Storm surge and tsunami countermeasures

1. Outline of Studies and Activities

Event	Subject	Research	Reflection of results
December 2004 Earthquake off the Coast of Sumatra, Indonesia November 2007 IPCC Fourth Assessment Report	・Appropriate communication of hazard information to residents ・Appropriate evacuation guidance ・Maintenance and awareness of hazard maps ・Sea level rise ・Storm surge disaster risk	Research Stage 1 **■Research on coastal hazards and Hhazards of coastal disasters** ・Identification of hazard map technology issues ・Study of disaster information communication methods ・Development of dynamic hazard maps, etc. **■Research on damage caused by tsunamis and storm surges** ・Methodology for estimating damage from tsunami-drifted debris ・Study of disaster mitigation effects of structures, etc.	◆ Support for the creation of hazard maps by port managers ◆ Development of a moving hazard map and support for its introduction in multiple municipalities ◆ Support for port managers in their studies on tsunami debris damage ◆ Support for disaster prevention education by local governments ◆ Support for the selection of evacuation sites by local governments ◆ Support for the revision of port technical standards
October 2009 Typhoon No. 18 Mikawa Bay Storm Surge March 2011 The Great East Japan Earthquake	・Tenacious structures that can withstand unexpected external forces ・Increased need for rapid and accurate evacuation	Research Stage 2 **■Research on design methods that take into account the effects of earthquakes and tsunamis** ・Survey of damage ・Examination of damage mechanism ・Examination of tenacious structures, etc. **■Research on evacuation from tsunamis and storm surges** ・Tsunami evacuation questionnaire ・Tsunami evacuation simulation, etc.	◆ Support for the formulation of seawall tsunami resistance design guidelines ◆ Support for the creation of storm surge disaster risk maps by local governments ◆ Application to area disaster mitigation planning ◆ Support for the revision of port technical standards ◆ Support for the revision of coastal technical standards
October 2014 IPCC Fifth Assessment Report September 2018 Typhoon No. 18 Damage to Osaka Bay Sep/Oct 2019 Typhoon No. 15/19 Damage to Tokyo Bay	・Sea level rise ・Storm surge disaster risk ・Measures against container collapse and drifting	Research Stage 3 **■Research on storm surge countermeasures and storm surge disaster risk estimation** ・Improvement of storm surge damage prediction model ・Storm surge inundation forecasting considering climate change, etc. **■Container protection against typhoons** ・Countermeasures against container collapse ・Countermeasures against container drift, etc. **■Research on design method considering global warming** ・Study of adaptive design method considering sea level rise, etc.	◆Application to phase-specific storm surges and storm response planning

- The tsunami generated by the Great East Japan Earthquake and other massive earthquakes, and typhoons that are growing in size as a result of global warming, have caused extensive damage in many areas of Japan.
- In order to cope with large-scale coastal disasters caused by tsunamis and storm surges that exceed expectations, and to ensure the safety and security of aging structures, it is necessary to establish and integrate hard measures such as those for port and coastal facilities and soft measures such as those as those for evacuation systems.

Research Stage 1: Research on evaluation of disaster hazard levels for tsunamis, storm surges, etc. in coastal areas (2010-)

<Background/Issues> In order to smoothly implement tsunami and storm surge countermeasures that integrate hard and soft measures, it is necessary to appropriately assess the local risk level for coastal disasters. For this purpose, it is necessary to understand the current status of coastal protection facilities in the target area, expected external forces, and the situation of human lives and assets in the surrounding areas. However, these factors have not been fully understood because of the lack of a systematic evaluation method for disaster risk in coastal areas.

<Research Outline and Results> We collected and organized necessary data, extracted data items for use in hazard mapping, etc., conducted risk assessment using a unified method, and developed a support method for promoting soft measures such as hazard mapping with the participation of local residents. We also developed a risk communication tool for coastal areas that can be used by residents and government officials in workshops and other settings to establish the conditions for disaster occurrence on a trial-and-error basis.

Research Stage 2: Research on hard and soft measures in light of the Great East Japan Earthquake (2011-2015)

<Background/Issues> Based on the damage caused by the tsunami from the Great East Japan Earthquake, two tsunami levels were assumed, and it was decided to study "tenacious" structures that would not lose their protective functions, as much as possible, even in the case of a tsunami exceeding the assumed tsunami level. In addition, the plan called for supporting local governments in formulating efficient and simple evacuation plans that can be carried out promptly and appropriately in the event of a tsunami.

<Research Outline and Results> Design methods aiming at tenacious coastal structures were studied and reflected in the "Guidelines for Tsunami Resistance Design of Seawalls (Breast Walls) in Ports and Harbors" (Ministry of Land, Infrastructure, Transport and Tourism, November 2013). In addition, we developed a sophisticated tsunami evacuation simulation program to assist local governments and others in formulating tsunami evacuation plans, developed an evacuation planning method using tsunami evacuation simulations, and developed tsunami and other observation techniques using oceanic shortwave radar installed to observe tidal currents and drifting debris.

Research Stage 3: Research to enhance the safety of waterfront areas against strong winds and storm surges caused by giant typhoons (2016-)

<Background/Issues> With the risk of storm surge disasters increasing due to sea level rise, the three major bays and other urban waterfront areas required the development of technology necessary for meticulous observation of tidal levels and waves, as well as advanced storm surge inundation forecasts, in order to ensure safety from storm surges in port areas.

In addition, Typhoon No. 21 in 2018 and Typhoon No. 15 in 2028 caused the collapse and drift damage of warehoused containers in the ports of Osaka Bay and Tokyo Bay. The collapse and drifting damage of containers can hinder the rapid resumption of port functions and cause other problems.

<Research Outline and Results> We developed a simple device for detailed observation of tide levels and confirmed that it was sufficiently accurate. In addition, to improve the accuracy of storm surge inundation forecasting, we proposed a calculation formula for the maximum wind speed radius and central pressure of typhoons, which enables probabilistic evaluation.

Furthermore, the qualitative wind resistance performance was ascertained through experiments using container models, and some of the results were reflected in the "Guidelines for Storm Surge Risk Reduction Measures in Port and Harbor Areas Outside Embankments" (Ministry of Land, Infrastructure, Transport and Tourism, March 2019).

2. Main Research Results

Research Stage 1: Development of moving hazard maps (Risk maps)

We developed a "moving hazard map" (an evacuation simulation in which residents can experience the evacuation by inputting their homes, evacuation start time, routes, etc.) and held explanatory meetings for residents on an ongoing basis. The effectiveness of the moving hazard map in changing the attitude and behavior of residents was measured, and the educational effect was ascertained. In addition, we provided technical support in the formulation of a data maintenance guideline and the provision of a core system as a mechanism for dissemination.[1),2)]

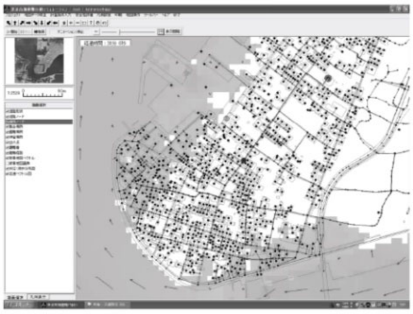

Figure-1 Example of a moving hazard map screen

Research Stage 2-1: Study on the design methodology for coastal structures considering earthquake and tsunami action

Utilizing the results of field surveys[3),4)] at the affected ports, we analyzed the damage patterns and examined the damage mechanisms of the breastworks due to overtopping by tsunamis exceeding the design tsunami and the resulting scouring.[5),6)] Based on the results, the basic concept of the tenacious structure of the breastworks was summarized in the "Guidelines for the Tsunami Resistance Design of Breakwaters (Breast Walls) at Harbors" (Ministry of Land, Infrastructure, Transport and Tourism, November 2013).

Figure-2 Example of damage to coastal protection facilities (Kamaishi Port Coast)

Research Stage 2-2: Improvement of safety against tsunamis in port areas

The tsunami evacuation simulation was improved and upgraded based on actual measurements, etc., and we summarized the planning method and points to keep in mind in the process of tsunami evacuation planning using the improved tsunami evacuation simulation.[7)]

In addition, we improved the data acquisition system and noise reduction system using oceanic shortwave radar, and evaluated the performance of the tsunami observation technique.[8)]

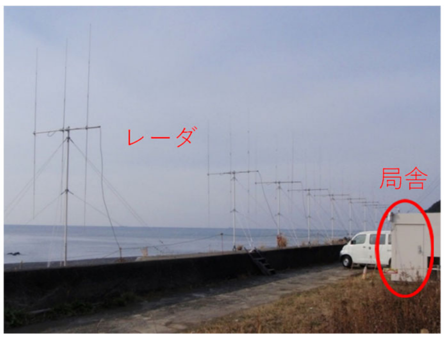

Figure-3 Oceanic shortwave radar

Research Stage 3-1. Study on the safety of port areas against storm surge disasters

The wave height estimation by oceanic shortwave radar was found to be sufficiently accurate offshore. We also confirmed that the simple device developed for detailed tide-level observation was sufficiently accurate, and can be used without missing measurements even during a typhoon.[9] In order to improve the accuracy of storm surge inundation predictions, we found that the maximum wind speed radius of a typhoon can be approximated by a log-normal distribution with respect to the central pressure, and we proposed evaluation formulas for each coefficient of the log-normal distribution to allow a probability evaluation in the typhoon model used for storm surge estimation.[10),11)]

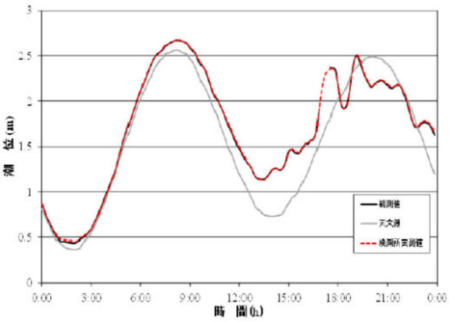

Figure-4 Observation results from simple tide-level observation device

Research Stage 3-2: Research on typhoon protection for warehoused containers

Experiments were conducted in the NILIM wind tunnel tank using container models with different stacking methods, number of tiers, and fastening methods to understand the qualitative wind resistance performance, and some of the results were reflected in the "Guidelines for Storm Surge Risk Reduction Measures in Port and Harbor Areas Outside Embankments" (Ministry of Land, Infrastructure, Transport and Tourism, March 2019). In addition, similar model tests were conducted to measure the impact and compensating forces acting on the container drift barriers, and to quantify the external force conditions under which containers can overcome the drift barriers. In the future, we plan to propose quantitative wind resistance measures according to the wind speed levels and quantitative design methods for the drift barriers.


Figure-5 Experimental view of a container collapsing in a wind tunnel tank Wind resistance due to different fastening methods

3. List of Related Reports and Technical Documents

(1) Research reports and materials

1) Fundamental Study on Evaluating the Safeness of Tsunami Evacuation in Consideration of the Characteristics of Urban Structures and Tsunami Inundation, NILIM Technical Note No. 537 http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0537.htm
2) Study on the effects of the mitigation measures on tsunami evacuation safety and research on the evacuation building location method, NILIM Technical Note No. 675 http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0675.htm
3) Field Survey of the 2011 off the Pacific Coast of Tohoku Earthquake and Tsunami on Shore Protection Facilities in Ports, NILIM Technical Note No. 658 http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0658.htm
4) Field Survey of the 2011 off the Pacific Coast of Tohoku Earthquake and Tsunami on Shore Protection Facilities in Ports (II), NILIM Technical Note No. 781 http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0781.htm
5) Characteristics of Damage to Coastal Protection Facilities in Ports due to the 2011 off the Pacific Coast of Tohoku Earthquake and Tsunami, NILIM Technical Note No. 810 http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0810.htm

6) Measurement of height, velocity and pressure of the water overflow over a seawall, NILIM Technical Note No. 917 https://www.ysk.nilim.go.jp/kenkyuseika/pdf/ks0917.pdf
7) Applicability of Tsunami Evacuation Simulation for Evacuation Activity during the 2011 off the Pacific Coast of Tohoku Earthquake Tsunami, NILIM Technical Note No. 742 http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn0742.htm
8) NILIM Project Research Report No. 57 http://www.nilim.go.jp/lab/bcg/siryou/kpr/prn0057.htm
9) A field experiment for the simple measurement of tide level using ultrasound, NILIM Technical Note No. 959 https://www.ysk.nilim.go.jp/kenkyuseika/pdf/ks0959.pdf
10) Effects of Typhoon Parameters on Storm Surge in the Three Major Bays of Japan, NILIM Technical Note of NILIM No. 1039 https://www.ysk.nilim.go.jp/kenkyuseika/pdf/ks1039.pdf
11) Stochastic Formula between the Radius of Maximum Wind Speed and Central Pressure of a Typhoon, NILIM Technical Note No. 1040 https://www.ysk.nilim.go.jp/kenkyuseika/pdf/ks1040.pdf

(2) Guidelines for the use of research results

12) Guidelines for the Tsunami Resistance Design of Seawalls (Breast Walls) in Ports and Harbors https://www.mlit.go.jp/common/001020131.pdf
13) Guidelines for Storm Surge Risk Reduction Measures in Areas Outside of Harbors and Dikes https://www.mlit.go.jp/common/001282935.pdf

4. Future Outlook

Japan is expected to continue experiencing huge earthquakes in the surrounding seas, which will be accompanied by the generation of huge tsunamis. In addition, according to reports by the IPCC and other organizations, the trend in global warming will remain unchanged, future typhoons will grow in size, and sea levels will rise. Therefore, we will continue conducting research to reduce the damage to ports and coastal facilities from tsunamis and storm surges, and protect the lives and property of the people living in coastal areas.