Tsunami Countermeasures at Hamaoka Nuclear Power Station
-- Design and Construction of Tsunami Protection Wall

1. Overview of tsunami protection wall

Chubu Electric Power Company's Hamaoka Nuclear Power Station had promptly started safety improvement measures work, including tsunami countermeasures, after the disaster at Tokyo Electric Power Company's Fukushima Daiichi Nuclear Power Station that was caused by the 2011 Great East Japan Earthquake. To protect the plant from tsunami flooding, a tsunami protection wall (Figure 1) and other measures were implemented. Furthermore, measures to prevent flooding of the buildings were implemented by reinforcing the pressure resistance and watertightness of the reactorbuilding external walls, etc., (Figure 2). Moreover, to enhance safety in emergencies, redundant and diversified systems have been installed, including for the power systems and cooling water injection systems.

The tsunami protection wall is a major pillar of the tsunami countermeasures. The wall was constructed between the dune embankment on the ocean side of the site and the plant facilities. The crown height of the wall is 22 m above sea level and the total length is approximately 1.6 km. The wall is connected to improved cement-mixed soil embankments 22-24 m above sea level at both ends.

Figure 1. Tsunami protection wall at Hamaoka Nuclear Power Station

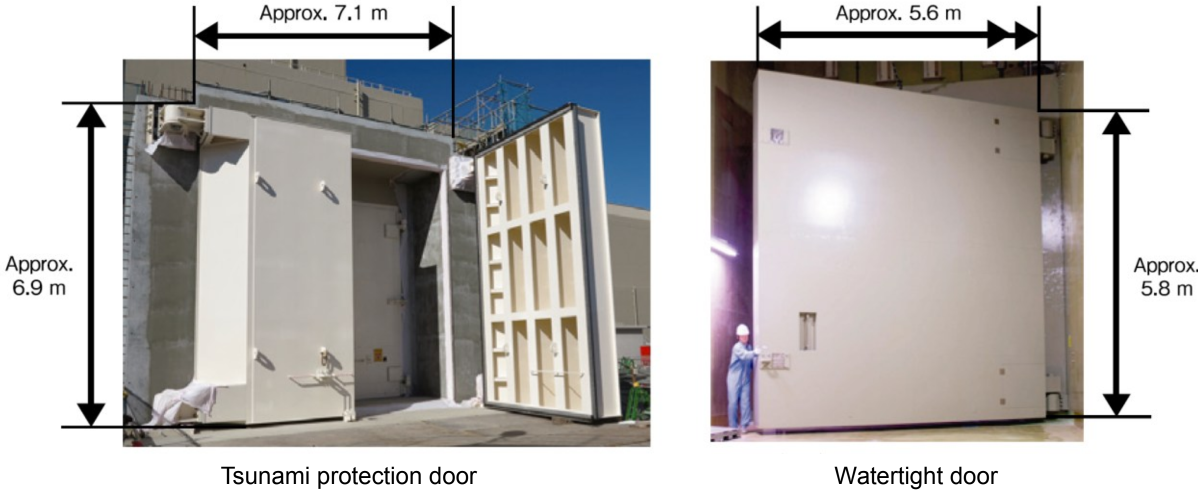

Figure 2. Measures to prevent flooding in buildings (left: reinforced protection door, right: watertight door)

2. Design of tsunami protection wall

(1) Structure of tsunami protection wall

The Hamaoka Nuclear Power Station is located in an area where a huge earthquake is expected to occur in the Nankai Trough. Therefore, the structures have always been designed with a sufficient safety margin so as to avoid major deformation even from external forces far beyond the design external force.

To construct a tsunami protection wall that will be resilient in earthquakes and tsunami, a new structural system for seawalls was adopted. An L-shaped composite wall consisting of steel and steel-framed reinforced concrete is attached to the foundation of an underground wall of reinforced concrete that was built up from within the bedrock (Figure 3).

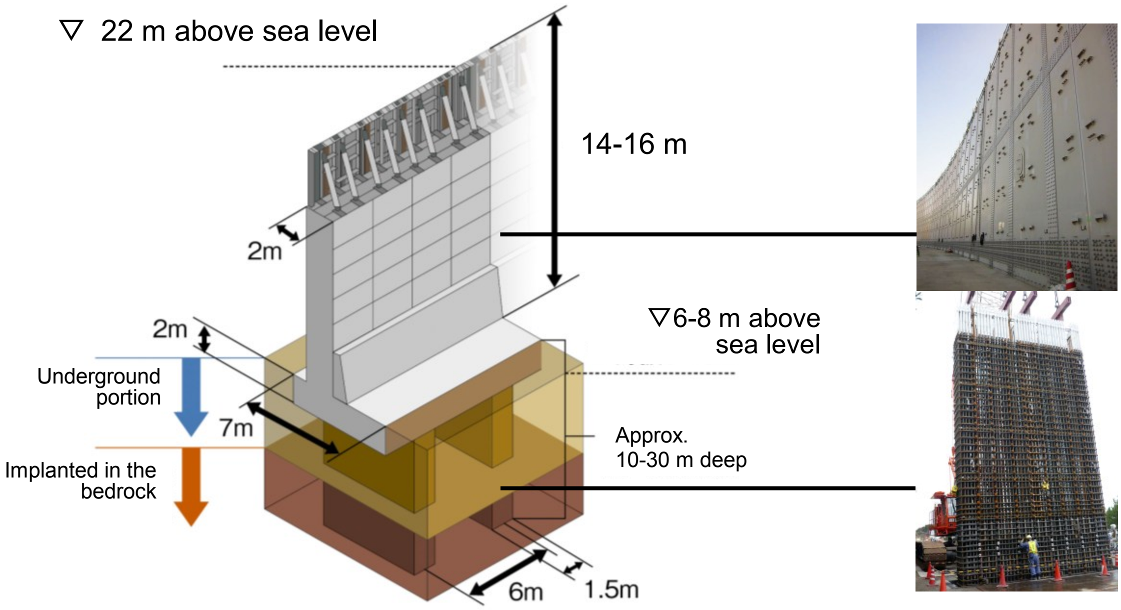

Figure 3. Structural overview of tsunami protection wall

The seismic structural design of the protection wall was based on an earthquake response analysis of the design earthquake ground motions for a huge earthquake in the Nankai Trough. Large-diameter reinforcing steel, such as D51 steel, was mainly used for the underground wall and other sections. The structurally critical lower part of the vertical wall is a composite structure of a steel shell filled with concrete to enhance seismic resistance.

The protection wall is also designed to withstand a huge tsunami produced by an earthquake in the Nankai Trough. The design tsunami height was set at 22 m above sea level in front of the protection wall.

(2) Verification by experiment

Experiments were conducted to verify the wall's seismic and tsunami resistance. For seismic resistance, the ground including the protection wall and the dune embankment was reproduced by fabricating a shear soil layer test specimen on a scale of 1:30. A vibrating experiment on a 30-G field using a centrifugal loading device was conducted to study the behavior of the protection wall during an earthquake. As a result, the response of the underground wall was confirmed to be within an elastic range, even in response to an input acceleration corresponding to maximum of 2000 gal at actual scale. (Figure 4)

Figure 4. Centrifugal model experiment (left: test specimen; right: centrifugal loading device)

For tsunami resistance, to verify the design wave power for the tsunami protection wall, the topography of the site was reproduced at a scale of 1:40 in a large wave-generating channel and a wave power experiment was conducted. This verified that the wave power used for the design of the protection wall was sufficiently conservative (left in Figure 5). Moreover, assuming possible overflow, an immersion experiment was conducted using a 1:150 scale model that reproduced the plant site and the sea area in front of the site in a large planar wave-generating water tank. Data on the behavior of a tsunami that overflows the protection wall and enters the site was obtained and the prediction accuracy of the numerical simulation was studied (right in Figure 5).

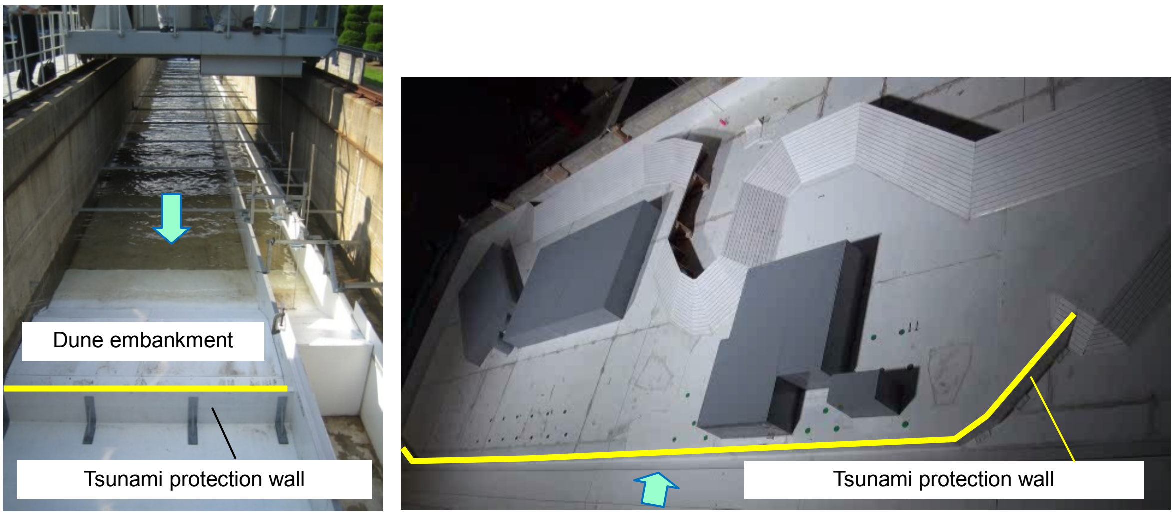

Figure 5. Hydraulic experiment (left: large wave-generating channel experiment; right: large planar wave-generating experiment)

3. Construction of tsunami protection wall

The construction of the tsunami protection wall began with foundation work for the underground wall eight months after the Great East Japan Earthquake in November 2011.

For the underground wall, 218 units were constructed at 6 m intervals and arranged so that they were perpendicular to the vertical tsunami protection wall. Dedicated excavators were used to drill to the prescribed depth. After erecting reinforced frames assembled at the site, highly fluid concrete was placed.

The wall is L-shaped and stands 14-16 m high on a site that is situated 6-8 m above sea level. A total of 109 blocks, each 12 m long, were constructed. For the steel structure portion of the wall, blocks were fabricated in a factory with one block divided into 15 pieces that were transported to the site, connected, and erected using splice plates and about 14,000 high-strength bolts (Figure 6).

Each block of the wall was supported by two underground wall units, with the reinforcing steel at the top of the underground wall tucked into the steel frames of the stud-welded floor slab. Reinforcing steel was arranged around them and highly fluid concrete was placed to ensure that they became an integrated structure.

In parallel with the underground wall work, the steel structures of the wall were fabricated in a factory. The wall blocks started to be built in order in the sections where the construction of the foundation had been completed. Work was carried out all day and night. With these efforts, the work period was shortened and the wall was completed to a height 22 m above sea level in December 2014.

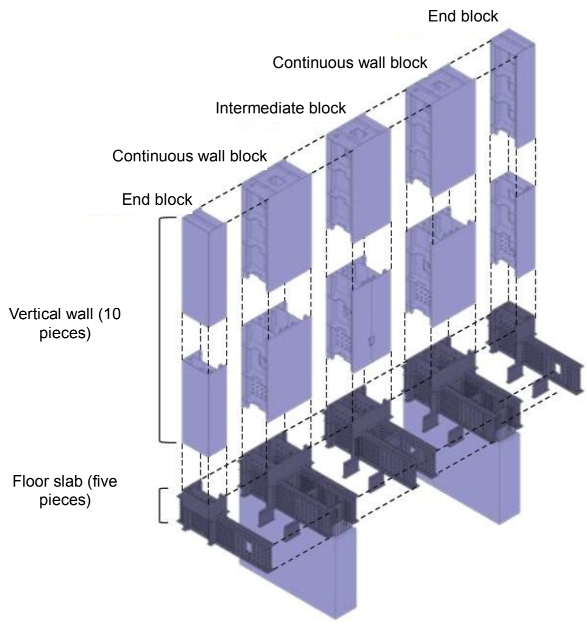

Figure 6. Wall (steel structure section)

4. Conclusion

The Hamaoka Nuclear Power Station has worked on tsunami countermeasures and serious-accident countermeasures in addition to the tsunami protection wall. Efforts will continue in order to achieve the world's highest level of safety.