BOOK OF ABSTRACTS

THE FOURTH INTERNATIONAL WORKSHOP ON COASTAL DISASTER PREVENTION

- Future Disaster Management against Tsunami and Storm Surge in Asia-Pacific Region -

Open Event of the 1st Asia-Pacific Water Summit

December 1 - 2, 2007

Yokohama Symposia

THE FOURTH INTERNATIONAL WORKSHOP ON COASTAL DISASTER PREVENTION

- Future Disaster Management against Tsunami and Storm Surge in Asia-Pacific Region -

Open Event of the 1st Asia-Pacific Water Summit

December 1 - 2, 2007
Yokohama Symposia

Devastating tsunami and storm surge disasters have occurred in the world recently such as the Indian Ocean Tsunami in 2004, the storm surge generated by Hurricane Katrina in 2005, the Java Earthquake Tsunami in 2006 and the Solomon Islands Earthquake Tsunami in 2007. It is concerned that tsunamis and storm surges in the future would also cause even more serious disasters. Taking into consideration the discussion in the previous workshops, in this workshop, we will discuss on future tsunami and storm surge disaster reduction and management especially in the Asia-Pacific region. The workshop consists of technical sections in which disaster experiences, rehabilitation activities after disasters and state-of-the-art technologies for disaster reduction are presented by researchers, engineers and government officials gathering from all over the world and a panel discussion section in which the discussion of this workshop is summarized.

Organizers:

- Port and Airport Research Institute (PARI), JAPAN
- Coastal Development Institute of Technology (CDIT), JAPAN
- Ministry of Land, Infrastructure and Transport (MLIT), JAPAN

Support:

- Port and Harbor Bureau, City of Yokohama, JAPAN
- Japanese Section of International Navigation Association
- Panel on Wind and Seismic Effects, U.S.-Japan Cooperative Program in Natural Resources

1st Asia-Pacific Water Summit Beppu Japan 2007 PARI CDIT Ministry of Land, Infrastructure and Transport

第４回国際沿岸防災ワークショップ

～アジア・太平洋の津波・高潮防災を考える～

第１回アジア・太平洋水サミットオープンイベント

2007 年 12 月 1～2 日
横浜シンポジア（産業貿易センタービル９階）

2004 年インド洋津波，2005 年ハリケーンカトリーナによる高潮，2006 年ジャワ島地震津波，2007 年ソロモン諸島地震津波などにより，近年，甚大な津波・高潮災害がアジア・太平洋地域で発生しています．2004 年インド洋津波直後から毎年実施してきた国際沿岸防災ワークショップでの議論を踏まえつつ，本ワークショップでは，アジア・太平洋地域におけるこれからの津波・高潮防災に何が必要なのかを，世界の研究者，技術者，行政関係者を含めて一般参加形式のワークショップとパネルディスカッションを通して考えます．

主催:

- 独立行政法人港湾空港技術研究所
- 財団法人沿岸技術研究センター
- 国土交通省港湾局

後援:

- 横浜市港湾局
- 国際航路協会日本部会
- 天然資源の開発利用に関する日米会議耐風耐震構造専門部会

1st Asia-Pacific Water Summit Beppu Japan 2007　PARI　CDIT　Ministry of Land, Infrastructure and Transport

AGENDA

December 1 (Saturday)

9:30 – 10:00 Registration

10:00 – 10:30 Opening Ceremony

10:00 Call to Order by Mr. Yoichi Sakai, General Manager, Coastal Development Institute of Technology, Japan

10:05 Opening Remarks by Mr. Hiroshi Kanazawa, President of Port and Airport Research Institute, Japan

10:15 Remarks by Mr. Narikuni Nakao, Director-General of Ports and Harbors Bureau, Ministry of Land, Infrastructure and Transport, Japan

10:30 – 11:50 Technical Session 1 – Countermeasure against Storm Surge Disaster

Chairman: Hiroyasu Kawai, Head of Hydrodynamics and Storm Surge Div., Port and Airport Research Institute, Japan

10:30 *Cyclone and Storm Surge Disaster Prevention in Bangladesh*

Fuad Hassan Mallick, Professor, Dept. of Architecture, BRAC University, Bangladesh

10:50 *Storm Surge Disaster Prevention in Korea*

Dong-Young Lee, Principal Research Scientist, Korea Ocean Research and Development Institute, Korea

11:10 *Storm Surge Disaster Prevention in Oceania – with special reference to New Zealand*

Terry Healy, Professor, Dept. of Earth & Ocean Sciences, University of Waikato, New Zealand

11:30 *Storm Surge Protection after Hurricane Katrina in the US*

Billy Edge, Professor, Dept. of Civil Engineering Texas A&M University, USA

11:50 – 13:20 Lunch

13:20 – 15:00 Technical Session 2 – Advanced Technologies of Tsunami and Storm Surge Disaster Prevention/Reduction

Chairman: Takashi Tomita, Research Director, Tsunami Research Center, Port and Airport Research Institute

13:20 *Structures of Storm Surge Disaster Prevention* and Airport Research Institute

17:00 *Information Technology for Advancement of Evacuation –Development of Interactive Evacuation Simulator-*

Katsuya Oda, Head of Coastal Disaster Prevention Div., National Institute for Land and Infrastructure Management, Japan

December 2 (Sunday)

9:30 – 10:00 Registration

10:10 – 11:30 Technical Session 4 – Lessons from Disasters

Chairman: Katsuya Oda, Head of Coastal Disaster Prevention Div., National Institute for Land and Infrastructure Management, Japan

10:10 *Characteristics of Storm Surge Disasters in Japan*

Tomotsuka Takayama, Director of Institute of Technology for Disaster Management, Coastal Development Institute of Technology, Japan

10:30 *Tsunami Disaster and Integrated Counter Measure in Japan*

Fumihiko Imamura, Professor, Disaster Control Research Center, Tohoku University, Japan

10:50 *Towards an Integrated Tsunami Disaster Mitigation in Indonesia*

Subandono Diposaptono, Directorate General of Marine, Coasts, and Small Islands, Ministry of Marine Affairs and Fisheries, Indonesia

11:10 *Assessment of Tsunami Risk to the Port City of Galle in Sri Lanka*

Nimal Wijayaratna, Senior Lecturer, Dept. of Civil and Environmental Engineering, University of Ruhuna, Sri Lanka

11:30 – 13:00 Lunch

13:00 – 14:00 Technical Session 5 – Future Disaster Prevention Strategy

Chairman: Koji Fujima, Professor, Dept. of Civil and Environmental Engineering, National Defense Academy, Japan

13:00 *A Strategy for Storm Surge Disaster Reduction*

Masahiko Isobe, Professor, Dept. of Environmental Studies, University of Tokyo, Japan

13:20 *Disaster Reduction Strategy of Tsunami*

Yoshiaki Kawata, Professor and Director of Disaster Prevention Research Institute, Kyoto University, Japan

THE FOURTH INTERNATIONAL WORKSHOP ON COASTAL DISASTER PREVENTION

CYCLONE AND STORM SURGE DISASTER PREVENTION IN BANGLADESH

Fuad H Mallick, *PhD*
Director, Post Graduate Programs in Disaster Management
BRAC University, Dhaka.
Bangladesh
fuad@bracuniversity.ac.bd
Md. Humayun Kabir
Coordinator, Post Graduate Programs in Disaster Management
BRAC University, Dhaka
Bangladesh
mhk@barcuniversity.ac.bd

1. INTRODUCTION

Bangladesh is no stranger to disasters. The nature of which either bring on extensive damage within a short span of time i.e. cyclones and storm surges or slow moving long staying type i.e. floods which disrupt lives for extended periods of time. The former are devastating and do massive damage. As recently as a few weeks ago cyclone SIDR claimed over 3000 lives (at the time of writing this abstract) and caused widespread damage to crops and property. That in the coastal region of Bangladesh such disasters will happen time and again is well understood. Although there has been no serious experience of Tsunami, that too remains a possibility. Then again, Bangladesh is also known to deal with disasters quite well given its poor economic conditions and lack of resources. Over the past years disaster preparedness has been on the agenda and it can be said that loss of lives due to cyclones and storm surges has been less compared to 2 or 3 decades ago. This is the result of improvement in early warning systems, people's awareness through government and non-government initiatives, mechanisms of getting the warning across to people and the effectiveness of cyclone and storm surge shelters and means of relatively improved construction of buildings.

2. PREPAREDNESS AGAINST CYCLONE AND STORM SURGES

The cyclone shelters built as a part of the "Study on Multipurpose Cyclone Shelter Programme" presents a means of reducing the loss of life and property in the event of cyclones and storm surges. Since the houses of the people who live in disaster prone areas are mainly non-engineered and the people do not have the means to build resistant houses, these cyclone shelters are effective in harbouring the potential victims in the event of a cyclone or storm surge. Early warning systems are in place where the people are asked to take shelter in such structures to overcome the wrath of the disaster. Designed to withstand high winds and provide basic facilities for the people who take shelter in them, they are built elevated from the ground to protect from storm surges. During normal times they are used for different purposes. There is variety in design and which take into account engineering and architectural issues as well as issues of social importance. Also methods for strengthening non-engineered structure against cyclones have been devised. Most of them still remain outside the economic means of the population it is meant to serve.

3. PROBLEMS ENCOUNTERED

Although there are early warning systems and means of warning individual families to take shelter, in many cases, it is reported that many of them do not go to the shelters leaving their belongings. The number and capacity of the cyclone shelters are still inadequate compared to the public demands. It has been found from the field investigation that the existing shelters have been constructed mainly on lands donated by the locals, which are in most cases located far from the community. As a result, most of the local people cannot easily move to the shelters during cyclone. Moreover, most of the shelters do not adequately provide facilities for the women, children and animals during disasters.

3. SUMMARY

The existing number of cyclone shelters is 1841. Although most of the cyclone shelters have been constructed after the devastating cyclone of 1991, they are still insufficient. In order to prevent damages from cyclone and storm surge, there is no alternative but to construct shelters and engineered buildings. The number of shelters needs to be increased considering the demands of the local people and geographical location. In order to completely reduce the losses of cyclone and storm surge, a holistic approach is essential incorporating all stakeholders.

Figure 1. A multipurpose cyclone shelter constructed by BDRCS

4. REFERENCES

Ahmed, K.I. (2001) *Participatory Action Research on Building-for-Safety Options for Low-Income Rural Housing in Flood-Prone Areas*. Research report. Dhaka, BUET and UK, University of Exeter.

Ahmed, K.I. (ed.) (2001). *Low-Income Housing: Multi-Dimensional Research Perspectives.* Dhaka, Grameen Trust.

BUET and BIDS (1993). Multipurpose Cyclone Shelter Programme, Final Report, UNDP/World Bank/GoB Project, Dhaka.

STORM SURGE DISASTER PREVENTION IN KOREA

Dong-Young Lee, Korea Ocean Research and Development Institute,
Ansan, Korea, dylee@kordi.re.kr

Byung-Ho Choi, Sungkyunkwan University,
Suwon, Korea, bhchoi@yurim.skku.ac.kr

1. INTRODUCTION

There are two major methods in mitigating the hazard caused by storm surges: one by short-term prediction of impending extreme water level using available information to take immediate actions to reduce risk such as evacuation, rescue, etc. and the other by long-term statistical prediction of extreme water level as a basic information to take long-term and rather fundamental counter-measure to reduce coastal hazard. Both methods require accurate information on meteorological forcing and field observation data from water level observation network.

After significant damages caused by Typhoon Maemi for the southern coastal area of Korea in 2003, Korean government has been taking actions to counter-measure to reduce storm surge disaster along the coast of Korea.

2. WATER LEVEL OBSERVATION SYSTEM IN KOREA

National Oceanographic Research Institute(NORI) has been working to improve and expend real-time coastal observation network including tide observation system. Real-time water level data sampled at every 1 minute is provided by NORI for its major tide stations.

Understanding of tide and wind waves is well advanced with accumulation of field observation data obtained from tide and wave monitoring systems. However, our understanding on the long waves besides tide is limited due to lack of field observation data. Recently, the wave monitoring program conducted by Korea Ocean Research and Development Institute (KORDI) has been expended to include continuous monitoring of all the frequency range of waves by monitoring subsurface pressure data sampled every 0.5 second interval continuously at several locations with minimal local effect around Korea.

3. STORM SURGE PREDICTION SYSTEM

Korea Meteorological Administration(KMA) operates storm surge prediction system with the help of NORI that is in charge of real-time water level observation in Korea. Effort to reduce grid size of the predictive model is underway to improve space resolution of the storm surge prediction.

Since the extreme water level rise caused by severe typhoon is time and site dependent and affected by waves in shallow water quite a lot, the development of fine mesh storm surge prediction system coupled with wave model is necessary. Research program to develop coastal wave and storm surge prediction system for the coastal waters of Korea is carried out by university and research institute such as Sungkyunkwan University and KORDI.

An intensive field experiment is planned at western coastal waters of Korea where tide range is large to study wave-current interaction and other coastal processes at coastal waters of macro tide environment jointly by KORDI and universities. The prediction of proper meteorological forcing is essential in storm surge prediction. Research cooperation between KORDI and Port and Airport Research Instiute(PARI) is on-going in the analysis and transformation of typhoon parameters and accurate estimation of typhoon wind field and resultant storm surge.

4. ESTIMATION OF DESIGN WAVE HEIGHT AND WATER LEVEL

Design wave height for the return period of 20, 30, 50 and 100 years for 16 directions at each grid point of 18 km grid size for the waters around Korean peninsular has been estimated by means of extreme wave analysis using the wave simulation data for major typhoons that affected Korea since 1951 and the continuously hindcasted wave data since 1979. These data are used as input boundary condition for shallow water wave model to produce shallow water design wave height.

Estimation of extreme storm surge caused by typhoon along the coast of Korea is being carried out by KORDI, while that caused by tsunami along the east coast of Korea is being carried out by Hanyang University and Sungkyunkwan University with the financial support from Ministry of Maritime Affair and Fisheries(MOMAF) by means of long-term simulation of extreme water level caused by typhoon and tsunami that affected Korea in the past. The impact of global climate change in the estimation of extreme water level becomes an important issue now, which may require lots of research and discussion in the future. The safety of coastal structures with updated design criteria will be evaluated for the major port facilities of Korea to take proper measure to reduce coastal hazard.

5. DISCUSSION

Recently big damages of coastal and port facilities have been frequently experienced due to the severe typhoon in the region. Extreme wave height and water level tend to increase in the region due to the increase of typhoon intensity. The design criteria of harbour facilities in the region is mostly determined by the typhoon. The intensity of typhoon in the region is expected to increase in the future due to the impact of global climate change. Cooperation among the neighboring countries like Japan and Korea is necessary to cope with the common problem of coastal hazard reduction caused by typhoon in the region.

4th International Workshop on Coastal Disaster Prevention
December 1-3, 2007, Yokosuka, Japan

STORM SURGE DISASTER PREVENTION IN OCEANIA – WITH SPECIAL REFRENCE TO NEW ZEALAND

Terry HEALY
Research Professor, Coastal Marine Group,
Department of Earth and Ocean Sciences
University of Waikato, P.B. 3105, Hamilton
New Zealand

t.healy@waikato.ac.nz

ABSTRACT

1. Natural coastal hazards impacting the oceanic islands of New Zealand are similar to those in Japan, but the response is different due to a hugely different population density, settlement patterns and pressure on the coastline for resources.

2. The most frequent coastal hazards for New Zealand include coastal erosion, storm surge and flooding, and tsunami run-up. To date such hazards have been classed as "non-catastrophic hazards".

3. Their impacts have caused only limited loss of life – not a "disaster". The more catastrophic natural hazards in the coastal zone (earthquake effects, accompanying local tsunamis, and volcanic eruptions) have only rarely occurred since human settlement in New Zealand (after about 1200 AD), but the geological configuration and record shows catastrophic hazards can be expected in the future – for which one could expect disastrous loss of life and property.

4. Policy management of natural hazards in the coastal zone in New Zealand is guided by the principles of *sustainable management* within the New Zealand Coastal Policy Statement 1994.

5. Operational management of non-catastrophic coastal hazards is under the Regional Councils (equivalent to Prefecture Governments), who are required to produce Regional Coastal Environmental Plans. These policies and rules govern the response to natural coastal hazards. For catastrophic events in the coastal zone, operational management is under the Ministry of Civil Defence and Emergency Management, based upon protocols for impact reduction, readiness, response, and recovery.

6. Storm surge hazard in New Zealand typically is manifested as:

a. Wave run-up and frontal dune overwash, with flooding of the hinter-dune swale.
b. Wave focusing on frontal dunes.
c. Flooding on alluvial lowlands, particularly adjacent to river mouths from a combination of marine storm surge effects, and catchment river discharges.

7. Storm surge response options historically have included structure protection by rip-rap revetments, sea walls, and dikes (locally termed "stopbanks")

8. Although not planned a recent expansion of mangroves has acted to mitigate against storm surge damaging coastal dikes.

9. In more recent decades, emphasis has been on "soft engineering" approaches including beach renourishment, dune care and enhancement, and implementation of "coastal hazard zones" or development setbacks.

10. In some cases artificial dunes have been reconstructed including with a solid 'dike' core overlain by an artifical dune at Omaha. In some locations beach scraping to reform a dune has occurred.

11. In particular for ocean beaches, New Zealand has tended toward mitigation of storm surge by planning requirements of sizeable setback, and maintenance and enhancement of natural dunes.

12. Mitigation of coastal hazards is based upon identification and scientific investigation of the hazards, their impacts and risks, and the resulting rules in the coastal environmental plans. Education in the schools and of the public, and continuing scientific research, is an integral component of mitigation for coastal hazards.

13. REFERENCES

Healy, T.R., (1987): The importance of wave focusing in the coastal erosion and sedimentation process. *Coastal Sediments 87*, American Society of Civil Engineers, pp 1472-1485.

Healy, T., (2002). Enhancing coastal function by sensible setback for open duned coasts. *Solutions to Coastal Disasters '02,* American Society of Civil Engineers, pp. 794- 807.

Healy, T.R. and Dean, R.G., (2000). Methodology for delineation of coastal hazard zone and development setback for open duned coasts, *In*: J.B. Herbich (editor) *Handbook of Coastal Engineering.* McGraw-Hill, pp. 19.1-19.30.

STORM SURGE PROTECTION AFTER HURRICANE KATRINA IN THE US

Billy L. Edge, Director Haynes Coastal Engineering Laboratory
Civil Engineering Department, Texas A&M University
College Station, Texas 77843-3136
b-edge@tamu.edu

1. INTRODUCTION

Traditionally, hurricane protection systems in the United States were based on the standard project hurricane (SPH) which is the most severe storm that is considered reasonably characteristic of the region in which the basin is located or the more severe maximum probable hurricane (MPH) which is a hypothetical steady state hurricane having meteorological parameters that will give the highest sustained wind speed that can probably occur at a specified coastal location. These approaches for the design storm were used in the design of various storm surge protection works including many seawalls constructed on the Atlantic, Gulf and Pacific coasts. The works have also included large dunes as a part of beach nourishment projects and levees for low lying areas. The Galveston seawall in Texas, constructed after the 1900 hurricane killed over 8,000 people, was constructed prior to these methods yet it has worked very effectively.

2. RISK ANALYSIS

Because of the interest in risk and reliability during the 1990's, the Empirical Simulation Technique (EST) was established to account for the uncertainty and risk in prediction of the MPH and SPH. The EST primarily used the historical storms, their tracks and meteorological parameters to identify the envelope of all extreme event effects including wind, waves and surge at a particular coastal site. The bootstrap methodology also allowed for simulation over a several hundred year period using a re-sampling approach. Moreover, the EST methodology lends itself to the addition of several hypothetical storms as well to the training set. Still the method is hindered by the small number of hurricanes affecting a particular area.

3. STORM SURGE APPROACH FOR DESIGN

After the flooding in New Orleans from hurricane Katrina, the Corps of Engineers decided that the Joint Probability Method would provide better estimates of the risk for locations along the Gulf of Mexico. This was felt to be the best approach to describe the hazard in the best statistical sense at any and all locations. For example in evaluating the future storms for New Orleans, all historical storms passing through the Gulf of Mexico have been mapped onto a five dimensional surface representing central pressure, radius to maximum winds, forward speed, direction of landfall and Holland's radial pressure profile parameter. Many potential tracks of storms are selected with combinations of parameters for the development of surge and wave conditions within computational reason. The five-dimensional surface is used to establish a response surface for each indexed frequency of interest. The storm effects are generated using a PBL model for the winds, ADCIRC for the storm surges and WAM, STWAVE, and SWAN for computing waves. The final component is implementation of the Boussinesq model for determining runup and overtopping. This methodology is now supported both by the Department of Homeland Security and the Corps of Engineers for evaluating risk for hurricane flooding and is used to establish the criteria for designing the 400 miles of levee for the 100 year storm.

STRUCTURES OF STORM SURGE DISASTER PREVENTION

Nobuhisa Kobayashi, University of Delaware
Newark, Delaware USA, nk@udel.edu

1. INTRODUCTION

Coastal structures such as sea walls and dikes were designed for no overflow of a design storm tide (sum of surge and tide) and for little overtopping of design wind waves. Most of the existing structures were constructed after storm surge disasters that occurred decades ago. Some of these structures are deteriorating and have not been maintained adequately. At the same time, the population and assets protected by coastal defense structures have increased considerably since the last storm surge disaster. Moreover, the risk of excessive overtopping and overflow is increasing due to sea level rise, storm intensification and land subsidence.

One option to reduce the future risk of storm surge flooding is to increase the crest height of the structure but this option may not be feasible technically and aesthetically. Furthermore, the increased crest height may not be sufficient for storms exceeding the design conditions. Another option is to reinforce the structure in such ways as to accommodate minor overflow or excessive wave overtopping within an acceptable damage during severe storms that are equal to or exceed the design conditions. This option aims at increasing the resiliency of the structure so that it will not fail catastrophically during storms exceeding the design conditions. The first step for this resilient design is to quantify and predict excessive overtopping and overflow on coastal structures such as a dike that is examined in the following.

2. WAVE OVERTOPPING AND OVERFLOW

Earthen levees are designed for little wave overtopping during a design storm but excessive overtopping and overflow can occur due to the combined effects of an extreme storm, sea level rise and land subsidence. The transition from little wave overtopping to excessive wave overtopping and overflow on an impermeable smooth levee is examined in wave-flume experiments consisting of 107 tests as shown in Fig. 1. A numerical model based on time-averaged continuity, momentum and wave action equations is developed to predict the cross-shore variations of the mean and standard deviation of the free surface elevation and depth-averaged fluid velocity of irregular waves in the presence of onshore steady flow. An empirical formula is proposed to express the wave overtopping and overflow rate in terms of the computed variables on the seaward slope of the levee. The formula is shown to predict the measured overtopping and overflow rates within a factor of about 2 as shown in Fig. 2. The numerical model is applied to an earthen levee in Louisiana depicted in Fig. 3. The numerical model will need to be extended to the landward slope of the levee and coupled with a model for levee erosion and breaching.

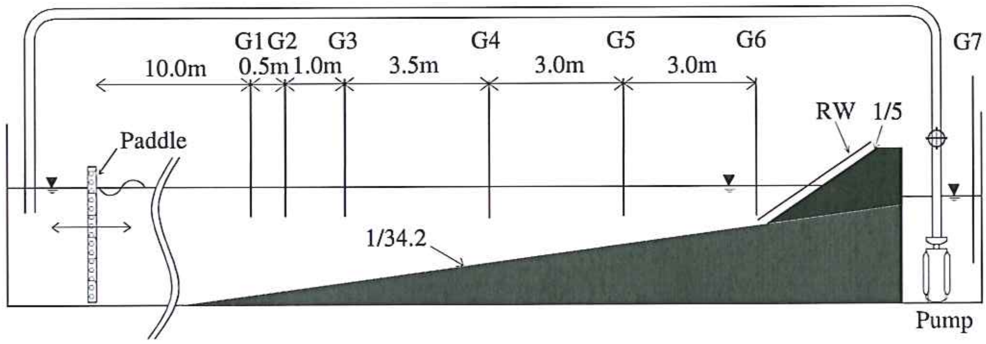


Fig. 1. Experimental setup in wave flume.

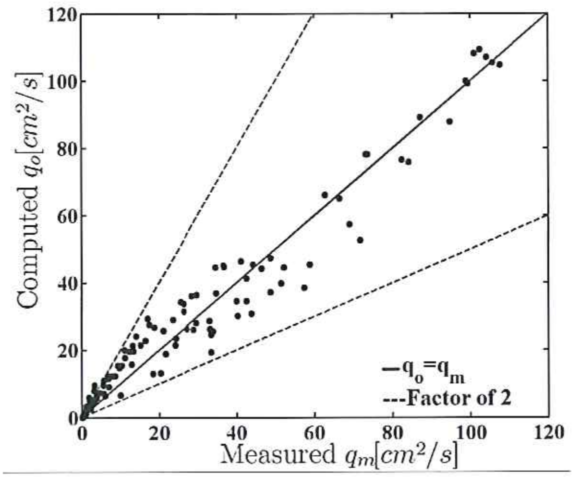


Fig. 2. Measured and computed wave overtopping and overflow rates.

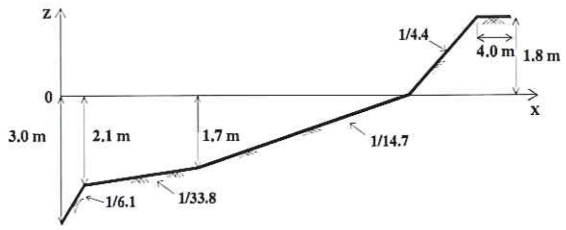


Fig. 3. Earthen levee geometry in Louisiana.

SIMULATION OF STRUCTURAL DAMAGE DUE TO TSUNAMI

Solomon C. Yim, solomon.yim@oregonstate.edu
Oregon State University, Corvallis, Oregon USA
Fai Cheung, cheung@hawaii.edu, Geno Pawlak, Pawlak@hawai.edu,
H. Ronald Riggs, riggs@hawaii.edu and Ian Robertson, ianrob@hawaii.edu
University of Hawaii, Manoa, Hawaii USA
Ying Lu Young, yyoung@princeton.edu
Princeton University, Princeton, New Jersey USA

1. INTRODUCTION

The Sumatra earthquake-induced tsunami in December 2004 caused severe damage to a significant number of structures along the coasts of the Indian Ocean. To understand the mechanics of tsunami inundation and impact effects on US coastal structures, the National Science Foundation (NSF) is supporting fundamental studies on both numerical and experimental simulations of fluid effects on structures. In this paper, we describe numerical model development and experimental studies in a collaborative NSF funded Network for Earthquake Engineering Simulation Research (NEESR) project conducted by researchers at the University of Hawaii (UH), Princeton University (PU) and Oregon State University (OSU). Multi-year large-scale experiments with multiple slopes and unique reef geometries are being performed to validate the resulting numerical models at the OSU NEES 3-D Tsunami Wave Basin (TWB) and the 2-D Large Wave Flume (LWF). The intent of the research is to develop performance-based engineering design guidelines for tsunami resistant coastal structures.

2. NUMERICAL MODEL DEVELOPMENT

Numerical models of tsunami propagation, seafloor roughness and tsunami effects on seafloor scour are being developed at UH and PU, while wave impact, coupled fluid-structure interaction models of tsunami inundation, impact effects on coastal structures and debris flow are being developed simultaneously at both UH and OSU using complementary numerical solution techniques and software. Specifically, the tsunami wave propagation model being developed is based on a multi-grid three-dimensional (3-D) finite-volume (FV) solution of the modified Boussinesq equation; the seafloor scour model is based on a semi-analytical method developed at Princeton; the fluid-structure interaction models at UH are based on the FV solution of the Reynolds-averaged Navier-Stokes (RANS) equation in FLUENT and OpenFOAM; and the coupled fluid-structure interaction, impact and debris flow models at OSU are based on particle finite-element, boundary element and smoothed particle hydrodynamic solvers of the RANS, potential flow and state equations, respectively, being developed collaboratively with LS-DYNA.

3. EXPERIMENTAL STUDIES

Corresponding experimental studies spanning over three years (2006-2009) on tsunami propagation, seafloor roughness and scour, and tsunami impact on structures are being conducted at the OSU NEES TWB (50m x 26.5m x 2m) and the LWF (104m x 4m x 5m). Experiments to date have been conducted in the TWB using a piston wavemaker with a 2m maximum stroke and 2m/sec maximum velocity. Three beach slopes (1/5, 1/10 and 1/15) with various roughnesses are used. A crest at the slope transition with various heights (0.05, 0.10, and 0.15m) is employed to simulate different reef formations. Tests are conducted at water depths ranging from 1.0 to 1.25m with solitary wave heights from 0.1 to 0.6m. Wave height and pressure along the wave propagation direction as well as horizontal and vertical forces on the structures are measured. In addition, the wave profile around the structure is tracked using a laser and video cameras to capture the physical behavior of the breaking or broken bore at impact. Selected test cases will be repeated and additional ones will be conducted at the LWF to examine model-scaling effects when a new piston wavemaker with a 4m maximum stroke and 4m/sec maximum velocity becomes available in late 2008. The LWF will enable experimental tests with a typical water depth of 3m.

SOME DETAILED NUMERICAL SIMULATIONS OF 2004 INDIAN OCEAN TSUNAMI

Koji Fujima, National Defense Academy, Yokosuka, Kanagawa, Japan, fujima@nda.ac.jp
Yoshinori Shigihara, National Defense Academy, Yokosuka, Kanagawa, Japan, shigi@nda.ac.jp
Kazuhiko Honda, Port and Airport Research Institute, Yokosuka, Kanagawa, Japan, honda@pari.go.jp
Hideaki Yanagisawa, Tohoku Univ., Sendai, Miyagi, Japan

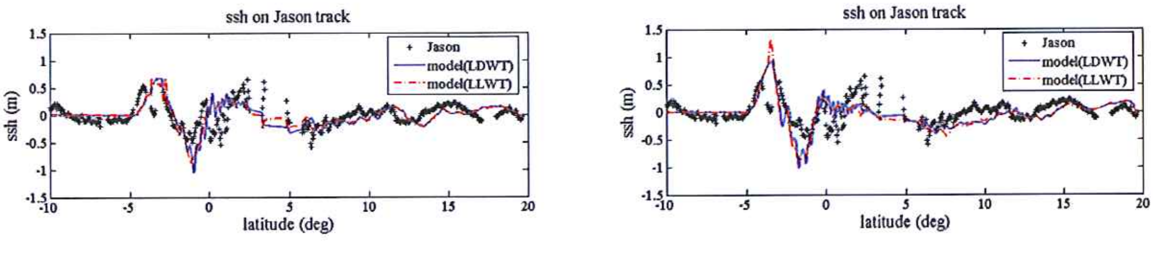
1. INTRODUCTION

Indian Ocean Tsunami, occurred on 26 December 2004, propagated over the entire Indian Ocean, and attacked not only Indonesia and Thailand but also India, Sri Lanka, the Maldives, and east Africa whose location is several thousands kilometers away from the epicenter. In the case of trance-oceanic tsunami, the dispersion effect plays an important role in general. Thus, Shigihara and Fujima (2006) conducted the numerical simulations considering the dispersion effect, and compared with the results without considering the dispersion effect. They concluded that the dispersion effect is restricted in the east side of the tsunami source, e.g. Indonesia and Thailand, and not negligible in the west side, e.g. Maldives and Africa. In addition, their simulation result suggested that the dispersion effect was negligible also in the southwest coast of Sri Lanka.

However, the several breaking wave-peaks were recorded in the video which was taken by a tourist at Khao Lak, Thailand. A few researchers suggested that those waves were formed as the result of soliton fission (e.g. Matsutomi et al., 2006). In addition, some numerical simulations suggested that the reflected waves from the Maldives played an important role in the southwest coast of Sri Lanka. Those waves reached about 5 hours after the earthquake, although the simulations of Shigihara and Fujima ended 5 hours after the earthquake. Thus, in this paper, detailed simulations were conducted for southwest coast of Sri Lanka and Khao Lak, Thailand. The dispersion effects in these areas are discussed through the simulations.

2. EFFECT OF RAPTURE VELOCITY

At first, the effect of the rupture velocity on the dispersion effect was examined using the fault model proposed by Oie et al. (2006). The numerical results of the linear long wave theory and the linear dispersive wave theory were compared with the water surface elevation obtained by the satellite, Jason 1, in Figure 1. The right figure shows the results where the final deformation is used as the initial condition of water elevation statically; and the left figure shows the result where each fault deformed with the time-lag, that was determined based on the rupture velocity, v. In the case of static model ($v = \infty$), the dispersion effect is large in 5°S to 2.5°S. However, in the case of $v = 1$ km/s, the contribution of dispersion effect is small; and the simulated results agree with the data of Jason 1. Thus, when the rupture velocity is considered in the simulation, the contribution of dispersion effect becomes small. Note that $v = 2$ to 3 km/s is adequate according to the seismological research. However, the simulation using $v = 2$ to 3 km/s can not explain the data of Jason 1 sufficiently. Thus, $v = 1$ km/s is used in this paper.



(a) $v = 1.0$ km/s (b) $v = \infty$ (static)

Figure 1. Comparisons of numerical results by the fault model of Oie et al.(2006) and the data of Jason 1 (LLWT: Linear Long Wave Theory, LDWT: Linear Dispersive Wave Theory)

3. EXAMINATION IN SRI LANKA

The numerical results using the nonlinear dispersive wave theory is compared with the results using the nonlinear long wave theory (Tomita et al., 2006). The fault model proposed by Koshimura et al. (2005) is used in this examination, because Tomita et al. showed that this model successfully reproduced the tsunami height along the southwest coast of Sri Lanka. However, we did not conduct the inundation simulation; e.g. the vertical wall was set at the coastline. The smallest grid spacing was 15m in Galle Bay and 135m except Galle Bay. Figure 2 shows the time-history of water elevation. In the area of north of Galle, the reflected waves from the Maldives arrive 5 houes after the earthquake. However, the numerical results of nonlinear dispersive wave theory are similar to those of nonlinear long wave theory. Thus, the dispersion effect is restricted even for the reflected waves from the Maldives.

3. EXAMINATION IN THAILAND

The inundation simulation was conducted for Khao Lak. In the deep sea area, nonlinear long wave theory was adopted because the dispersion effect was small and the nonlinear dispersive wave theory was used in the area where water depth was shallower than 30m. The smallest grid spacing was 17m. The fault model proposed by Oie et al. was used in this simulation. Figure 3 shows comparison of water elevation. As the result, the dispersion effect was restricted even at Thailand. The several breaking waves taken in the video might be formed by not the soliton fission but the other reason, e.g. reflection, refraction, and so on.

4. REFERENCES

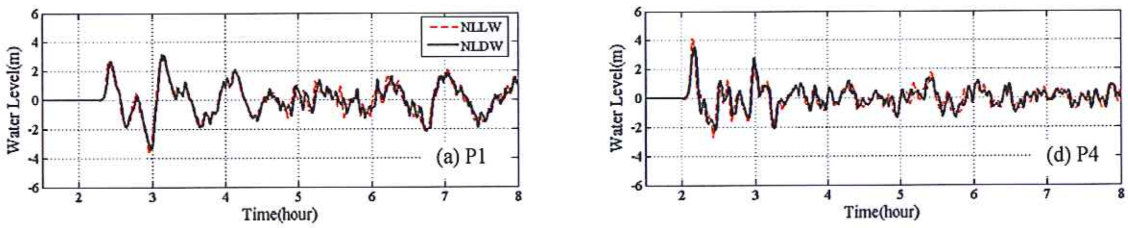
Shigihara, Y. and Fujima, K. Wave Dispersion Effect in the Indian Ocean Tsunami, Jour. of Disaster Research, Vol.1, No.1, pp.142-147, 2006.

Matsutomi, H. et al. Aspects of Inundated Flow due to the 2004 Indian Ocean Tsunami, Coastal Eng. Jour., JSCE, Vol.48, No.2, pp.167-195, 2006.

Oie, T. et al. Numerical Modeling of the 2004 Indian Ocean Tsunami and Damage Assessment in Banda Aceh, Annual Jour. of Coastal Eng., JSCE, Vol.53(1), pp.221-225. (in Japanese)

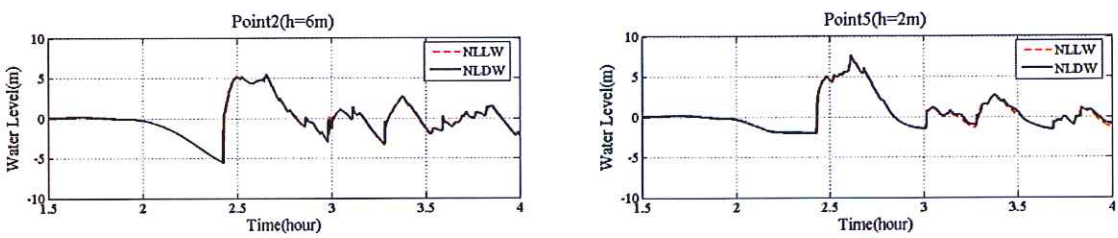
Koshimura, S. et al. Estimation of the Possible Tsunami Disaster Potential within the Indian Ocean, Annual Jour. of Coastal Eng., JSCE, Vol.52(2), pp.1416-1420, 2005. (in Japanese)

Tomita, T. and Honda, K. Basic Study on Numerical Analysis of the 2004 Indian Ocean Tsunami in Sri Lanka, Annual Jour. of Coastal Eng., JSCE, Vol.53(1), pp.251-255. (in Japanese)



(a) Location at 25km northwest of Galle (h = 10 m)　(b) Location at 15km southeast of Galle (h = 10 m)

Figure 2. Time-history of water elevation in the southeast coast of Sri Lanka
(NLLW: Non-Linear Long Wave theory, NLDW: Non-Linear Dispersive Wave theory)



(a) Location at h = 6 m　(b) Location at h = 2 m

Figure 3. Time history of water elevation in Khao Lak

STOCHASTIC TYPHOON AND STORM SURGE SIMULATION

Hiroyasu Kawai, Port and Airport Res. Inst., Yokosuka, Kanagawa, Japan, kawai@pari.go.jp
Noriaki Hashimoto, Kyushu University, Fukuoka, Japan, hashimoto-n@civil.kyushu-u.ac.jp
Kuniaki Matsuura, Japan Weather Association, Tokyo, Japan, matsuura@mes.jwa.or.jp

1. INTRODUCTION

There are three purposes in storm surge simulations: (1) real-time prediction with a quick model for the preparedness from a few days before typhoon arrival, (2) hindcast with a precise model for the description of storm surge phenomena and the *deterministic* determination of the design tidal level for defense facilities, (3) probabilistic evaluation with a stochastic model for the *probabilistic* understanding of the safety level in coastal areas.

This paper introduces the combination of a stochastic typhoon model and a conventional storm surge model as an example of the simulation (3) and discusses on the return period of the current design tidal level determined by the storm surge simulation of Typhoon Vera in 1959. The evaluation of the return period is quite difficult without such stochastic simulation because of a short period of tide observation.

2. SIMULATION MODEL

A stochastic typhoon model is a Monte Carlo simulation model based on typhoon statistics. The model determines the frequency of typhoon appearance in each season in each year, gives the initial location and parameter values of each typhoon, and describes their variation with time by using an auto-regression model for each parameter, as shown in Figure 1. This study used a stochastic typhoon model (Hashimoto et al. 2004, Kawai et al. 2006) to make stochastic typhoons during 500 years. Some of typhoons are more intensive than Typhoon Vera and take more severe track for bays.

The marine surface pressure field of each typhoon is given with the Myers empirical model. The wind field is given as the sum of a gradient wind component and the typhoon forwarding effect. The storm surge was computed with a one-layer long wave model. Figure 2 shows the computational domain with a minimum grid interval of 1.8 km.

At each computational grid, the best-fitting extreme value function for storm surges was selected among the Gumbel (FT-I), FT-II, and Weibull Distributions and then the possible maximum value and the extreme value with a return period of 10 to 1,000 years were estimated.

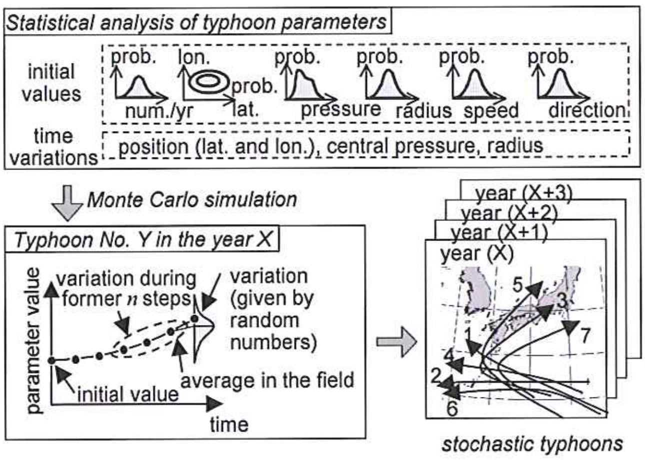


Figure 1. Concept of stochastic typhoon model

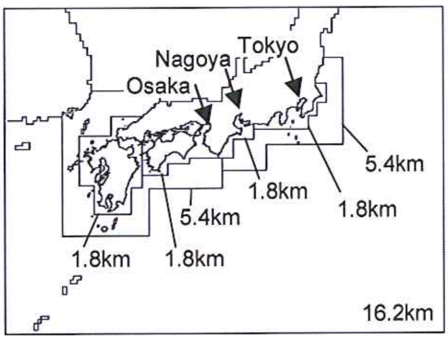


Figure 2. Computational domain for storm surge simulation

3. SIMULATION RESULT

Figure 3 shows the distribution of a 1000-year-return storm surge. The storm surge reaches 4 m at the northeast end of some bays. The current design tidal level includes an astronomical high tide and a design storm surge of 3.0, 3.5, and 3.0 m for Tokyo, Nagoya, and Osaka respectively. The design storm surge for Tokyo includes a wide margin. That is a reason why the return period of the design storm surge for Tokyo is relatively long around 1,000 years and that for Nagoya and Osaka is around 100 years.

The current design tidal level assumes the coincidence of the design storm surge with an astronomical high tide. The range of the spring tide is about 1.5 to 2.4 m at these places. By this reason, the return period of the design tidal level is much longer than that of the design storm surge. Figure 4 shows the extreme tidal level at these places. The design tidal level is 5.7, 5.9, and 4.8 m above the lowest water level at Tokyo, Nagoya, and Osaka respectively. The return period is around 10,000 years at Tokyo and several hundred years at Nagoya and Osaka, while that of the Primary Flood Defense in the Netherlands is 10,000 or 1,250 years.

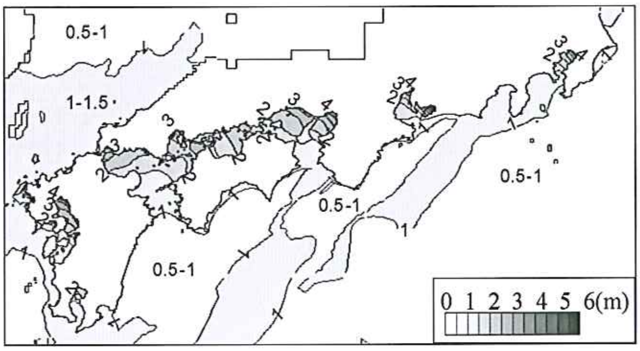


Figure 3. 1000-year-return storm surge

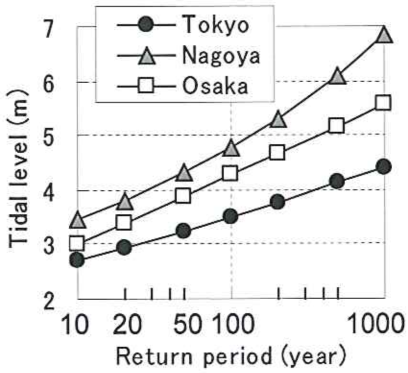


Figure 4. Extreme Tidal Level

4. CONCLUDING REMARKS

According to the simulation result, the current design tidal level for storm surge defense at Tokyo, Nagoya, and Osaka seems to have a long return period under current climate. Such the assessment is necessary for other places not only in Japan and for future conditions with typhoon intensification and mean sea level rise. On the other hand, we should be aware of wide areas below sea level on the inside of the defense, and moreover some port facilities in the outside of the defense.

5. REFERENCES

Hashimoto, N., Kawai, H. and Matsuura, K. Development of stochastic typhoon model for performance design of coastal structures, Proc. of 29th Int. Conf. on Coastal Engg., ASCE, pp 3615-3627, 2004.

Kawai, H., Takahashi, S., Hiraishi, T., Hashimoto, N., Matsuura, K. Lessons Learned from Recent Storm Surge Disasters and Estimation of Extreme Tidal Levels for Coastal Defense Performance by Using Stochastic Typhoon Model, Proc. of Int. Conf. on Ocean and Polar Engg., vol.3, pp.1792-1799, 2007.

Advanced ocean floor network for earthquakes and tsunamis around the Nankai Trough in Southwestern Japan - Towards the understanding of mega-thrust earthquakes – part 2

Yoshiyuki Kaneda*, DONET group

*Japan Agency for Marine-Earth Science and Technology,2-15 Natsushima-cho,Yokosuka,Kanagawa ,237-0061 JAPAN

E-mail :kaneday@jamstec.go.jp

In Japanese seismogenic zone, the Nankai Trough is well known as the mega thrust earthquake generating tsunamis, with the interval of 100-150 years.

These mega-thrust earthquakes always generate the great tsunamis.

In historical earthquakes around the Nankai trough, great tsunamis attacked on the coastal town and generated huge damages. The 1944 Tonankai and the 1946 Nankai earthquakes, each hypocenter was located off the Kii peninsula. The results of recurrence cycle simulation of mega- thrust earthquakes using precise structural model, ruptures are starting from The Tonankai seismogenic zone aheadof the Nankai seismogenic zone. These results are consistent with past two earth quakes such as 1954 Ansei earthquake, 1944/1946 Showa earthquake.

Therefore, the observation and research of the Tonankai earthquake seismogenic zone is very important and significant to understand the Nankai trough seismogenic zone system.

Based on such previous researches, we proposed and have been starting to deploy the dense ocean floor observatory network system around the Tonankai seismogenic zone.

This advanced dense ocean floor observatory network system has useful functions and purposes as follows,

1) Redundancy, extension and advanced maintenance system using the looped cable system, junction boxes and the ROV/AUV etc.
2) Speedy evaluation and notification for earthquakes and tsunamis
3) Provide observed data such as ocean floor deformation derived from pressure gauges to improve the simulation and modeling researches about the mega-thrust earthquakes, this means the data assimilation, will be quite important to improve the simulation research.
4) Understanding of the interaction between the crust and upper mantle around subduction zone.
5) Developing advanced technology

In this project, another ocean floor deformation monitoring system and new cable system with in lined sensors are under developing..

This system is equipped with 20 precise pressure gauges and 20 broad band seismometers and accelerometers. Therefore, reliable estimation of earthquakes and tsunamis will be possible.

Especially, this observatory will provide us with the tsunami early warning around the Nankai trough because of the real time monitoring of the Tonankai seismogenic zone.

Actually, at two Kuril earthquakes in 2006 and 2007, the first arrival of generated tsunami and later phase reflected and diffracted by irregular bathymetry through propagations were observed by JAMSTEC ocean floor networks such as Kushiro and Muroto system.

These facts indicate the importance and significance of real time monitoring of floor behavior.

In this paper, we will explain the advanced dense ocean floor observatory network system in detail.

DEVELOPMENT OF THE JAPANESE NATIONWIDE GPS BUOY NETWORK

Toshihiko Nagai, Port and Airport Research Institute,
Yokosuka, Kanagawa Japan, nagai@pari.go.jp
Katsuyoshi Shimizu, Port and Airport Research Institute,
Yokosuka, Kanagawa Japan, shimizu-k87s3@pari.go.jp

1. INTRODUCTION

Newly developed GPS buoy system applying the RTK-GPS techniques to exact measurement of offshore floating buoys is to be the future of offshore wave and tsunami monitoring system for Japanese coastal line. As GPS buoys can be installed in deeper and more offshore area than the existing seabed-installed wave gauges, earlier tsunami detection can be realized using appropriate filtering techniques of observed data. By considering frequency response characteristics of the buoys, the GPS buoy system can also be used for routine observations of directional sea waves, swells and infra-gravity waves with wide frequency range. Furthermore, with some additional equipment for correction of the buoy motion, information on offshore winds and currents can be obtained. This paper introduces a basic design of desirable observation network and multipurpose data processing system.

2. GPS BUOY SYSTEM

Figure 1 shows a concept of the GPS Buoy system. Field pre-experiments have proved its applicability to offshore waves, tides and tsunami observation. Setting an on-land reference GPS base station within 20km from the buoy, Real-Time Kinematical method is applied. The first deep-sea GPS buoy system was already installed in April 2004 at100m deep and 13km off the Muroto-Misaki cape.

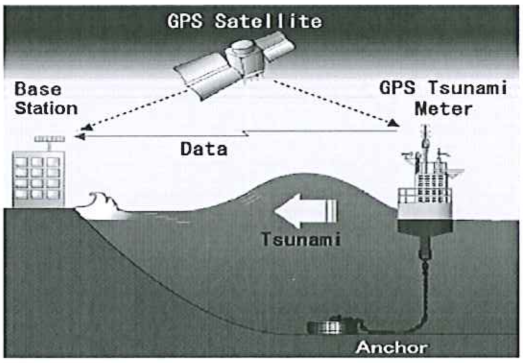


Figure 1. Concept of the GPS Buoy System

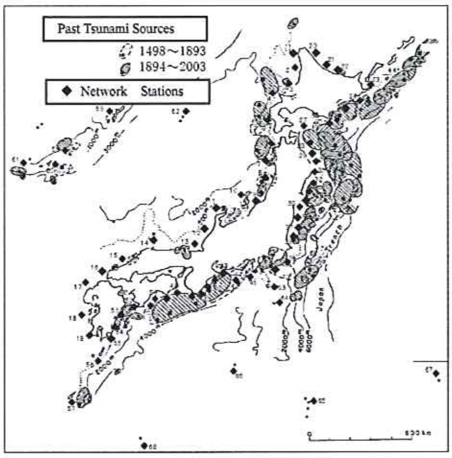


Figure 2. Proposed Offshore Tsunami Observation System Network in Japan with GPS Buoys

3. TSUNAMI OBSERVATION NETWORK STUDY

Tsunami detection time intervals between the existing NOWPHAS (Nationwide Ocean Wave information network for Ports and HArbourS) wave stations and the nearest coast were estimated, assuming that tsunami propagation velocity follows the linear long wave theory. Based on the estimation, a desirable form of offshore tsunami observation network was designed. Figure 2 shows our proposed offshore observation network. Offshore tsunami sensors are to be installed with intervals of about half-length of the tsunami wave source zone in order to obtain offshore tsunami height distribution along the coast. Therefore, considering possible horizontal scale of near coast tsunami generating earthquakes (Hatori, 2004), tsunami detection stations should be installed at intervals of 50-100km along the Pacific coast as shown in Figure 2. Small islands on the ocean are suitable points for long-distance tsunami detection, which will help to prevent tsunami disasters around the world.

4. REAL-TIME TSUNAMI DETECTION

The time-stepped real-time tsunami detection system is based on consideration that tsunami periods are generally very large like several tens of minutes and that tsunami warning is necessary before knowing the first wave height and period of tsunami.

Figure 3 shows three steps for obtaining tsunami information. In order to make the best use of offshore tsunami sensors capable of observing tsunami profiles about 10 minutes before it reaches the coastline, offshore tsunami information data service cannot wait until the offshore sensor finishes an observation of the complete figure of the first tsunami wave, especially its height and period. Therefore the authors propose an offshore tsunami data service operated by three time stages.

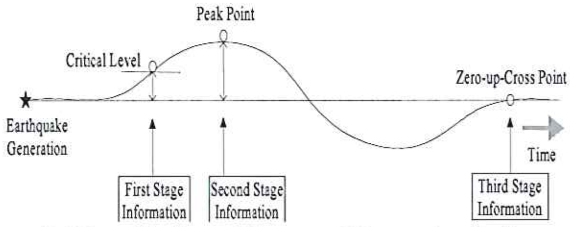


Figure 3. Time Series of Tsunami Detection Information

To eliminate high frequency components caused by wind waves and swells, numerical low-pass filter profile is determined considering its real-time efficiency. Elimination methods of astronomical tides, other slow sea level changes, miss fixed phenomena and data loss, which may appear during observation, are also discussed. Applicability of the proposed system is confirmed by using actual offshore tsunami observation data obtained during 2004 Tokaido-off earthquake tsunami and 2005 Miyagi-off earthquake tsunami propagation

5. DIRECTIONAL WAVE ANALYSIS

For wind wave and swell observation, heaving and rolling response of the moored buoy needs to be considered. New data processing system for GPS vertical and horizontal displacement record is developed considering the buoy's frequency response. Obtained directional wave data are compared with those through the seabed-installed wave and current gauges of 27m deep, using frequency banded analysis method based on the directional wave spectrum. For the frequency banded wave height analysis, higher frequency components should be corrected based on the heaving response of the buoy. Lower frequency components of the horizontal buoy motion are complicated due to the slow drift oscillation of the buoy. Within the intermediate frequency band corresponding periods of between 6 and 30 seconds, wave directions are properly obtained from the horizontal buoy motion. Comparison is also made for wave climate characteristics observed at the two stations.

6. ACKOWLEDGEMENT

NOWPHAS system has been operated by associated agencies of the Ports and Harbors Bureau of the Ministry of Land, Infrastructure and Transport (MLIT). The GPS buoy system off the Muroto-Misaki was developed by cooperative research among the Earthquake Research Institute of University of Tokyo, Hitachi Zosen Corp., Disaster Reduction and Human Renovation Institute, and PARI, with financial assistance by the Ministry of Education and Science. Authors would like to express sincere gratitude to those concerned.

7. REFERENCES

Hatori, T. Tsunami Source and Wave Energy Distribution along the Coast of Japan, Chikyu Monthly, Vol.27, No.3, Kaiyo-Syuppan Co., pp.166-170, 2005. (in Japanese)

Nagai T., Ogawa H., Terada Y., Kato T., and Kudaka M. GPS Buoy Application to Offshore Wave, Tsunami and Tide Observation, Proc. of the 29th International Conference on Coastal Engineering (ICCE'04), vol.1, pp.1093-1105, 2004.

Nagai T., Kato T., Moritani N., Izumi H., Terada Y. and Mitsui M. Proposal of Hybrid Tsunami Monitoring Network System consisted of Offshore, Coastal and On-Site Wave Sensors, Japan Society of Civil Engineers, Coastal Engineering Journal Vol.49 No.1, pp.63-76, 2007.

RECENT ADVANCES OF TSUNAMI WARNING SYSTEM IN JAPAN

Yohei Hasegawa, Japan Meteorological Agency,
Chiyoda-ku, Tokyo, Japan, yhasegawa@met.kishou.go.jp

1. TSUNAMI WARNING IN JAPAN

Tsunami Waning Service in Japan is conducted by Japan Meteorological Agency (JMA). JMA changed its Tsunami Warning System from the previous one with empirical method in 1999. The present system utilizes tsunami numerical simulation technique and database, which has improved tsunami height estimating accuracy with higher spatial resolution. Issued Tsunami Warning/Advisory Bulletin includes estimated maximum height with specific numerals from "0.5m" to "over 10m" by eight steps and estimated arrival time for 66 coastal regions.

Figure1. 66 Regions for Tsunami Warning

Table1. Tsunami Warning/Advisory Bulletin

Type of Tsunami Bulletin		Estimated Maximum Height
Tsunami Warning	Major Tsunami	"3m","4m","6m","8m","over 10m"
	Tsunami	"1m","2m"
Tsunami Advisory	Tsunami Attention	"0.5m"

2. SPEEDUP OF WARNING BY EEW TECHNIQUE

Earthquake Early Warning is a new service of JMA that provides warning against strong ground shaking before its arrival. Immediate determination of earthquake parameters such as location and magnitude is an essential component of EEW technique, which is performed in only several seconds to several tens. Utilizing this quick determination technique, JMA's Tsunami Warning has been made possible to be issued in only two minutes after the earthquake occurrence.

Since the start of the operation with this technique in October last year, JMA has issued two Tsunami Advisories by using it. The first case is "The Noto Hanto Earthquake in 2007" in March 2007 with magnitude of 6.9. The second one is "The Niigataken Chuetsu-oki Earthquake in 2007" in July 2007 with magnitude of 6.8. JMA issued Tsunami Advisory at each event only in 2 minutes and 1 minute respectively. However, in the case of earthquake occurrence much far off the coast, the determination accuracy may not reach the level available for Tsunami Warning. Conventional procedure of Tsunami Forecast is taken in such a case.

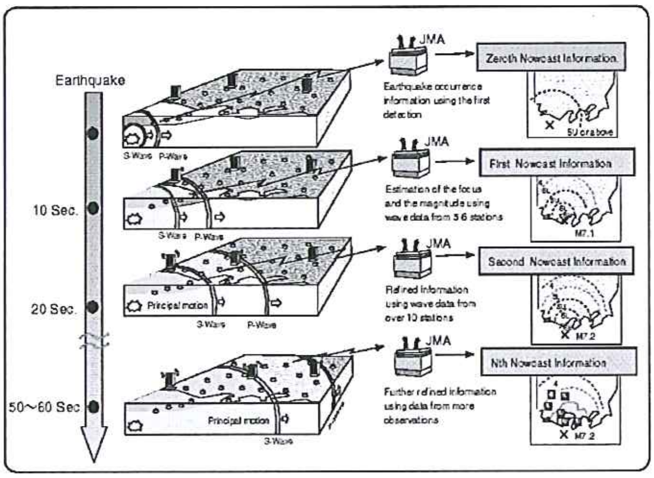


Figure2. Outline of Earthquake Early Warning

3. RAPID REVISE AND CANCELLATION OF WARNING BY CMT SOLUTION

JMA started utilizing Centroid Moment Tensor (CMT) solution for Tsunami Warning this July. Newly developed System for Automatic Estimation of Earthquake Mechanism calculates CMT solution and provides focal mechanism and moment magnitude in 10 to 20 minutes.

Since the first Tsunami Warning/Advisory must be issued as fast as possible, especially for near field tsunamis, it is done with assumed focal mechanism and rapidly determined usual magnitude. Such a manner of estimation that uses limited information about the fault rupture, however, sometimes has difficulties in dealing with so-called "tsunami earthquake" whose real scale may be underestimated by usual magnitude, and in cancelling the Warning/Advisory before sufficient tsunami observations are collected. Focal mechanism and moment magnitude are closely related to the actual scale of the generated tsunami, and therefore, utilizing results from the new system cope with those difficulties and enables the Tsunami Warning System to carry out rapid revision and cancellation of Warning/Advisory.

DISASTER AWARENESS OF INFORMATION TO COMMUNITY

Fusanori Miura, Yamaguchi University
Ube, Yamaguchi Japan, miura@yamaguchi-u.ac.jp

1. INTRODUCTION

Typhoon No.18 in 1999 (T9918) caused serious damage to coastal structures and facilities such as seawalls, coastal dikes, housing, and so forth, along the Suo-nada coastal line in Yamaguchi Prefecture. The main cause of the damage was severe storm surge. After the disaster, the government of Yamaguchi Prefecture revised the design standards for coastal structures. At the same time, the government developed a Disaster Prevention Information System (DPIS). The system observes rain falls at 129 sites, water levels of rivers at 98sites, water levels of 21 dams and tidal levels at 14 ports in the prefecture, and all the records are sent to the prefectural offices in real time. Not only municipal governments in the prefecture but also the people in the prefecture can get the information through internet in real time [1]. In addition, the prefectural government encouraged municipal governments to develop hazard map for storm surge and river flood. Moreover, the prefectural government supports Community FM broadcast stations to equip disaster prevention facilities.

In this paper, some examples are shown how the prefectural and municipal governments supplied disaster prevention information to the people before and during typhoons attack since the T9918.

2. UTILIZATION OF HAZARD MAP

After the T9918, the local government of Sanyo town, one of the most severely damaged areas in the prefecture at the typhoon, made hazard map against storm surge just after the disaster. The government distributed the map all the families in the town.

Severe typhoons attacked the west part of Japan repeatedly in 2004. Many cities on the Seto-inland-sea coastal line suffered from storm surges and struggled to supply citizens with disaster prevention information. Some cities failed to deal with supplying the information, but Sanyo town handled well it by making the most use of the hazard map. In the hazard map, three areas are designated, i.e., first, the area where inhabitants must evacuate enough before the typhoon attack, second, the area where inhabitants can evacuate just before the attack, and third, the area where inhabitants need not to evacuate. According to the map, some officers called citizens especially old people and handicapped people to evacuate. At the same time, other officers observed danger zones according to the map and set up the countermeasures. This action was broadcasted on NHK TV program.

3. APPLICATION OF DISASTER PREVENTION INFORMATION SYSTEM AND COMMUNITY FM BROADCASTING

Ube city, where the author lives, was attacked by typhoon No.5 this summer. The typhoon was very strong and severe storm surge was expected, and what was worse, the time was midnight. Ube city anticipated possible disasters by forming Disaster Prevention and Countermeasure Headquarter. Ube city gave weather information to citizens through internet and Community FM broadcasting, and also announced to evacuate to the people who needed to.

From 8 p.m., the author went into the FM radio studio, and accessed the home page of the DPIS and got the tidal level information at the Ube port, then informed the present situation and warned the listeners to be careful. At the same time, we in the studio kept contact with the Headquarter at the city hall, and supplied the information about the tidal level at the port and also the water level at the river which flows the downtown of the city. The special program was continued untill 12 p.m. after conformation that the tidal level would not increase any more judging from the weather report and the tidal level at Ube port.

Fortunately, damage was very small because the power of the typhoon suddenly decreased.

4. REFERENCE

[1] http://y-bousai.pref.yamaguchi.jp/OP04_10_f00.html

DYNAMIC HAZARD MAPPING USING NUMERICAL MODEL OF STOC

Takashi Tomita
Research Director, Tsunami Research Center, Port and Airport Research Institute
Yokosuka, Kanagawa Japan, tomita@pari.go.jp
Kazuhiko Honda
Researcher, Tsunami Research Center, Port and Airport Research Institute
Yokosuka, Kanagawa Japan, honda@pari.go.jp
Hiroshi Higashino
Postdoctoral Fellow, Tsunami Research Center, Port and Airport Research Institute
Yokosuka, Kanagawa Japan, honda@pari.go.jp

1. Introduction

Evacuation is a crucial measure to save human lives from tsunamis. In areas where time is not sufficient to complete successful evacuation before tsunami arrival, in particular, structural measures are necessary for reduction of tsunami resulting in support of evacuation. Through estimation of the tsunami affected by structures, appropriate combination of structural measures and non-structural measures to save human lives is essential to establishment of an integral measure to prevent and reduce disasters caused by a huge tsunami. To estimate such tsunamis, we have developed a numerical model named STOC (Tomita et ak., 2006) which is a combination model of a non-hydrostatic three-dimensional model of STOC-IC and quasi three-dimensional model of STOC-ML. STOC-IC is a Reynolds Averaged Navior Stokes (RANS) model to calculate the tsunami affected by structures including buildings and rigid houses in a coastal city whose area is several tens of square kilometers. STOC-ML is a multi-level model in which the ocean is divided vertically into some layers. The approximation of hydrostatic pressure is assumed in each layer of STOC-ML.

In this study, a technique to present numerical results by STOC is investigated, because better presentation provides better images of tsunami damages to residents and others.

2. Conventional Presentation of Tsunami Hazards

Conventional tsunami hazard mapping provides tsunami inundation areas and distribution of the maximum inundation depth by possible tsunamis in a target area, as shown in Fig, 1. It creates easy and good understanding of tsunami hazardous areas, resulting in the increase of people's awareness and preparedness against the tsunamis. The Ports and Harbours Bureau, Ministry of Land, Infrastructure and Transport in Japan and the Port and Airport Research Institute have prepared the Guideline for Development and Utilization of Tsunami Disaster

Management Map in ASEAN and Indian Ocean Tsunami affected countries with consideration of states of developing countries, based on Manual for Tsunami and Storm Surge Hazard Maps in Japan. In the guideline which will be published in March 2008, maps for tsunami disaster management, such as an evacuation map, are distinguished from a hazard map, and step-by-step development of hazard mapping is recommended depending on development of numerical models and acquirement state of detailed data of bathymetry, topography and structures.

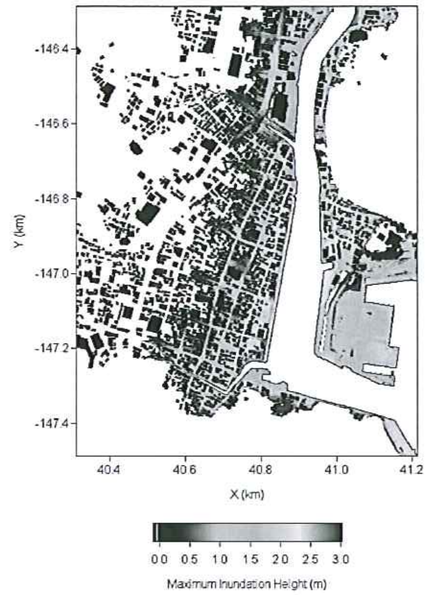


Figure 1. Conventional hazard map.

Figure 2. Snapshot of dynamic hazard map.

3. Dynamic Hazard Mapping

Numerical results including protection effect of structures and buildings in a target area can provide realistic tsunami disaster images to community members there. In particular, estimation of tsunami fluid velocity and wave force as well as inundation depth may create the detailed images of tsunami hazards, resulting in establishment of an integrated countermeasure against the possible tsunamis. Such tsunami dynamics are estimated by accurate numerical models such as STOC using the detailed bathymetry, topography and structure data. Effective presentation way of calculation results is the moving images of computer graphics. We named such a presentation technique the Tsunami Dynamic Hazard Map. Figure 2 is an example snapshot of tsunami dynamic hazard map. Red bars in the figure indicate the areas in which houses and buildings are damaged. Indexes to indicate occurrence of tsunami damages are inundation depth, tsunami flooding velocity and tsunami wave force which are investigated with hydraulic model experiments and field survey of actual damages.

In an ongoing study, a numerical model is developed for estimation of large body drift due to a tsunami using STOC and its calculation results are included in dynamic hazard map.

References

Tomita, T. and Honda K. Tsunami Estimation Including Effect of Coastal Structures and Buildings by 3d Model, Proc. Coastal Structures, ASCE, Venice, 2007. (in Printing)

INFORMATION TECHNOLOGY FOR ADVANCEMENT OF EVACUATION
-Development of Interactive Evacuation Simulator-

Katsuya Oda, National Institute for Land and Infrastructure Management,
Yokosuka, Kanagawa Japan, oda-k92y2@ysk.nilim.go.jp

1. INTRODUCTION

The preparation of tsunami and storm surge hazard maps, that facilitate successful evacuation of residents from tsunamis and storm surges, are progressing nationwide. However, in fact, many residents do not evacuate even though tsunami evacuation warnings or orders are officially issued. Therefore, what can be done in order to get such residents to evacuate?

Interactive evacuation simulators, which have been developed and advanced by the National Institute for Land and Infrastructure Management, are tools that promote the evacuation of residents by destroying stereotyped disaster images and normalcy bias i.e. the entrenched "I'll be alright" biased mindset, and also enhance risk communication among residents administrative agencies and experts in disaster mitigation planning.

2. TACKLING 'RELUCTANT TO EVACUATE RESIDENTS'

The behavioral pattern of the 'Reluctant to Evacuate Residents' is diagrammatically illustrated in Figure 1. When a tsunami is generated, evacuation instructions or orders are reported by community wireless systems together with information about the level of risk being broadcasted on television networks, which compel us to recognize the nature of the threat and necessity for evacuation. In contrast, a normalcy bias, an entrenched biased viewpoint, comes into play that makes one believe that one will be alright and that there is no 'real' threat of personal imminent danger. People who are placed into this kind of conflicting paradoxical train of thought (cognitive dissonance) act to eliminate dissonance. Such attitudes result in the occurrence of two categories attitudes: 'Escape and Evade Residents' and 'Reluctant to Evacuate Residents'. The 'Escape and Evade Residents' eliminate dissonance; whereas the 'Reluctant to Evacuate Residents' find reason to justify themselves by not running away. For example, there is the 'stereotyped disaster image' whereby, according to the distributed paper hazard map, a person's house is shown not to be at risk from flooding or the depth of floodwater is low. Despite tsunami warnings/alerts being issued hitherto, nothing happened; therefore, a 'false sense of security' ensues which leads the person to believe that, this time also, they will be safe from imminent danger.

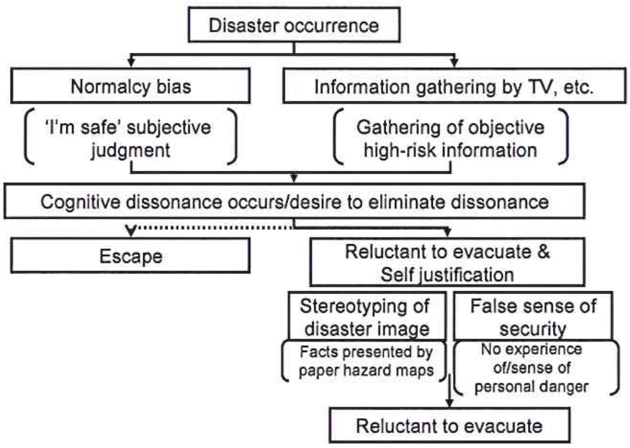


Figure 1. Behavioral Pattern of 'Reluctant to Evacuate'

3. INTERACTIVE EVACUATON SIMULATOR

Actual disasters are dissimilar in that the scale of disaster and the mode of damage do not follow advanced forecast models. In order to facilitate actual safe evacuation behavior, it is necessary to advance the level of risk communication for the purpose of cultivate understanding by relaying information regarding the various aspects of disasters and the best ways in which to evacuate between residents, administrative agencies, and trained experts. The National Institute for Land and Infrastructure Management is advancing the development of interactive evacuation simulator, which should be called an animated hazard maps on PCs, aimed at tackling the problems of hazard maps while promoting risk communication.

Simulators are intended to be used by residents and administrative agents at workshops, town meetings and so on. These are evacuation simulators that can assimilate hourly changes in tsunami inundation statuses, housing collapses due to earthquakes, and evacuation route blockages due to fires, as shown in the image in Figure 3. As for the residents, as shown by the system layout and operation procedure in Figure 2, they will be able to deepen their understanding firsthand through trial and error in deciding whether safe evacuation is possible, what are the optimum evacuation methods available, and so on, by individually inputting the evacuation start sites and timescale, evacuation methods: on foot or by wheelchair, etc., and available evacuation routes.

A feature of this system is that it will give the user a personal sense of evacuation under disaster generated conditions by allowing the user to optionally select the evacuation routes and evacuation sites of the region.

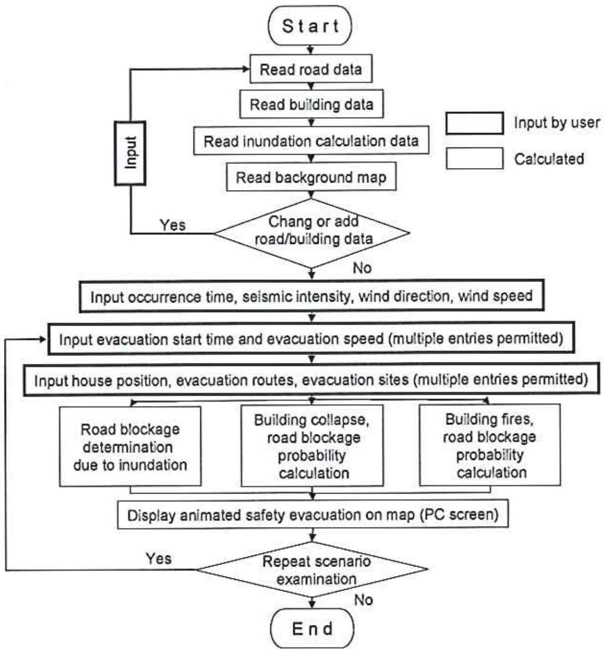


Figure 2. Basic System Configuration

4. ACTIVITIES AIMING FOR PRACTICAL APPLICATION

The development of the simulator is almost finished. The interactive evacuation simulators are presently undergoing trials in several participating regions where studies aimed at taking practical effective measurements along with efforts for promoting their popularization are progressing.

A trial simulator was developed at a coastal part of Kochi City prone to huge tsunami disaster. This simulator is scheduled to be trialed using multiple earthquake and tsunami inundation scenarios together with surveying feedback from residents by questionnaire for the purpose of analyzing the evacuation decision-making arrangements that exist at the residents' personal level and to reflect these findings in the system.

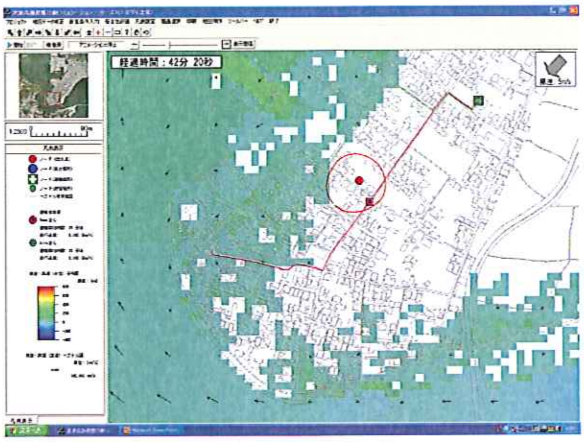


Figure 3. Snapshot of Display of an Evacuation Simulation

5. REFERENCES

Kumagai, K. et al. Study on Tsunami and Storm Surge Evacuation Simulator (Interactive Hazard Map) in Coastal Areas, Proceedings of the 35th Symposium on Safety Engineering, pp.143-144, 2005(in Japanese).

Oda, K. Development of Dynamic Hazard Maps -Aiming to Rise Enhance Residents' Awareness of Disaster form Tsunamis and Storm Surges and to Support Risk Communication-, Annual Report of NILIM 2006, pp.43, 2006.

Kumagai, K. et al. Development of the Tsunami Evacuation Simulation System and Production Trial at the Model Area ,Proceedings of Infrastructure Planning, vol.33, Japan Society of Civil Engineering, 2006(in Japanese).

Oda, K. et al. Development of Tsunami and Storm Surge Evacuation Simulator to Enhance Residents' Awareness of Coastal Disasters, Civil Engineering Journal, vol. 45, no.12, Public Works Research Center, 2007(in Japanese, to be published).

CHARACTERISTICS OF STORM SURGE DISASTERS IN JAPAN

Tomotsuka TAKAYAMA
Managing Director, Coastal Development Institute of Technology
takayama@cdit.or.jp

1. INTRODUCTION

Japan is located on the tracks of typhoons which are defined as movable strong atmospheric depressions and correspond to hurricanes in North America and cyclones in Indian Ocean. The typhoons cause storm surges of abnormal sea level rises which are composed of two main factors of wind set-up and barometric rise. The wind set-up is increased in proportion to the square of wind speed and in inverse proportion to the sea depth. The barometric rise is induced by atmospheric depression and increases with 1cm to 1 hPa reduction of air pressure.

Japan has much suffered from the storm surge. Most of the storm surge disasters have occurred in shallow bays such as Tokyo, Ise and Osaka bays. This characterizes storm surge disasters in Japan and is quite different from the disasters in USA and Bangladesh. This paper describes past and future characteristics of the storm surge disasters in Japan, investigating past disasters and considering present urbanization.

2. PAST CHARACTERISTICS OF STORM SURGE DISASTERS IN JAPAN

The large disasters of storm surges are listed up on Table 1. Table 1 shows that most of the storm surge disasters occurred in semi-closed sea areas but not in open sea coasts. The semi-closed areas are as small as 50-60km long and 20-30km wide of Tokyo, Ise and Osaka Bays. Therefore, the magnitude of the storm surge is at most about 3.5m. On the other hand, the magnitude reaches more than 6m in the Mexican Gulf coast of USA and in the Indian Ocean coast of Bangladesh because the shallow sea faces to open sea and expands to more than 100km in those coasts. Though Table 1 shows that a large storm surge occurred in Tosa Bay facing to the Pacific Ocean, it was confirmed that the storm surge included the large affection of wave set-up because of the steep slope of sea bottom. Therefore, the storm surge is not normal compared with the others which is mainly affected by the wind set-up and barometric effect.

Table 1 Past storm surge in Japan

Name of typhoon	Places	Anomaly (cm)	Death	Inundated houses
Taishou 6th (1917)	Tokyo Bay	230	1,127	302,917
Muroto (1934)	Osaka Bay	310	2,703	401,157
Sou-Nada (1942)	Sou-Nada	160	891	132,204
Makurazaki (1945)	Kagoshima Bay	>200	2,076	217,326
Jane (1950)	Osaka Bay	240	398	301,919
Ise-Wan (1959)	Ise Bay	345	4,697	363,611
2nd Muroto (1961)	Osaka Bay	241	194	384,120
Typhoon 10 (1970)	Tosa Bay	235	12	40,293
Typhoon 18 (1999)	Suo-Nada & Yatsushiro Sea	211	30	18,001
Typhoon 16 (2004)	Seto Inland Sea (Uno &Takamatsu)	160	16	44,935
Typhoon 18 (2004)	Seto Inland Sea (Hiroshima)	180	22	—

Large sea ports are located at inmost part of the bays in Japan. For an example, Tokyo and Yokohama Ports are situated in the innermost of Tokyo bay. The historically largest storm surge caused miserable disasters in the coastal areas along Ise Bay in 1959. Nearly 5,000 people were sacrificed by the storm surge and a lot of houses were destroyed. Especially, a number of timbers which were drifted away from the storage sea areas in Nagoya Port enlarged the destruction of residential houses. In the storm surge generated by the 2nd Muroto typhoon in 1961, many vessels moored in Osaka Bay were drifted on the wharfs and destroyed warehouses and others though no person was killed by direct action of the storm surge.

Though the development of Japanese industry demanded large amount of water, the supply of the water was not sufficient. The industry secured the insufficient water by pumping up from the underground. Consequently, the ground subsided due to pumping up. Fig.1 shows the time history of the ground subsidence. Though the subsidence began to occur before1935, rapid subsidence expanded in wide area of Osaka City from 1950. The storm surge barriers constructed to prevent the storm surge diminished their ability due to gradual dropping-down of the crown level.

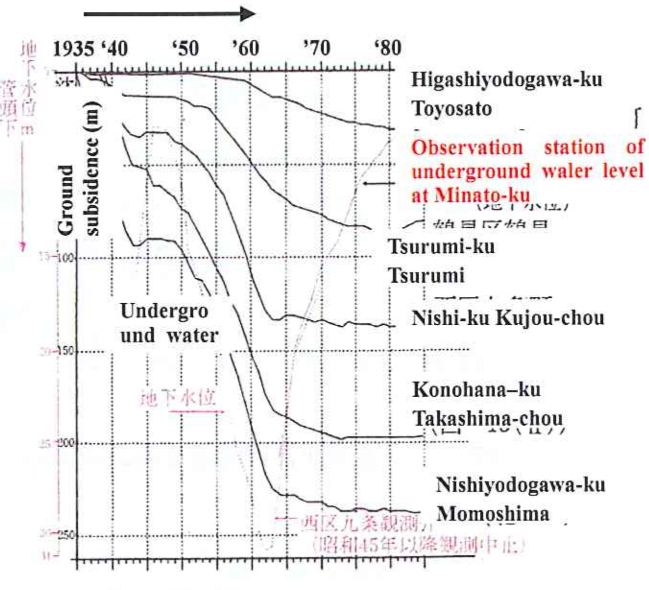


Fig.1 Time history of ground subsidence in Osaka

3. FUTURE CHARACTERISTICS OF STORM SURGE DISASTERS

Big sea ports are located in inmost parts in the major bays in Japan, as described above. Timbers and vessels in the ports become dangerous weapons even now. Empty containers stored in the port have become another dangerous weapon. The behaviors of the containers which may be drifted away should be predicted.

Most of the storm surge barriers were constructed soon after Ise Wan Typhoon which caused the most miserable disaster in Nagoya City in 1959. More than 40 years have passed since their construction. They may have become too old to resist the external forces related to storm surge. If they are destroyed, the destruction leads to miserable disaster such as the disaster caused by Hurricane Katrina in New Orleans. Therefore it is very important to check the resistant ability of the barriers.

The past ground subsidence due to pumping up of underground water has created wide area below mean sea level. About 4 millions people now live in the areas of the three major bays in Japan. If the storm surge barriers are destroyed at a typhoon, infinitely large amount of sea water overflow into the areas and very big disaster will be predicted to happen. Underground areas are utilized for shopping mole or subways in the urban areas. If sea water which overflows the barriers flow into the underground spaces many people will be killed and the urban system will be stopped. Therefore it is very important to confirm what disaster will happen in accordance with the magnitude of the typhoon.

4. CONCLUDING REMARKS

The present paper investigated past storm surge disasters and clarified what factors enlarged the disasters. In Japan almost all the storm surge disasters have occurred in the bays like Tokyo, Ise and Osaka bays, and drifted timbers and vessels enlarged disaster because large sea ports were located at inmost part of the bays. The ground subsidence caused by pumping up of water for industry diminished the resistant ability of the storm surge barriers.

The empty containers have recently become dangerous weapon in addition to the timber and vessels. It is very important to predict the behaviors of the drifted containers at storm surges.

The past ground subsidence caused by pumping-up of underground water have created large low areas below the mean water level. The low areas is highly populated and concentrated by the urban functions. The security of the area from storm surges is serious in Japan.

TSUNAMI DISASTER AND INTEGRATED COUNTER MEASURE IN JAPAN

Fumihiko Imamura, Disaster Control Research Center,
Aoba 6-6-11, Sendai 980-8579, Japan , imamura@tsunami2.civil.tohoku.ac.jp

1. INTRODUCTION - Tsunamis in Japan

It keeps suffering great damage due to the tsunamis from the ancient time in coast of our country in Japan. A human damage is especially remarkable, for example, the 1896 Meiji great Sanriku tsunami is one of major ones, causing 22,000 victims. Such a damage in Japan has repeated and is the reason why "TSUNAMI", Japanese word of waves in harbor, become international word meaning a series of waves generated by abrupt and large disturbances of the ocean surface such as earthquake, volcanic eruptions, landslides, slumps, and meteor impacts. Over 30% of the tsunami victims in the world bring it about in Japan. Although a tsunami is one of most terrible natural disaster, it is possible that human loss can be reduced zero if evacuation for safe zone in the elevated area before the tsunami arrival can be taken, because time is left from the earthquake generation to the coastal attack. However, there are misgivings that such action of evacuation and behavior isn't done suitably at present.

A Japanese coast rapidly changed more remarkably due to the constructions of the emergency countermeasure such as wave breaks and sea walls after the 1959 Ise storm surge and the 1960 Chilean tsunami. And the rapid growth of economy and industry resulted the dramatic change in land-use, human community, and high density transport network in the coast. The various facilities which didn't exist at the time of the previous tsunamis in Japan are built in the coast and large number of fishery and leisure boasts and vessels including combustible large tankers are in the harbor and ocean. According to the result of earthquake and tsunami in Tokai, Tonankai and Nankai area by the special survey committee in the Central Disaster Management Council (CDMC) in 2003, the tsunami with more than 10 m wave heights should affect the all coastal area in the western pacific coast of Japan, in which the disaster reduction structure system such as sea walls in Japan no longer fully protect the tsunami. And we are now facing new suffering patterns of damage in the seaside industrial area such as large scale fire and failure of power plants and industry and the stop of sea transport services at the multiple stages to be especially afraid

2. Implement and Maintain a Tsunami Awareness Program

Once the areas of tsunami flooding hazard have been identified, a community-wide effort of tsunami hazard awareness is essential to educate the residents as to appropriate actions to take in the event of a tsunami. Awareness education must include at a minimum: the creation of tsunami evacuation procedures to remove residents from the tsunami hazard zones; the implementation of an education program for schools to prepare students at all age levels; the conduct of periodic practice drills to maintain the preparedness level; and involvement of community organizations to educate all sectors of the population at risk. The IOC has a program to assist countries in implementing tsunami awareness. Written educational materials in numerous languages, educational curriculums, videos, and reports from communities with comprehensive awareness programs are available through the International Tsunami Information Center (e-mail: itic@noaa.gov). A workshop making hazard map with the residents, government member and experts in the community are important for awareness, sharing experiences, and making the plan for the evacuation

3. Tsunami information and response of the people

We investigated the tsunami information/warning and response of the people including evacuation in recent tsunamis including the 2004 Sumatra, in order to discuss the essential role of the early tsunami warning. There three stages for carrying out safety evacuation after the earthquake; the first is to collect the information of tsunami warning and natural phenomenon such as strong shakes and abnormal on the coast, the second is to make decision of evacuation based on the risk perception, the third is to select proper route and place for safety evacuation from tsunami attack. Unless the three stages should be completed adequately, people could not be survived. We found the balance between tsunami warning and risk bias in individual on response. If the risk on the warning overcome the risk bias, they could make the decision of evacuation, which suggest us an idea of proper and essential role of the warning system. Moreover, in diary life, the functions with risk communication and education so on are important to decrease the risk bias.

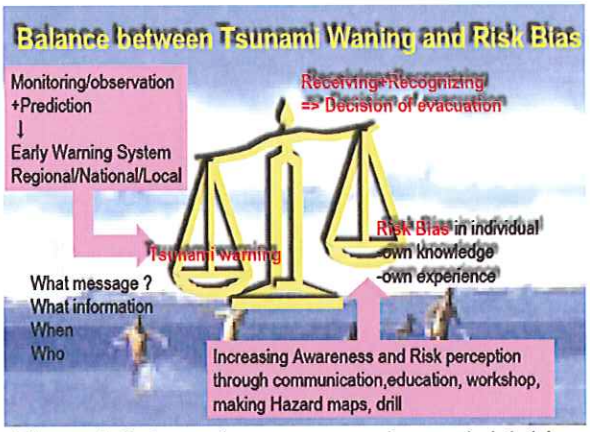


Figure 1 Balance between warning and risk bias

4. Comparison between the 2006 SW Java and the 2007 S Sumatra

Those are not case in Japan but valuable to discuss the process/ways for tsunami mitigation. Since the 2004 Sumatra earthquake, there are a series of earthquakes followed by the tsunamis. The worst of the tsunami damage among those is the 2006 SW Java. Table 6.1 shows the comparison between 2006 SW Java (Imamura, 2007; BAKORNAS, 2006) and 2007 S Sumatra, including the earthquake intensity, tsunami runup and damage on the human and houses. Although the magnitude of the 2006 is smaller than the 2007, the tsunami and its human damage of the 2006 is mush larger than the 2007, on the other hand, the intensity of the 2007 is larger than the 2006, causing the much more houses damage. This suggest that the severe houses damage due to the strong quake by the earthquake of M8.4 in 2007 is significant, however the quick response of the people after the quake and tsunami information on TV and radio based on the awareness of the tsunami after the 2004 could save their lives.

Table 1 Comparison between the 2006 SW Java and the 2007 S Sumatra

	2006 SW Java	2007 S Sumatra
Earthquake Magnitude and Max.Mercari Modified Intensity scale	M7.7 , MMI< 5	M8.4, MMI=7-8
Tsunami Runup heights	2-7m	2-4m
Dead	637 Most due to the tsunami	21 No due to the tsunami
Missing	165	0

Reference:

Imamura, F., The 2006 SW Java tsunami and its damage, Fire and science, vol.6, no.1,No.19, pp.52-59, 2007, in Japanese.

Towards Integrated Tsunami Disaster Mitigation
Indonesian Experience

Subandono Diposaptono*

*Deputy Director for Mitigation of Coastal Disaster and Marine Pollution
Ministry of Marine Affairs and Fisheries, Republic of Indonesia,
Gedung DKP Lt.10, Jl. Medan Merdeka Timur No 16, Jakarta Pusat, INDONESIA,
E-mail: sbdn@cbn.net.id

I. Background

Indonesian coastal area has been developing along with the development of population and cities since a long times ago. Coastal area provides space, transportation and access for distribution of people and goods that eventually accelerate the development of trading, settlement and city. Coastal area with its white sandy beach is also a beautiful place for recreations and tourisms. Almost in every Indonesian main island, we can find many big cities in coastal area that is now very developed and populated place.

The problem comes because actually Indonesian coastal area is also very prone area for natural disaster such as tsunami. Aware or unaware we put ourselves in more risks and danger by developing more infrastructures, economy properties, and settlements in coastal areas.

Tsunami is one of the most catastrophic natural disasters in Indonesian coastal area. It is very devastated and has considerable impacts especially the Indian Ocean Tsunami 2004.

This paper presents the implementation efforts to mitigate tsunami disaster for coastal areas and small islands in Indonesia. Structural and non-structural counter measures were developed to mitigate the tsunami disaster. The coastal environment is very sensitive and dynamic, therefore development of tsunami disaster mitigation should be designed and planned based on the Integrated Coastal Zone Management (ICZM) concept.

II. The Nature of Tsunami Disaster in Indonesia

Indonesia has been affected by Tsunami since recorded history. There are records of more than 100 such events over the last 400 years. These records indicate that between 1600 and November 2007 there have been 109 tsunamis. This suggests energy of earthquakes and subsequent tsunamis increasing with time interval between earthquakes and a recorded tsunami approximately once every four years. The data suggests that frequency has increased in the last half century although it is not certain if this is because of better records and monitoring or reflects greater seismic activity. Certainly the potential for impact of coastal communities has increased greatly in that time. From 1960 - November 2007 there have been 22 significant tsunamis. This indicates that the frequency of tsunamis is around one in every two years.

Some of Indonesian coastal areas of highest potential risk by tsunami include: the West coast of Sumatra, South coast of Java, South coast of Bali, North and South coast of Nusa Tenggara, islands of Maluku, North coast of Papua, and most of Sulawesi (Celebes) coast.

III. Tsunami Disaster Mitigation in Indonesia

To minimize the impact of tsunami disasters in Indonesia, nationally we always improving our capabilities to mitigate, and manage these events.

The Ministry of Marine Affairs and Fisheries (MoMAF), Republic of Indonesia is also pro active in minimising the impact of tsunamis on coastal communities. Through the Directorate General for Marine, Coasts and Small Islands, of MoMAF, we are continuing to formulate national policy and programs to mitigate the adverse impacts of tsunami disasters in Indonesia.

The priority issues for tsunami disaster mitigation include nine intervention areas: i) legislation and regulation, ii) risk assessment, iii) integrated coastal planning and management, iv) coastal disaster mitigation plan, v) coastal community empowerment, vi) coastal habitat rehabilitation, vii) retrofitting, viii) development of evacuation route, and ix) establishment of tsunami early warning system.

The enactment of Disaster Management (Law No. 24/2007) and Coastal and Small Island Management (Law No. 27/2007) provide Indonesia a strong legal basis for better disaster reduction program. According to this law, disaster reduction should be institutionalized through national and local development plan. This perspective will ensure the sustainability of the program in term of planning and budgeting.

This also will reduce the inconsistency of the policy due to the change of national and local leader. The Law 27/2007 gives clear mandate for all stakeholders in reducing the negative impacts of coastal disaster and increasing community participation and environmental conditions.

The law 27/2007 absolutely gives a legal instrument to mitigate coastal disaster. The law 24/2007 also provides a direction for better disaster governance. The problem is, this law should be translated in a more operational regulation in form of government regulations, presidential regulations, and ministerial regulation. It will cover land use regulation, building code, coastal structural design, etc.

The mitigation of coastal disaster also emphasized the implementation of ICZM. In ICZM we will try to make a balance between the natural resources, human utilization, and disaster mitigation aspects.

According to ICZM planning, the disaster mitigation plan is develop to give more emphasis on the disaster reduction program. This mitigation plan reflects the change in disaster management paradigm in Indonesia. It is reflected in more community planning such as land use planning, inundation management plan, reduce vulnerability, and increase coastal community resilient. An integrated disaster mitigation plan is important especially in very developed coastal area. This plan provides guidance for stakeholders in reducing their vulnerability to coastal hazard for long time.

Hazard mitigation or management plan is directed to reduce the human vulnerability in all possible aspects. It covers activities to reduce the weakness aspects and improve access to resource, social integration, institutional coordination, public awareness, and building safety. The plan must be discussed and communicated with another area because the hazard is not limited by administrative boundary.

We have been facilitating 4 local governments i.e. Padang, West Sumatra, Serang, West Java, Denpasar Bali, and Lombok Tengah, West Nusatenggara in developing participatory local strategic plan for coastal hazard mitigation. By doing this, it does not mean that the impact of coastal disaster can be avoided, however, it will have planned accordingly, educated and campaigned in community, mitigated and eventually will reduce the loss of lives, social, and economic and also improve the level of resilience for future event.

In this regard, public education must be conducted regularly. Issues such as nature of hazard, probability and magnitude, area likely to be flooded, proper responds and community preparation are necessary to know. Picture, map, questioner, event scenario are useful in awareness and education program.

We also use traditional and cultural events in the awareness campaign. This method is intended to increase community resilience that should understand the nature of disaster, able to mitigate the impact, disseminate and change information and have a disaster mitigation planning.

In the field of structural countermeasure we have also implementing coastal habitat rehabilitation. The objective of the habitat rehabilitation is to increase the coastal environment capacity to provide its services for livelihood and protection from coastal disaster. Coastal forest will dissipate part of the tsunami wave energy via turbulent flow through porous structures. It has been implementing in the form of coastal forest and mangrove planting.

MoMAF has also retrofitting houses in several coastal areas in Indonesia. So far, the MoMAF has built an initial 200 earthquake and tsunami 'friendly' houses in several coastal district/cities that are prone to earthquake and tsunami. It is hoped that these designs and concepts will act as a catalyst to rekindle interest in traditional architecture and so will be replicated by local builders.

Early warning saves lives. That's a very obvious lesson from the tsunami event. Early warning systems are considered the foundation of disaster mitigation. With the advances in science and technology, accurate forecasting of the occurrence of a natural hazard has saved thousands of lives and protected properties. It is very unfortunate indeed that the Indian Ocean lacks a tsunami warning system like the one installed in the Pacific.

Indonesia is prepared and committed to develop and manage a National Tsunami Early Warning System (TEWS) as part of the Regional Indian Ocean TEWS. Indonesia has designed framework that will be used for establishing an effective and durable Indonesian TEWS on national scale which could provide a tsunami warning in less than 5 minutes wherever earthquakes occur. The numbers of TEWS are 22 buoys which consist of 2 buoys from USA, 9 buoys from Germany, and 11 buoys from Indonesia.

The high technology early warning system proposed is, however, expensive, is subject to tampering and/or theft and requires on-going maintenance and possibly has safety issues. Although it can be a useful tool to warn of tsunamis, this is only one aspect of the issue.

Another challenge to overcome is the time imperative for issuing tsunami warning. Even in the event that an early warning system is deployed, Indonesia is a vast Archipelago with over 3,000 inhabited islands with all the concomitant communication challenges that this implies. Even with better communication it may not be possible to adequately warn all people in all potential impact areas in a timely fashion. In conclusion, this system has a role to play in Indonesia but to be more effective, additional information transmission methods about tsunami need to be developed.

Because Indonesia has suffered from a large number of tsunami events since ancient times, some local cultures developed their own 'early warning systems. In many cases however, this knowledge has been lost. As part of the Government of Indonesia's efforts, the traditional knowledge systems about tsunami are being revisited.

The effectiveness of local traditional knowledge shared information about SMONG (local word for tsunami) was found at the Simelue Island, NAD province of Indonesia after the Indian Ocean tsunami 2004.

The tradition of SMONG has been passed down for several generations by the Simelue people. SMONG is a local word refers to a particularly severe tsunami that struck in 1907. The story of SMONG has been shared by the people of these islands for as long as anyone remembers. Applying the wisdom passed on through local cultural information exchange networks, the local people interpreted the warning signs (sensing a quake, seeing the sea level drop, etc.), to mean that one should immediately run to the hills or high ground. Since the information about SMONG has life saving consequences and therefore of high value, it was incorporated into the culture as part of local wisdom and survived to save most of the local population in 2004.

IV. Conclusion

- Indonesian coastal areas are prone to tsunami disaster that threaten the sustainability of social and economic development. The mitigation program is essential for the country and it has been in right direction under the new laws in disaster management and coastal and small island management.
- The mitigation activity covers many aspects. It covers intervention of nine main activities from governance, risk assessment, ICZM, mitigation plan, community empowerment, habitat rehabilitation, retrofitting, development of evacuation route, and development of tsunami early warning system.
- The mitigation program should be continued and developed comprehensively through structural and non structural countermeasure.

ASSESSMENT OF TSUNAMI RISK TO THE PORT CITY OF GALLE, SRI LANKA

Nimal Wijayaratna, University of Ruhuna,
Galle, Sri Lanka, nimal@cee.ruh.ac.lk
Samantha Hettiarachchi, University of Moratuwa,
Moratuwa, Sri Lanka, samantha@civil.mrt.ac.lk

1. INTRODUCTION

Indian Ocean tsunami on December 26th 2004 provoked major losses in many coastal cities in Sri Lanka, including the port city of Galle in the south coast. It demonstrated the high vulnerability for tsunamis, and lack of disaster preparedness of the city community. Mass self evacuation and wide spread panic reported during 2005 and 2007 Indian Ocean tsunami early warnings are clear indications that the city community is at high risk. This paper is about an assessment of the tsunami risk to the city of Galle.

2. HAZARD ASSESSMENT

Tsunami risk is assessed as the likely impact on the people and the property during a future tsunami by taking the risk as the union of hazard and vulnerability. Therefore to determine the risk from tsunami, hazard should be established adequately. It is a common practice that the tsunami hazard is established as the probability that a tsunami of a particular magnitude will occur within a certain period of time. However, for Sri Lanka, likelihood of occurrence of a tsunami of any magnitude is extremely difficult to estimate due to the limited historic records. However, 2004 Indian Ocean tsunami was the largest ever event to record in the region and it is expected that a tsunami with a higher devastating power is extremely unlikely to occur in the near future. Further, it was a far field tsunami and Sri Lanka may not experience near field tsunamis. Therefore, there will be no major change in the inundation pattern in the city due to wave transformation process inside the continental shelf when far field tsunamis with different origins are concerned. Therefore a tsunami inundation map with inundation contours based on the 2004 event was used to establish the tsunami hazard, though there are no reoccurrence probabilities attached to the inundation figures.

3. VULNERABILITY ASSESSMENT

Risk is a pre-disaster scenario and vulnerability not only aggravates the disaster impacts but also hinders disaster prevention. Establishing the vulnerability is more difficult due to the involvement of many interrelated components which are not easily quantifiable. Vulnerability is defined and explained in different ways. Anderson and Woodrow (1989) divided the vulnerability into three components; physical and material, motivational and attitudinal, and social and organizational. Maskrey (1998) has proposed an elaborated list of vulnerability components; physical, technical, economical, environmental, social, political, cultural, educational and institutional. In any vulnerability model, spatial variation of physical environment related vulnerability components are relatively easy to recognize. Therefore in the present study, only the physical environment related vulnerability was evaluated. Emphasis was given to the vulnerability arising due to insecure locations, infrastructure, livelihoods etc.

4. TSUNAMI RISK

Spatial distribution of hazard and vulnerability was mapped and compared for overlapping areas. Severities of hazard and vulnerability are mapped in four levels; zero, low, medium and high. A zero-zero combination of hazard-vulnerability gives a zero risk area where as a high-high, high-medium and medium-high combinations give a high risk area. A combination matrix is proposed to define the level of risk. Spatial distribution of the tsunami risk to the Galle city was mapped accordingly.

5. SUMMARY

Tsunami risk to the Galle city was assessed as the union of hazard and vulnerability. Hazard was established using inundation contours of 2004 Indian Ocean tsunami. Physical environment related vulnerability components were assumed to represent the vulnerability adequately. A four level tsunami risk map was developed showing the severity of tsunami risk to different parts of the city.

6. REFERENCES

Anderson, M.B. and Woodrow, P.J., Rising from the Ashes, Development Strategies in Times of Disaster, Westview Press, Boulder, Colorado, 1989.

Maskrey, A. (ed.), Navegando entre brumas (Navigating through the mist), Intermediate Technology Development Group (ITDG) and Latin American Social Studies Network for Disaster Prevention (LA RED), 1998.

A STRATEGY FOR STORM SURGE DISASTER REDUCTION

Masahiko Isobe, The University of Tokyo,
Kashiwanoha, Kashiwa, Chiba 277-8563, Japan, isobe@k.u-tokyo.ac.jp

1. INTRODUCTION

Storm surge disaster is one of the most serious coastal disasters. In many cases, storm surges are caused by tropical cyclones which are called differently as hurricanes, cyclones and typhoons according to the location on earth. The storm surge induced by Hurricane Katrina caused a huge damage especially on New Orleans in 2005. Cyclones caused severe storm surges in Indian Ocean especially in 1970 and 1991. Recently, Bangladesh was attacked by a cyclone again on November 15. Typhoons often cause damages along north-west of the Pacific Ocean including Japan. Prevention and reduction of storm surge disaster is one of the top priorities of coastal management.

Moreover, recent symptoms of global warming include sea-level-rise and intensification of tropical cyclones. This will make storm surges severer than before, so that we may need to raise defense level. However, a single countermeasure will not provide a satisfactory defense level. This paper discusses a strategy for prevention and reduction of storm surge damages on the basis of discussion in the Committee on Future Storm Surge Measures in Areas Below Sea Level hosted by the Ministry of Land, Infrastructure and Transport. The contents extend to the response to the global warming.

2. FRAMEWORK OF STRAGEGY FOR STORM SURGE

Japan has experienced severe storm surge damages especially just after the World War Two. Typhoon 13 in 1953 passed along Japanese archipelago, causing unprecedented damage through Japan. Typhoon Ise Bay in 1959 recorded the largest storm surge anomaly, 340cm, and killed more than 5,000 people. Based on this background, Japanese Seacoast Law was established in 1956. After this, coastal defense work was accelerated and reduced the damage significantly. At present, out of 35 thousand km total coastal line in Japan, 15 thousand km, about half of the total, need to be protected against storm surges, tsunamis and beach erosion. Coastal structures were constructed for 9.5 thousand km to protect coast, but it needs a long time to complete the construction. Moreover, we should take global warming issues into consideration. Thus we need a strategy for storm surge disaster prevention and reduction.

Since coastal structures can protect all human lives and assets, protection by coastal structures is the basic countermeasures against storm surges especially in densely populated regions such as Tokyo Bay, Osaka Bay and Ise Bay. However, height of storm surges may exceed the expected level used in the design of structures. So, disaster reduction measures for such unexpected events should be prepared. This is definitely necessary in the region where protection by structures has not been completed.

Details of these countermeasures are described in the following. It is necessary to combine these measures appropriately to minimize the storm surge disaster.

3. DISASTER PREVENSION BY COASTAL STRUCTURES

The present coastal structures will not be effective for protection against storm surges because of the sea level rise and intensification of tropical cyclone activity. If we defer necessary action to adapt to the global warming, we will not have enough time and resources for adaptation. On the other hand, since there is uncertainty in the projection of future sea level rise and intensification of tropical cyclone activity, excess investment to improve coastal structures might waste social resources. Therefore, a stepwise adaptation strategy is proposed in the present study.

Figure 1 depicts the concept of the strategy. As an example, the design maximum water level of a coastal levee is determined by adding storm surge anomaly and wave run-up height above the astronomical high tide (High Water Level, HWL). In addition, some freeboard is taken to accommodate unexpected phenomena. As Intergovernmental Panel on Climate Change (IPCC) pointed out, sea level rise has already been observed and intensification of tropical cyclone activity will likely occur. So, necessary crown height is increasing as shown in the figure. However, because of the freeboard, the structure will function fully to the design maximum water level throughout its lifetime. When the structure is reconstructed, we can use the mean sea level measured at that time instead of that determined in the past. This will automatically take the sea level rise into account in the design of coastal structures.

In the further future, quantitative projection of the sea level rise may become more certain and intensification of typhoon activity will become evident. If so, we will include these factors in the design at the time of reconstruction.

Thus, all coastal structures will adapt to global warming step by step and we can avoid unnecessary investment.

However, some technical problems remain. Since sea level fluctuates corresponding to large scale oceanic and atmospheric phenomena, we need to remove fluctuations with periods up to ten to twenty years. Structural strength is not guaranteed when storm surges reach freeboard. Moreover, engineering judgment will be necessary to judge intensification of typhoon activity.

4. DISASTER REDUCTION BY ENHANCING PREPAREDNESS

We need to be prepared for extreme event which exceeds preventive capacity of structures. Waves may overtop beyond seawalls and coastal levees and storm surges may penetrate inland. Even in these cases, damages should be reduced and minimized. Construction of secondary levees by using highway and railway embankments, river levees and series of buildings prevents further penetration of surges. Openings into underground spaces should be closed to avoid inundation. In order to evacuate people timely and safely, storm surge forecasting system should be improved. Real time monitoring of waves and storm surges will improve the system significantly.

5. CONCLUSION

As well as disaster prevention and reduction stated above, land-use planning will play an essential role under the decreasing trend of Japanese total population. Adequate combination of these measures will yield a best practice to storm surge disaster.

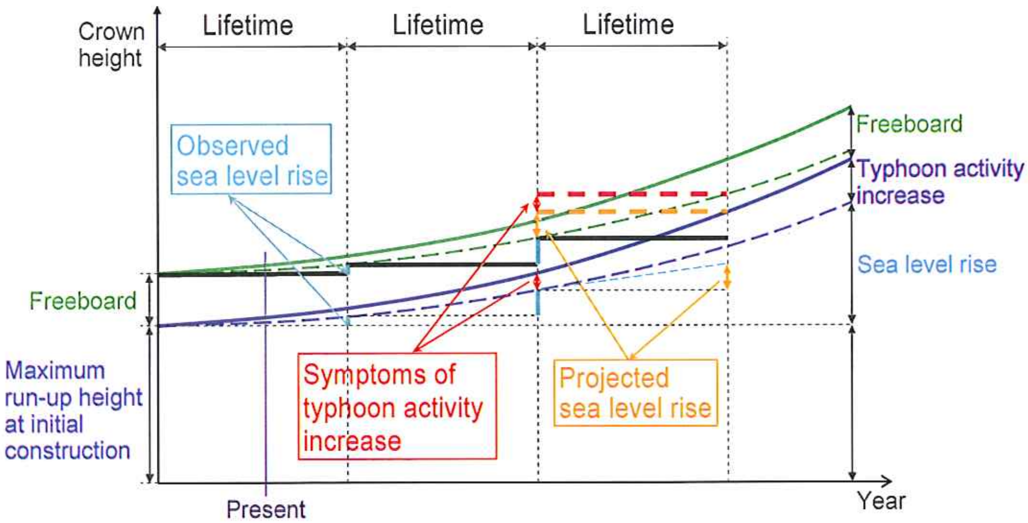


Figure 1. Strategy for adaptation of coastal structures.

DISASTER REDUCTION STRATEGY OF TSUNAMI

Yoshiaki Kawata, Research Center for Disaster Reduction Systems Disaster Prevention Research Institute Kyoto University, Kyoto Japan, kawata@drs.dpri.kyoto-u.ac.jp

1. INTRODUCTION

Through the Indian Ocean Tsunami, the terror and cruelty of tsunamis were delivered to people in their living rooms as very real images. There was also important knowledge to be gained and lessons to be learned which must be given serious thought. In this paper, I will discuss Japan's future tsunami strategies in light of these recent events.

2. CONTENT

Our paper has introduction and conclusion and other 6 chapters as

The Formation of Disaster Culture Should Start with Common Sense
The Realization of a Tsunami Disaster Reduction System through Selective Concentrated Investment
Strategic Plans for Tsunami Disaster Reduction
Real Examples of Strategic Plans in Osaka Prefecture
The Biggest Lessons Learned from the Sumatra Earthquake for Japan
Tokai, To-Nankai and Nankai Earthquake Problems

3. SUMMARY

The occurrence of Tokai, To-Nankai and Nankai earthquakes as shown in **Fig. 1** are very urgent and they accompany with tsunamis. Historically, tsunami damage was huge in comparison with earthquake damage. Therefore, how to reduce the tsunami damage is essential. **Table 1** shows the estimated damage. This expands with the damage link of the earthquakes and tsunamis, and, up to now, has become a super-large area disaster that has not been experienced. Moreover, last 60 years, our social structure has rapidly changed and social vulnerability has also increased year by year. Especially, the lifeline damage controls the progress condition of the recovery works of the stricken area.

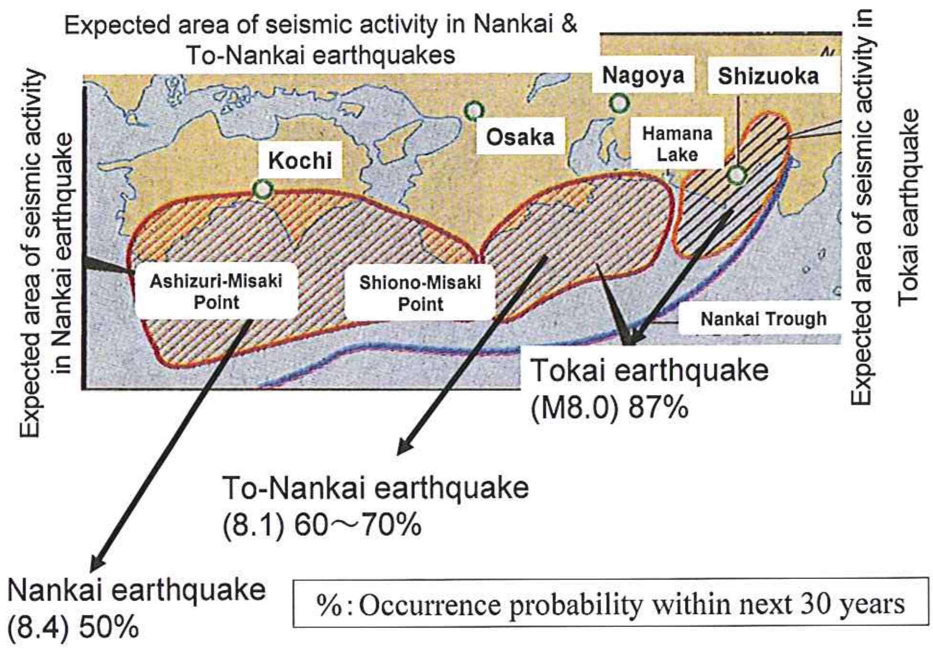


Fig. 1. Seismic zone of Tokai, To-Nankai and Nankai earthquakes and their occurrence probability

Table 1. Estimated damage caused by Tokai, To-Nankai and Nankai earthquakes and 1995 Kobe earthquake

Estimation of damage caused by possible EQs
(by technical investigation committees of Central Disaster Management Council)

(Maximum cases)	Tokai EQ	Tonankai & Nankai EQ	Kobe EQ 1995
Victims (persons)	9,200 (7,900 by strong tremors)	18,000 (8,600 by tsunamis)	6,436
Houses destroyed	260,000	360,000	105,000
Economic loss (billion yen)	37,000	57,000	10,000

In 1978, our government brought a Large-Scale Earthquake Countermeasure Law into force. The law focuses on Tokai earthquake. The outline of the earthquake disaster risk reduction strategy is shown in Fig. 2. Especially for tsunami, the prioritized actions to reduce possible tsunami victims is introduced in Fig. 3. We proposed the following efforts to reduce tsunami damage. 1) Early dispatch of tsunami warning because Japan Meteorological Agency usually forgets the existence of residents as customers of information, 2) Utility of measured seismic intensity meter located in every municipality to image coming tsunamis, 3) Promotion of hazard map and enlightenment residents who can not understand to apply it, 4) Senior citizen measures to reduce damage through health care, 5) Subways and underground shopping center measures because we have never experienced such new type inundation disasters, and 6) Dry riverbed user for sports, fishing and picnic measures. It is concentrated on the consideration of people who stayed in the danger zone such as coast and river.

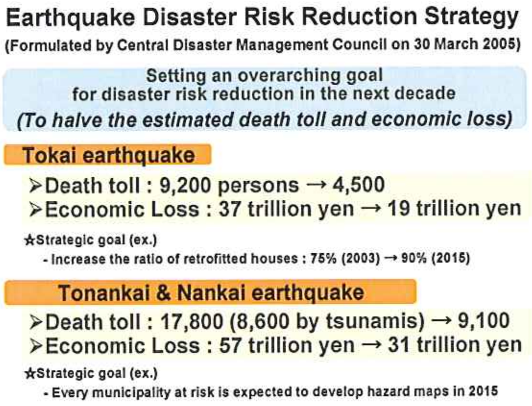


Fig. 2. Objectives of earthquake and tsunami disaster risk reduction strategy of Tokai, To-Nankai and Nankai earthquakes

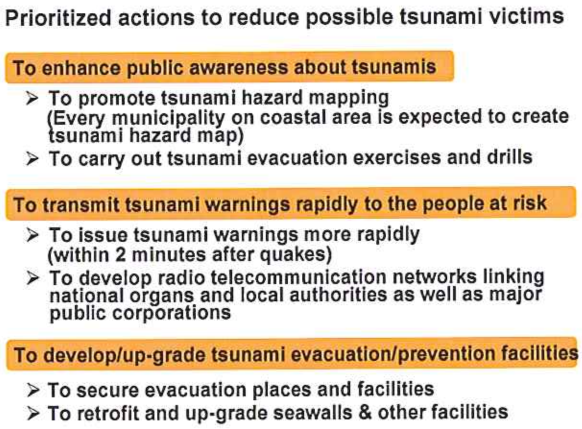


Fig. 3. Prioritized actions to reduce preventive tsunami victims due to Tokai, To-Nankai and Nankai earthquakes

A GLOBAL TSUNAMI REDUCTION STRATEGY: BUILDING EFFECTIVE TSUNAMI WARNING AND MITIGATION SYSTEMS

Laura S. L. Kong, International Tsunami Information Centre, Intergovernmental Oceanographic Commission (IOC), UNESCO, Hawaii USA, l.kong@unesco.org

1. BUILDING A GLOBAL SYSTEM TO GUARD AGAINST TSUNAMIS

Tsunami early warning systems must provide timely, understandable warnings within minutes that will then motivate ordinary citizens to quickly move out of harm's way. While implementation of the Indian Ocean tsunami warning and mitigation system is being pursued with highest urgency, the tsunami hazard exists in all oceans. *Every ocean basin and sea can be impacted by tsunamis, which can occur at any time without a precursor signal. In fact, some countries may be impacted by tsunamis from two or more basins.*

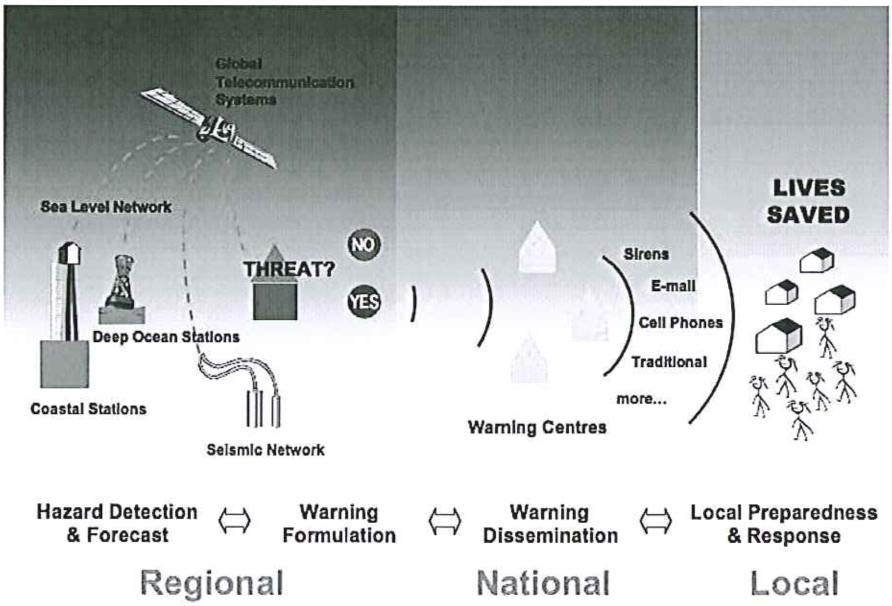
Until 2005, no tsunami early warning systems existed outside the Pacific. The IOC of UNESCO is currently leading the coordinating efforts to establish comprehensive tsunami warning and mitigation programmes globally. In addition to the 40-year old Pacific Ocean system, new systems are being built in the Indian Ocean, Caribbean, and the North Atlantic and Mediterranean. In the Pacific, sub-regional systems that can respond faster and specifically address sub-regional needs exist for the Northwest Pacific and are being planned for the Southwest and Southeast Pacific, Southeast Asia and Central America – Pacific Coast.

In general, we must be able to prepare for both local tsunamis which attack coasts within minutes, and for distant tsunamis like the M9.3 26 December 2004 Sumatra or the M9.5 22 May 2960 Chile tsunamis, which took hours to cross ocean basins. Because of the existence of destructive tsunamis from far distant sources, a single country cannot adequately protect itself from tsunami risks without international cooperation and data sharing.

However, to issue a warning without having prepared and exercised how the population should respond is ultimately useless. The IOC's approach requires progress in three mutually dependent components that are active at the international / regional, national, and local levels:

- **First**, assessing the tsunami hazard and risk especially at local levels to identify vulnerable communities;
- **Second**, preparing the population so they know what action to take in case of a warning; and
- **Third**, building an international, national, and local technological framework that warns of an advancing tsunami wave.

2. TSUNAMI EARLY WARNING



An effective tsunami early warning system is achieved when all persons in vulnerable coastal communities are prepared and respond in a timely manner upon recognition that a potential destructive tsunami may be approaching.

A tsunami warning system triggered by the continuous monitoring of large earthquakes with confirmation of tsunami waves can exist only through international cooperation under the principle of open exchange of observational data, and the availability of effective National Tsunami Response Plans that are immediately activated when warnings are issued in order to save lives. For responding quickly and efficiency, well-known and clear standard operating procedures for both warning centres and emergency operations centres should be in place and practiced so that stakeholders are familiar and understand their roles, responsibilities and the timely actions that are required. These are important lessons learned from past experience.

3. KEY ELEMENTS OF END-TO-END TEWS

Early Warning Systems can save lives. In particular, a number of elements are critical for an effective system to operate. These can be summarized as follows:

1. **Proper instruments that enable the early detection** of potentially harmful earthquakes and tsunamis. The data obtained by these instruments must be readily available to all nations continuously and in real-time to be effective.
2. **Warning systems that reliably inform the vulnerable populations** immediately and in an understandable and culturally appropriate way. The Warning Centre must be able to analyze and forecast the impact of tsunamis on coasts in advance of the waves' arrival, and the local, regional, and/or national Disaster Management Organizations (DMOs) must be able to immediately disseminate information on the threat and to enable evacuation of all vulnerable communities. The communications methods must be reliable, robust, and redundant, and work closely with the mass media and telecommunications providers to accomplish this broadcast.
3. **Awareness activities that enable ordinary citizens to recognize** a tsunami so that they know what to do. Citizens should recognize a tsunami's natural warning signs and respond immediately. This is especially true for the case of a local tsunami, which may hit within minutes and before an official tsunami warning can reach their communities.
4. **Preparedness activities which educate and inform** a wide populace, including government responders and those providing lifeline and critical infrastructure services, on the procedures and activities that must be taken to ensure public safety. Drills and exercises before an actual event, and proactive outreach and awareness activities are essential for reducing tsunami impact. Natural hazards science and disaster preparedness subjects that are part of the required curriculum taught to school children will prepare and carry awareness to the next generations. A Tsunami Coordination Committee comprised of all stakeholders involved in the identification of the risk, the warning guidance, and the pre- and post-disaster mitigation activities should meet regularly to collectively inform, decide, and share information.
5. **Planning activities that identify and create** the public safety procedures and products and build capacity for organizations to respond faster. It is necessary to create and widely disseminate tsunami evacuation or flooding maps, and instructions on when to go, where to go, and how to go. Evacuation shelters and evacuation routes need to be clearly identified, and widely known by all segments of the coastal population.
6. **Strong buildings, safe structures, and prudent land-use policies to save lives and reduce property damage** that are implemented as pre-disaster mitigations. Tall, reinforce concrete buildings may be adequate places to which people can vertically evacuate if there is no time to reach higher ground inland. Long-term planning to avoid placing critical infrastructure and lifeline support facilities in inundation zones will reduce the time needed for services to be restored.
7. **Stakeholder coordination as the essential mechanism** that facilitates effective actions in warning and emergency response. Clear designation of the national or local authority from which the public will receive emergency information is critical to avoid public confusion, which would compromise public safety.
8. **High-level advocacy that ensures** a sustained commitment to prepare for infrequent, high-fatality natural disasters such as tsunami.