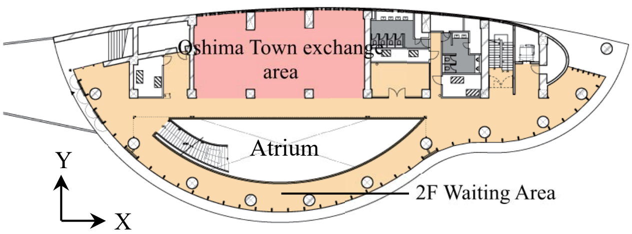


Fig. 3 Plan

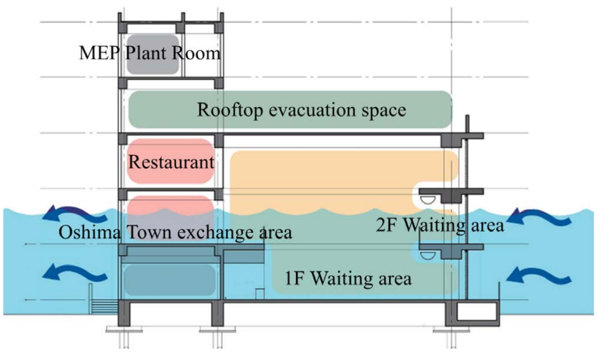


Fig. 4 Section

Fig. 5 Large atrium and glass façade

The design against tsunamis was based on the Practical Guide on Requirement for Structural Design of Tsunami Evacuation Buildings [1] and the Design Guidelines for Tsunami Evacuation Facilities at Ports and Harbors [2]. A curved façade that evokes the image of a ship was adopted to achieve a reasonable balance between collision resistance against the largest possible drifting objects (vehicles, jet boats, etc.) and a large interior atrium space.

3. Assumed Tsunami and Tsunami Wave Force

The tsunami anticipated for the site is based on those due to the Genroku-type Kanto earthquake and the Nankai Trough earthquake. Tsunami loads were obtained from the Nankai Trough earthquake, the tsunami of which had a large inundation depth.

According to the Practical Guide on Requirement for Structural Design of Tsunami Evacuation Buildings, the design tsunami wave pressure is defined as the hydrostatic pressure at the depth of 5.39 m multiplied by the water depth factor of 3, which is determined by considering the site. The design tsunami wave pressure at the lowest point is 159 kN/m^2 (**Fig. 6**).

Figure 7 compares the tsunami wave force and seismic story shear force, and the former greatly exceeds the latter.

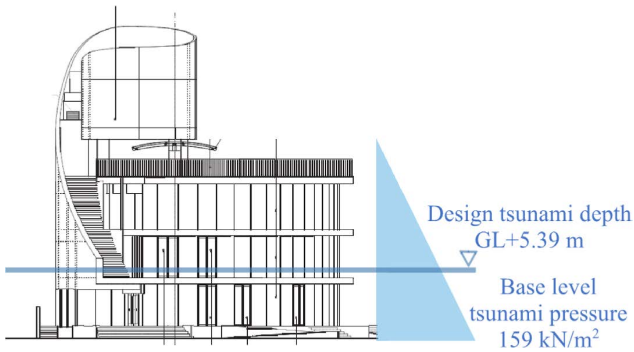


Fig. 6 Design tsunami depth and design tsunami wave pressure

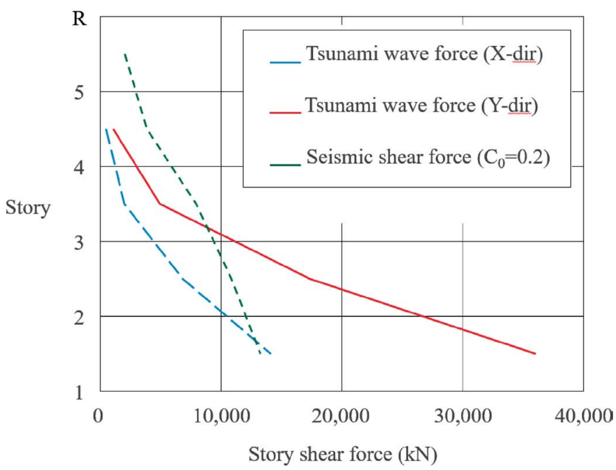
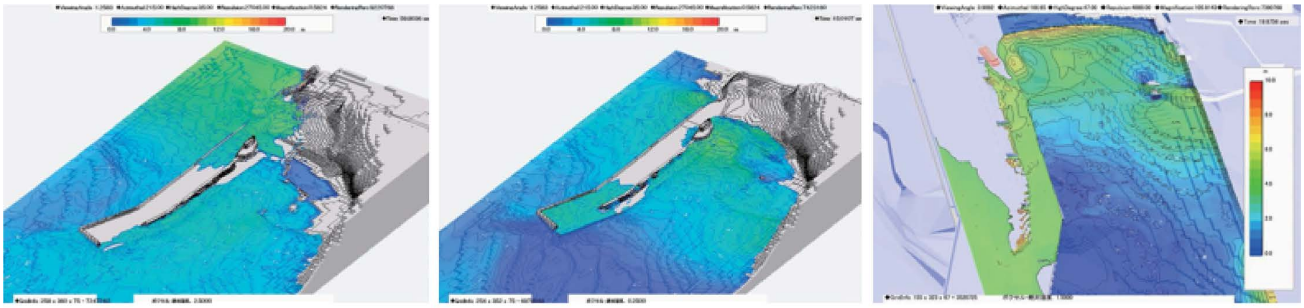


Fig. 7 Comparison of tsunami wave force and story seismic shear force



Genroku-type Kanto earthquake tsunami analysis

Nankai Trough earthquake tsunami analysis

Floating-object simulation

Fig. 8 Tsunami simulations

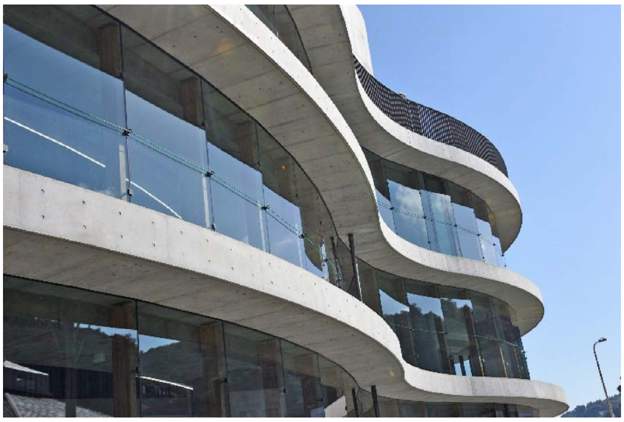


Fig. 9 Curved façade

For the tsunami simulations, the authors modeled the seafloor topography and the ground undulations around Okada Port and performed a three-dimensional free-surface flow simulation. The simulations were conducted for a Genroku-type Kanto earthquake and a Nankai Trough earthquake, and the tsunami height, wave pressure, arrival time, and behavior of floating objects such as ships were confirmed for each earthquake (**Fig. 8**). Considering the tsunami characteristics and the flow of floating debris obtained from the tsunami simulations, the building shape was designed with a curved façade to be able to mitigate these forces (**Fig. 9**).

The design tsunami wave pressure was chosen by considering the guidelines and the tsunami simulation results. The former had the larger wave pressure, such that value was chosen as the design wave pressure.

4. Structural Scheme

(1) Structural Framing Plan

Figure 10 shows the first-floor framing plan. The length of the building in the X-direction is approximately twice that in the Y-direction. Therefore, a moment-frame structure with shear walls was used in the Y-direction, which has a large pressure tributary area; that is, the tsunami wave force is large and the number of beams is small because of the atrium. In the X-direction, a pure moment-frame structure was used because it has a small pressure-sensitive area.

The drywalls are designed to be destructible in the event of tsunami damage, and the moment-frame structure in the X-direction is designed to share and divert tsunami loads acting in the Y-direction, which has a large pressure-receiving area.

(2) RC fin arches to protect building from tsunamis and drifting debris

To transfer the tsunami wave forces acting on the exterior walls around the atrium to the shear walls, RC fin arches were installed at the locations indicated in blue in **Fig. 11**. The RC fin arches are 400 mm thick and 4400 mm wide and resist tsunami wave forces and drifting debris.

The plan shape of the RC fins was designed to resist tsunami wave forces efficiently by forming an arch shape. The RC fin arches on the second floor were designed to resist tsunami wave forces up to 420 kN/m. The RC fin arches also serve to prevent direct impact of drifting debris and other objects carried by the tsunami on the main structural components such as the columns and beams.

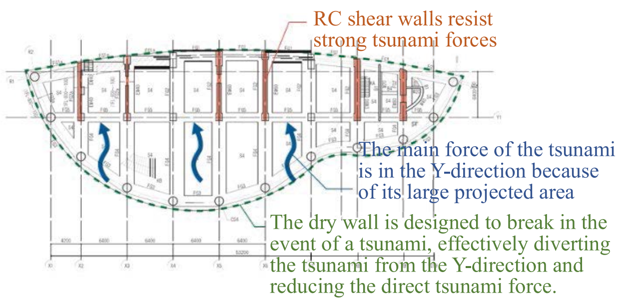


Fig. 10 First-floor beam plan

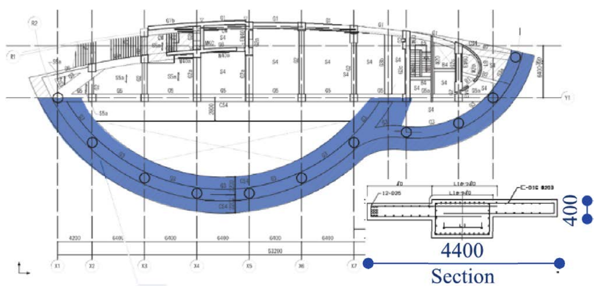


Fig. 11 RC fin arches

(3) PRC beams supporting the rooftop plaza

Prestressed reinforced concrete (PRC) beams are used for the long-span beams supporting the rooftop evacuation space as shown in **Fig. 12.** By prestressing the beams, the required ceiling height could be secured within the limited floor height.

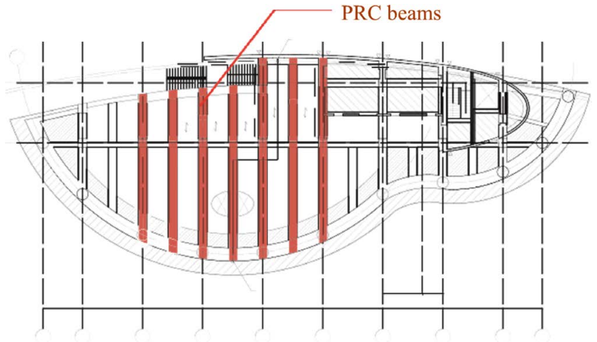


Fig. 12 PRC beams

(4) Planning for redundancy

Even if a drifting object should strike a column and destroy it, the building is planned such that the floor can be supported by the surrounding structure, thereby increasing the structural redundancy (**Fig. 13**).

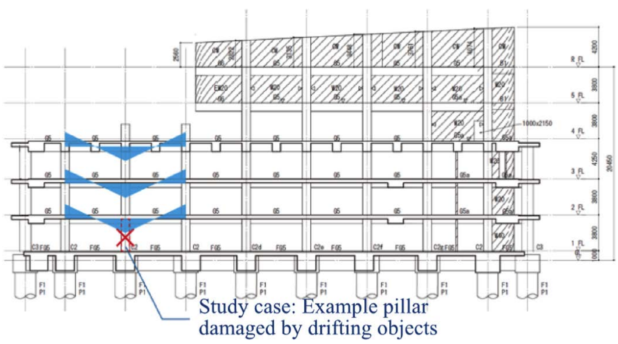


Fig. 13 Planning for redundancy

5. Conclusion

This building has two different uses as a waiting area for ship passengers and as a tsunami evacuation tower. By adopting RC fin arches, it was possible to create a building that satisfies both design intentions: bright and lively, yet robust (**Figs. 14** and **15**).

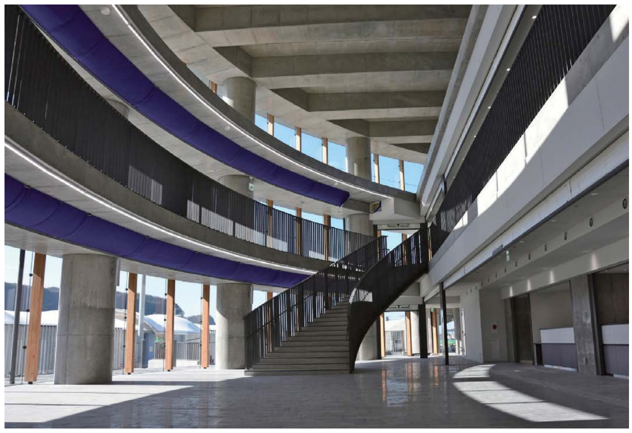


Fig. 14 Okata Port Passenger Terminal / Tsunami Evacuation Facility (interior view)

Fig. 15 Okata Port Passenger Terminal / Tsunami Evacuation Facility (night view)

This project won the Japan Concrete Institute Award in 2020.

References

[1] National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure, Transport and Tourism, Japan: *Practical Guide on Requirement for Structural Design of Tsunami Evacuation Buildings*, Tokyo, Mar. 2012 (in Japanese).

[2] Port and Harbor Bureau, Ministry of Land, Infrastructure, Transport and Tourism, Japan: *Design Guidelines for Tsunami Evacuation Facilities at Ports and Harbors*, Tokyo, Oct. 2013 (in Japanese).

概　要

伊豆大島の海の玄関口となる船客待合所を，津波に対する避難施設を兼ねた複合施設として計画した。

設計用浸水深5.39 m と非常に大きい津波荷重に対する安全性や冗長性を確保した上で「島の玄関口や地域のにぎわい拠点としての開放的な船客待合所」となるよう設計した。

開放的な津波避難施設に寄与する吹き抜けを実現するために，厚さ400 mm，幅4400 mm の RC フィンアーチを前面の外周に平面的に設け，外壁に作用する津波波力を抵抗要素であるコア部の耐力壁等に伝達できるようにしている。RC フィンアーチは津波から柱を守ると同時に，突出した床スラブにより津波により流されてきた漂流物が建物の主要架構に直接衝突することも防いでいる。また RC フィンアーチはその機能と共に特徴的な外観の形成にも寄与している。