Chapter 34

Countermeasures Against Great Earthquakes and Tsunamis in the Near Future

Field of expertise: Seismology

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Summary

After the Great East Japan earthquake disaster, the policy of the Japanese government for disaster risk reduction against great earthquakes and tsunamis changed to be able to cope with the maximum-size earthquakes in each region. One of the pillars of such countermeasures is the evacuation from tsunamis. The Japanese government is developing monitoring systems for earthquakes and tsunamis and a scheme for disseminating information. The stakeholders in society should work together to build an effective evacuation framework using such information.

Keywords: countermeasures against maximum-size earthquakes, monitoring system, iInformation dissemination, uncertainty

Introduction

Great earthquakes along the plate interface bring about damage by generating strong ground motions and large tsunamis. To make the society strong against intense shaking, significant nation-wide efforts constructing earthquake-proof buildings and seismically retrofitting the existing ones have been conducted. As a result, a high level of safety of the buildings has been attained as a whole, if not perfect, and the roadmap to further improvements is clear. On the other hand, a lack of countermeasures against tsunamis were highlighted by the Great East Japan earthquake, which led to a major policy change.

1: Problems Revealed by the Great East Japan Earthquake

What happened?

It was believed before the Tohoku disaster that the forecast of the approximate location and size, or the evaluation of the seismic potentials of earthquakes in different regions in Japan had been accomplished, in spite of the long-standing difficulty in predicting earthquakes. However, the earthquake that actually struck Tohoku ruptured a 500 kilometer long and 200 kilometer wide area along the plate interface to result in magnitude (M) 9.0, way above what was anticipated.

The reality of the damage

The “exceedingly unexpected” height and current of the tsunami from the M9 event caused devastating damage. The protective facilities such as the coastal embankments could not effectively stop the tsunami inundation. In many areas, evacuation was delayed for various reasons including the underestimation of the tsunami height in the initial warning, lack of information updates due to power outage, and the over-reliance on the protective facilities. The Fukushima Daiichi Nuclear Power Plant was no exception; a huge tsunami simultaneously destroyed layers of protective and safety equipment, leading to a fatal accident.

2: Paradigms Destroyed by the Earthquake

Conventional wisdom and necessary responses

The Headquarters of the Earthquake Research Promotion of Japan (HERP), founded in 1995 after the Great Hanshin-Awaji Earthquake, conducted a long-term evaluation of earthquakes such as calculation of a 30-year probability of earthquake occurrence for different areas in Japan. HERP valued what we could learn from past earthquakes and assumed that the same kind of earthquakes would occur in the future. As for the area off the coast of the Tohoku region, a historical earthquake significantly larger than an M8 had been found a few years before the 2011 M9 event. This initiated a movement of re-evaluation of earthquakes in the Tohoku region, but not to the degree where the evaluation was updated and reflected in the reinforcement of the countermeasures.

As noted before, many residents living near the coast could not take appropriate action for evacuation from the tsunami due to the communication breakdown after the initial underestimated warning and other reasons. Considering that the time between the detection of the earthquake and the arrival of the tsunami was around 30 minutes or more, the degree of damage due to the tsunami should have been much smaller if accurate information on the tsunami forecast had reached residents in a timely manner.

3: A New Approach

The Central Disaster Management Council (CDMC) of the Japanese government revised the policy of earthquake disaster risk reduction. Specifically, CDMC made clear that the ground motion and tsunami from the maximum-possible earthquakes should be considered in their published report (Cabinet Office, 2011). Complying with this policy change, fault models of M9 earthquakes and their associated tsunami heights were published for the areas of the Nankai Trough subduction in southwest Japan and that of the Japan trench to Kuril trench in northern Japan. The aforementioned report indicated that two levels of tsunamis should be anticipated and prepared for: The first level (L1) corresponds to the tsunamis caused by earthquakes that occur once in several decades to a hundred years or slightly more (large earthquakes, considered typical for the region), and the second level (L2) corresponds to the maximum-possible tsunamis caused by extremely rare earthquakes that occur every several hundred to a thousand years (Cabinet Office, 2011). Given the distinctions, the report also provided the basic concept such that a holistic approach including both hard (i.e., relying on man-made structures) and soft (i.e., not relying on man-made structures, evacuation for example) countermeasures are to be taken (Figure 34-1).

This concept was later legally authorized by the Act on Regional Development for Tsunami Disaster Prevention (taken into force in December 2011).

The new concept for disaster risk reduction requires that timely and reliable information for evacuation is disseminated and that appropriate responsive actions are taken. In the new tsunami warning system of the Japan Meteorological Agency introduced after the disaster, the initial tsunami warning for earthquakes greater than M8, whose accurate size cannot be estimated instantly, automatically assumes the maximum-level tsunami. However, repeatedly disseminating such uncertain and possibly over-predicted information would reduce the reliability of the tsunami warning, and further hampers residents' evacuation (so-called crying-wolf syndrome). Prompt and accurate estimation of the tsunami height thus leads to appropriate evacuation actions.

After the disaster, a new sea-cable observation system called S-net was deployed off the shore of north and northeastern Japan along the Japan and Kuril trenches, enabling early detection of earthquakes and tsunamis. The extension and upgrade of the DONET observation system, another sea-cable observation system installed along the Nankai Trough in south western Japan, also took place. Research on the near real-time estimation of fault models and tsunami predictions using data from these observation networks and from the GNSS Earth Observation Network System (GEONET) on land has been actively conducte (Ohta et al., 2018). Timely integration of this type of analysis into the alert system is highly expected. It makes effective evacuation, saving lives and important properties of the residents, into a reality.

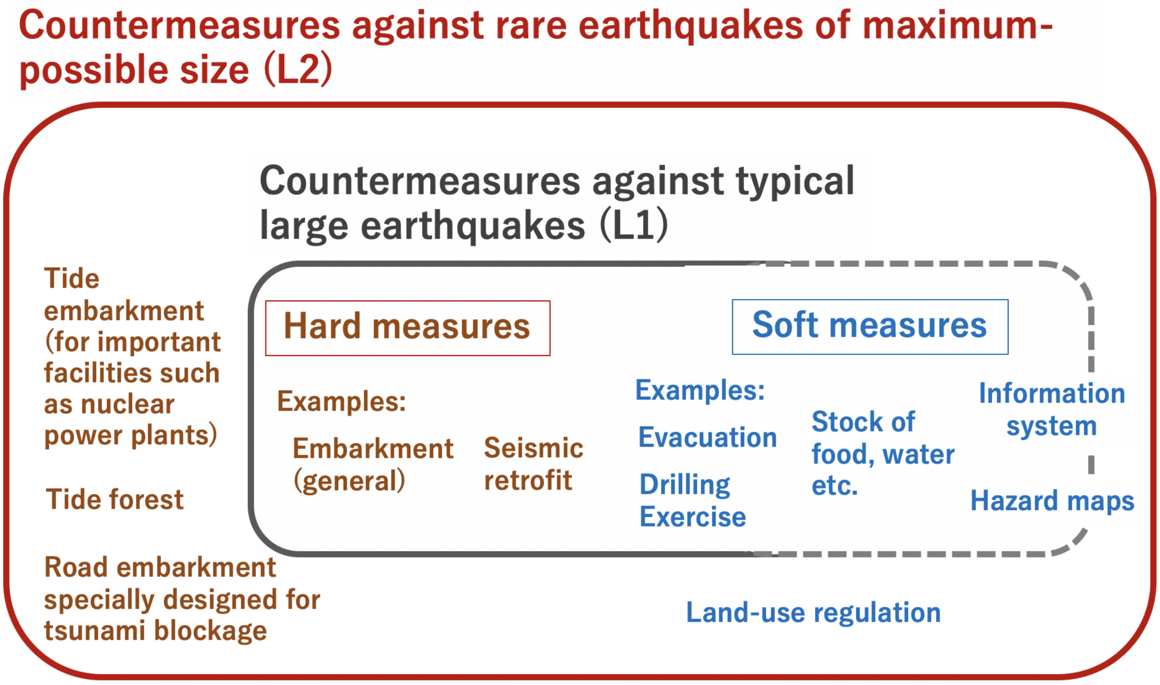

Figure 34-1. A conceptual figure showing the policy on the earthquake and tsunami disaster mitigation in Japan after the 2011 disaster. Compared to typical large earthquakes that occur once every several decades to one hundred years or slightly more (L1), the goal is to prevent damage mainly by relying on hard measures. Compared to the maximum-level earthquakes that occur much less frequently (L2), the goal is to minimize the damage in a holistic approach including not only through hard measures but also soft measures including tide forests and raised road developments for dissipating the tsunami energy in order to facilitate evacuation.

4: Achievements and the Future

A new approach to disaster science

In November 2017, JMA started a service to release warning information when the probability of having a great earthquake (larger than or equal to M8) along the Nankai Trough subduction is evaluated to have become higher than normal (Cabinet Office, 2019). The highest-level alert, as of the timing of writing, is issued for the cases where an M8-class earthquake occurred along the Nankai Trough and vigilance for another M8 or larger earthquake in the vicinity needs to be evoked. We can never be certain about the occurrence of a severe earthquake, but science can provide potentially useful information, such as the areas of elevated risk by using the data from the observation networks being deployed and extended. This new warning system has the potential to drastically decrease the number of victims by urging early evacuation from tsunamis.

Conclusion - from the author

One of the key factors for tsunami disaster mitigation is to appropriately react to the forecast and outlook of the future occurrence of earthquakes and associated tsunamis. The new warning system for great earthquakes along the Nankai Trough is not an easy information for the society to digest because it necessarily entails uncertainty, but if the stake-holders, including researchers, administrations, residents, and media, can discuss and work together consistently, future disaster risk reduction can surely be realized. I hope that the stake-holders from different sectors will be proactively involved in creating an effective warning system for anticipated disasters.

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