Commentary

Tsunami Resistant Engineering for Nuclear Safety (No. 6)

−Promotion of Disaster Reduction Around Nuclear Facilities and Risk Communication−

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Two level tsunami hazards were assigned to reflect tsunami sizes after the massive tsunami generated by the 2011 Tohoku earthquake devastated East Japan. Furthermore, measures for disaster management and reduction are planned, while discussions are to be held on reducing disasters around vital facilities in coastal areas. In areas around nuclear facilities, it is even more important for necessary measures to be prepared in anticipation of any facility-related accidents that may result from the devastation caused by a tsunami. To better manage and mitigate tsunami disasters in areas around nuclear facilities, it is vital for power utilities as well as the national and local governments to fulfill their assigned roles in a coordinated manner and work together with municipalities and local residents.

KEYWORDS: Nuclear safety, tsunami disaster reduction, Level-1 tsunami & Level-2 tsunami, risk communication

I. Tsunami Disaster Management and Reduction

1. Tangible and Intangible Measures Against Tsunamis

Tsunami disaster management has been planned in a comprehensive manner by combining tangible measures that rely on embankments and other protective structures with intangible measures that mainly involve alerts and evacuation. The reasons for this approach include the varying sizes of tsunamis as natural phenomena, their infrequent and localized nature, and the difficulty involved in predicting them. For instance, the tsunami caused by the 1896 Sanriku earthquake required the relocation of villagers from Toni, Iwate to an elevated settlement and the construction of a seawall in Taro. In Japan, public measures for tsunami disaster management are legally grounded in the Coast Act and the Basic Act on Disaster Management. The Coast Act forms the basis for the construction of embankments and other coastal protections by prefectural governments, while the Basic Act on Disaster Management forms

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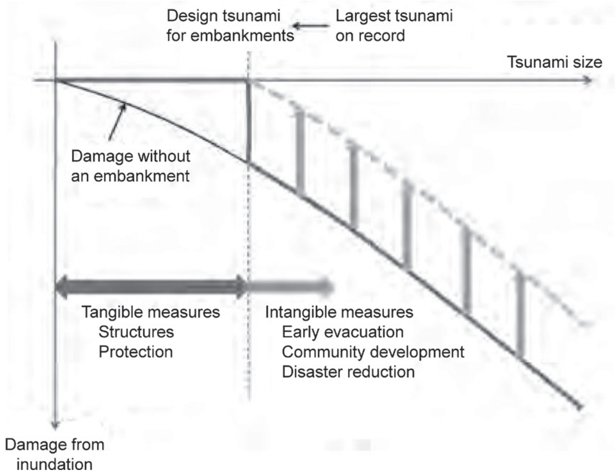

Figure 1 Schematic illustration of comprehensive tsunami disaster management

the basis for the development of local disaster management measures by municipalities. The major tsunami inundations that followed seismic events such as the 1993 Hokkaido earthquake and the 2004 Indian Ocean earthquake highlighted the importance of mutual assistance and self-help in addition to public assistance.

Figure 1 is a schematic illustration of the overall concept for a form of tsunami disaster management that employs a combination of tangible and intangible measures. The horizontal axis represents the tsunami height (size) and the vertical axis represents the increasing severity of damage in the negative direction. As shown in the figure, tangible measures are aimed at blocking the landward intrusion of seawater by using seawalls. They are designed by first envisaging the size of the target tsunami based on the largest tsunamis on record, while also giving due consideration to tidal and ocean waves. The damage that may be caused by a tsunami beyond the anticipated size is minimized by the adoption of intangible measures centered on early evacuation. This is the overall principle of tsunami disaster management. Many scientists and engineers have jointly investigated the tsunami triggered by the 2011 Tohoku earthquake. They have obtained data that will prove valuable in implementing the necessary measures against tsunamis in the future. Their analyses have highlighted the importance of intangible measures based on specific assumptions. They are also working to clarify the effectiveness and limits of tangible measures.

2. Two Anticipated Sizes of Tsunamis

Protective structures alone have limited efficacy in countering the massive tsunamis that occur once every several centuries or even less frequently. The specific sizes of tsunamis need to be envisaged in order to prepare intangible measures. Furthermore, it is sensible to envisage the frequency and size of a tsunami realistically by bearing in mind that concrete structures are useful for 50 years at most [1]. Accordingly, the following two sizes of tsunamis have been introduced [2, 3].

- Level-1 tsunamis: National and local governments ought to develop protective facilities in anticipation of the type of tsunami that occurs once every several decades or dozen decades

− Level-2 tsunamis: Municipalities ought to pursue disaster reduction to prepare for the type of massive tsunami that occurs once every several centuries

Of these two different tsunami sizes, it is obviously impossible to produce a clear definition for the probability of a massive Level-2 tsunami. However, even for the more frequently occurring Level-1 tsunamis, it is not necessarily possible to define their sizes through a probabilistic approach despite the fact that their cycles are known to be roughly several decades to dozens of decades. Nuclear facilities may well be prepared against Level-2 tsunamis, not to mention Level-1 tsunamis. This example only compares the height of an embankment with the expected degree of damage, but other measures could also reduce the level of expected damage.

II. Measures Taken for Key Facilities in Coastal Areas

A variety of key facilities can be found in coastal areas, including industrial, chemical, and power plants. These facilities are located in areas beyond those protected by embankments, so the following aspects of disaster management and reduction measures for these facilities should be considered by local communities and power utilities.

1. Devastation of Industry by a Tsunami and Its Recovery

Key facilities located outside of areas protected by embankments may even be affected by inundation caused by a Level-1 tsunami. Tsunami-related risks and their effects on key facilities need to be identified (clarification of weaknesses). In doing this, many scenarios should be envisaged by taking into account the various uncertainties associated with natural phenomena. The disaster triggered by the 2011 Tohoku earthquake affected many industries. Shibasaki [4)] estimates that an area submerged by about 2 m of water may take at least about 100 days to recover. However the amount of time required for an area to recover varies significantly depending on the type of industry, the surrounding environment, and the economic circumstances.

2. Measures Against Tsunamis to Ensure Business Continuity

Every effort must be made to simulate the resultant damage reliably based on the latest findings. Nonetheless, preparedness is necessary to facilitate the prompt assessment of damage caused by possible unanticipated events. Key facilities must build up an intelligence gathering capability that exceeds that of the public. They should also consider developing their own disaster management information systems since an amendment [5)] to the Meteorological Service Act now enables them to issue tsunami forecasts individually.

3. Impact on Surrounding Areas

If a structure must be built according to an appropriate business continuity plan, attention must be paid to its possible influence on tsunami heights in the surrounding area. To assess this possible influence, Arikawa et al. [6)] compared the tsunami height behind a new seawall with the tsunami heights in surrounding areas. As shown in **Figure 2**, this comparison

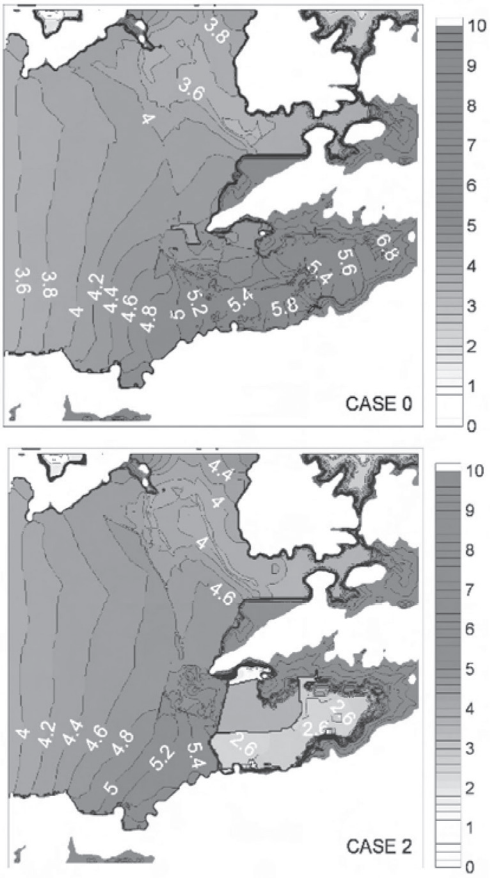

Figure 2 Comparison of tsunami heights before (top) and after (bottom) the construction of a seawall [6)]

demonstrates that the seawall reduced the tsunami height behind it by more than half. Notably, however, the tsunami height increased by roughly 60 cm in the area located to the north of the seawall after its construction. This increase was caused by a phase misalignment with the diffracted waves produced when energy is reflected back offshore after a landward intrusion. Given this, no sweeping judgements can be made about whether the construction of a seawall is a good or bad idea. In fact, an opposite phase can even reduce the tsunami height. For this reason, it is desirable for the impact of constructing a seawall to be closely examined through numerical simulations and necessary measures to be implemented, while engaging in consultations with local residents. The disaster caused by the 2011 Tohoku earthquake caused many types of unanticipated damage. To reflect on this lesson, it is crucial for community members, companies, and local governments to jointly identify the risks faced by society and continuously discuss and implement measures aimed at enhancing the local disaster management capacity.

III. Promoting Partnerships for Nuclear Disaster Management

1. Preparedness Against Nuclear Disasters Involving Tsunamis

(1) Nuclear emergencies and the challenges encountered during the disaster triggered by the 2011 Tohoku earthquake

In response to the accident that occurred at the Fukushima Daiichi Nuclear Power Plant, residents within a range of 20 km were ordered to evacuate one day after the earthquake struck. To facilitate this, buses were requisitioned to provide transport from an off-site center in Okuma. However, not enough buses could be dispatched from the respective municipalities due to coordination difficulties. According to a report by the Government Investigation Committee on the Accident at the Fukushima Nuclear Power Plant of Tokyo Electric Power Company, the major reasons for this include the understaffing of the Nuclear Emergency Response Headquarters, damage to roads due to the earthquake, and congestion from vehicles carrying evacuees [7)]. The investigation committee also identified problems in the choice of appropriate evacuation routes due to a failure to apply the radioactivity dispersion simulation results from the System for Prediction of Environmental Emergency Dose Information (SPEEDI) effectively [7)].

The massive tsunami devastated coastal settlements on the Oshika Peninsula, where the Onagawa Nuclear Power Plant is located. Residents there lost their homes to the tsunami and had to evacuate to shelters. However, the eastern half of the peninsula became inaccessible since the roads had been damaged by the earthquake and tsunami. Affected residents from surrounding settlements sought shelter at the nuclear power plant because they could not access other nearby shelters. The plant sheltered them inside. This experience demonstrates that, provided its soundness is maintained, a nuclear power plant can serve as a robust emergency shelter in the host community. The other side of the coin is that the provision of necessary assistance to the plant on the peninsula was complicated when access from other areas was disrupted by the damaged roads. In this respect, the Oshika Peninsula faces additional challenges due to its isolation in the immediate aftermath of a tsunami.

2. Nuclear Disaster Preparedness in Outside Areas

People must be evacuated swiftly without any trouble as soon as an evacuation order is issued in response to an increased risk of a nuclear emergency. The following measures are deemed important to ensuring that the host communities of nuclear power plants are prepared against tsunamis.

a) Build up the resilience of physical access from outside areas: Aseismic performance of roads and slopes around the area
b) Build up the resilience of off-site centers (e.g., against nuclear disasters) for responding to nuclear emergencies

Measure a) is even effective for evacuations in the event of a tsunami affecting a coastal area, a volcano eruption, and other such disasters, except that nuclear disasters involve a much larger scale of evacuation. Roads should be developed in anticipation of any such disasters in each area. In addition, nuclear emergencies should be anticipated in the development of roads in areas around nuclear power plants. Measure b) is necessary to facilitate information sharing among the relevant agencies during a nuclear emergency and to enable these agencies to respond effectively to a nuclear emergency (collection of radiation measurement data, delivery of information, and coordination of evacuation). The spatial distribution of the radiation dose predicted by SPEEDI should also be shared by learning from the failure to do so after the accident at the Fukushima Daiichi Nuclear Power Plant. The specific requirements can be found in the materials [8] compiled by the Nuclear and Industrial Safety Agency (NISA). They can be summarized into the following three key points:

a) Ensure the continuity of necessary functions even during a nuclear emergency that is compounded by the occurrence of more than one natural disaster
b) Secure alternative facilities
c) Conduct effective education and training under usual conditions and ensure its continuity

IV. Promotion of Local Partnerships for Nuclear Disaster Management

1. Importance of Risk Communication with Local Residents

(1) Challenges related to sharing information with local residents regarding the 2011 Tohoku earthquake and tsunami and the risks posed by the nuclear accident as well as pursuing local partnerships

The 2011 Tohoku earthquake and tsunami prevented the off-site center from responding properly to the subsequent accident at the Fukushima Daiichi Nuclear Power Plant. In addition, local residents were confused due to disruptions to the infrastructure for collecting and communicating crucial information on the nuclear accident and evacuation. Such problems should be avoided by promoting interactive communication among stakeholders and making the most of the limited time to discuss risk causes, factors, necessary measures, and their effectiveness with the aim of enabling decisions to be made with due consideration given to a diverse range of needs. For this reason, it is vital for trust to be built up under ordinary circumstances through regular interactive risk communication.

Going forward, nuclear risk communication should shift away from the conventional practice of making public addresses in public relations toward public acceptance. In other words, instead of expecting the public to simply receive and accept information, the focus should be on promoting interactive dialogues to incorporate the opinions of stakeholders into risk management measures in order to reduce risks. To build confidence in nuclear energy through risk communication, the first step involves clarifying the risk governance framework and mechanism for spiraling up nuclear safety. In the next step, information and opinions should be exchanged with local residents, the media, municipalities, and other stakeholders to incorporate their outcomes and reduce specific risks through risk management. To this end, risk profiles should be clarified and the effectiveness of protective measures, as well as their technical limitations and threshold criteria, should be presented in a scientific and reasonable manner. Also, intra-organizational risk communication (e.g., among the public relations department, the risk management department, and the engineering department) plays a significant role in risk management.

(2) Examples of risk communication practiced in the host communities of nuclear power plants

Certain outcomes have been obtained and compiled in earlier studies on practical risk communication in the host communities of nuclear power plants [9-11]. These studies examined how interactive (risk) communication has been practiced between power utilities and local residents as well as how it should be continued.

2. Enabling Technologies for Local Partnerships to Deal with Compound Disasters Involving Nuclear Accidents and Earthquakes, Tsunamis, or Other External Events

Already seven years before the 2011 Tohoku earthquake took place, the Japan Nuclear Energy Safety Organization (JNES) had been conducting research and development aimed at enabling technologies for local partnerships to deal with compound disasters involving nuclear accidents and natural disasters. The Indian Ocean earthquake and tsunami and the damage suffered by nuclear power plants in December 2004 prompted the JNES and member countries of the IAEA alike to recognize the importance of tsunami disaster management at and around nuclear facilities. To help improve the evacuation of residents in the event of a compound disaster involving a nuclear emergency and an earthquake or tsunami, the JNES has developed TiPEEZ (Protection of Nuclear Power Plants against **T**sunam**i**s and **P**ost-**E**arthquake Considerations in the **E**xternal **Z**one), a disaster response information system [12].

TiPEEZ consists of sub-systems for functions such as the following: assessing tsunami risks; providing informational support to surrounding municipalities by estimating evacuation plans for local residents based on estimated or actual damage to areas around the nuclear facilities caused by earthquakes and tsunamis; and sharing information with local governments and relevant agencies. Each sub-system functions autonomously in a coordinated manner to estimate the effective evacuation of residents by collecting and evaluating time-varying local information during compound disasters (**Figure 3**). TiPEEZ was provided to India in April 2009, and subsequently customized at the model site with technical assistance provided by the JNES. In February 2010, a simulated emergency drill was conducted using TiPEEZ at the

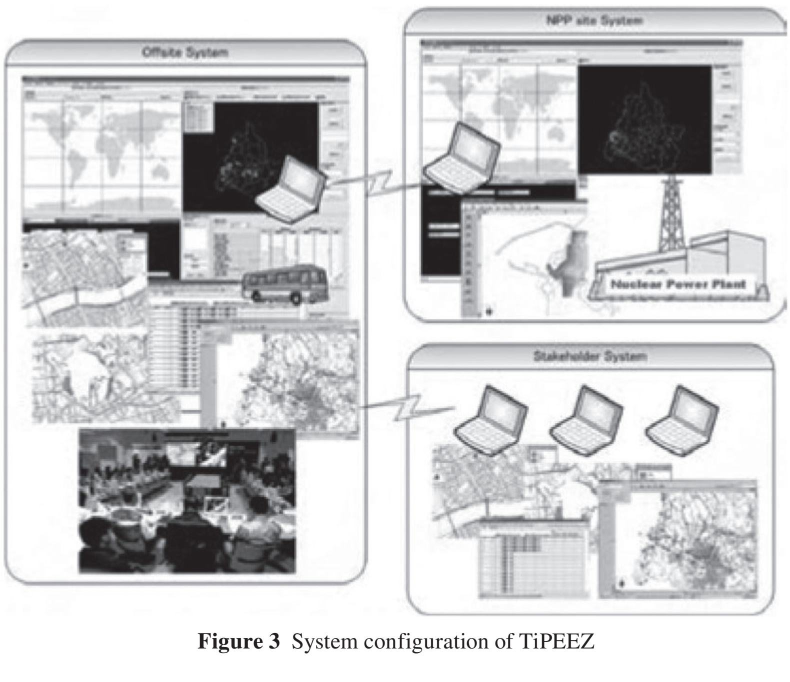

Figure 3 System configuration of TiPEEZ

headquarters of the Nuclear Power Corporation of India Limited (NPCIL) in Mumbai.

In Japan, following the disaster caused by the 2011 Tohoku earthquake, the local government of Kashiwazaki, a city where a nuclear power plant is located, requested technical assistance from the Niigata Institute of Technology, a local university, to plan some nuclear disaster response drills. In response to this, the university adopted TiPEEZ to perform the effective simulations needed to formulate nuclear disaster response drills involving earthquakes and tsunamis. This investigation on the applicability of TiPEEZ in the Kashiwazaki-Kariwa area was pursued through joint research conducted with the JNES [12)]. In this investigation, the Niigata Institute of Technology, as a kernel institution, led some demonstrations aimed at local government personnel and local residents.

3. Promoting Partnerships Among Nuclear Facilities and Local Communities

Currently, the local governments of affected communities are required to take the lead in evacuating local residents pursuant to the Act on Special Measures Concerning Nuclear Emergency Preparedness and Nuclear Emergency Response Guidelines, as well as other relevant laws, regulations, and guidelines. Nuclear power utilities and the national government need a partnership framework for assisting these local governments. With respect to risk communication, the information obtained from risk assessments concerning natural external events around nuclear facilities contains important findings that may be useful for disaster management in surrounding areas. Seamless collaboration in dealing with nuclear emergencies, tsunamis, and other natural disasters can be expected if risk-related information is shared among the host communities of nuclear facilities and local residents. Going forward, a more specific framework should be developed to facilitate partnerships among nuclear power plants and host communities in addition to the necessary legal system. Furthermore, nuclear facilities are expected to collaborate with their host communities even beyond this legal framework.

V. Conclusions

As a land that is prone to tsunamis, Japan has sought to cope with tsunami hazards in a comprehensive manner through the adoption of tangible measures that involve the use of necessary structures in combination with intangible measures that mainly involve alerts and evacuation. The massive tsunami that was triggered by the 2011 Tohoku earthquake prompted the assignment of two levels to reflect tsunami sizes with the aim of developing tangible plans for disaster management and reduction. Measures for reducing damage to key facilities in coastal areas were also considered. In communities around nuclear facilities, preparedness is even more important in order to be able to cope with any facility-related accidents that may result from tsunamis.

Tsunami measures that form part of coastal conservation efforts are conducted jointly by prefectural governments and the national government pursuant to the Coast Act. Meanwhile, municipalities take the lead in planning local disaster reduction measures pursuant to the Basic Act on Disaster Management. Communities around nuclear facilities must additionally collaborate with private business operators to implement the comprehensive measures required under the Act on Special Measures Concerning Nuclear Emergency Preparedness. To better manage and mitigate tsunami disasters in areas around nuclear facilities, it is vital for power utilities as well as the national and local governments to fulfill their assigned roles in a coordinated manner and work together with municipalities and local residents.

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