BOOK OF ABSTRACTS

THE THIRD INTERNATIONAL WORKSHOP ON COASTAL DISASTER PREVENTION AND TSUNAMI HAZARD MAP SEMINAR

February 12 - 13, 2007
Regency Room, Mount Lavinia Hotel, Colombo, Sri Lanka

Organizers（Japan）
Port and Airport Research Institute
Coastal Development Institute of Technology
Ministry of Land Infrastructure and Transport

Organizers（Sri Lanka）
University of Moratuwa
National Science Foundation
Disaster Management Centre

Supporting Organizations
Japanese Section of International Navigation Association
UJNR Panel on Wind and Seismic Effects

The 3rd International Workshop on Coastal Disaster Prevention

Date

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Venue

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Objectives

Tsunami disasters are summarized through overviews of damage by previous tsunamis around the world and advanced measures to prevent and mitigate tsunami disasters are presented and discussed in the workshop.

Agenda

February 12 (Monday)

9.30 – 10:30 - Opening Ceremony
- Mr. Makoto Owada (PARI, Japan)
- Prof. S.S.L. Hettiarachchi (Moratuwa University, SR)
- Mr. Masahiko Furuichi (MLIT, Japan)
- Speech by Chief Guest/Guest of Honour

10:30 – 11:00 - Tea

11:00 – 12:30 - Session (1) Tsunami Disasters and Initiatives for Prevention/Mitigation Activities around the world
- Prof. S.S.L. Hettiarachchi (Moratuwa University, SR)

  “Development of the Indian Ocean Tsunami

Warning System"
- Dr. Shigeo Takahashi (PARI, Japan)
  "Tsunami Disasters and Their Mitigation in Japan"
- Prof. W.P.S. Dias (Moratuwa University, SR)
  "Development of Design Guidelines for Buildings against Tsunamis"

12:30 – 13:30 - Lunch

13:30 – 15:00 - Session (2 a) Tsunami Disasters and Initiatives for Prevention/Mitigation around the world
- Dr. S.P. Samarawickrama (Moratuwa University, SR)
  "Strategic Approach and Investigations on Mitigatory Measures"
- Dr. Subandono Diposaptono (MMAF, Indonesia)
  "Mitigating Tsunami Hazards: An Indonesian Challenge"
- Dr. Anat Ruangrassamee (Chulalongkorn University, Thailand)
  "Effect of Tsunamis on the Eastern Coast of Thailand"

15:00 – 15:30 - Tea

15:30 – 17:30 - Session (2 b) Tsunami Disasters and Initiatives for Prevention/Mitigation around the world
- Dr. Jose Miguel Montoya Rodriguez (IMT, Mexico)
  "Tsunami Disasters and Prevention/Mitigation Activities in Mexico (tentative)"
- Dr. John R. Headland (Moffatt & Nichol Engineers, USA)
  "Tsunami Impacts on Moored and Maneuvering Ships"
- Dr. Yoshiyuki Kaneda (JAMSTEC, Japan)
  "Advanced Ocean Floor Network for Earthquakes and Tsunamis around the Nankai Trough in Southwestern Japan - Towards the Understanding of Mega-Thrust Earthquakes -"
- Dr. Yuji Nishimae (JMA, Japan)
  "Tsunami Warning Service in Japan"

18:00 – 20:00 - Reception
- Mr. Susumu Murata (CDIT, Japan)
- Remarks from Sri Lanka

February 13 (Tuesday)

09:00 – 10:30 - Session (3 a) Advanced Technologies of Tsunami Disaster Prevention/ Reduction

- Dr. Taro Arikawa (PARI, Japan)
  "Hydraulic Characteristics of Buoyancy-Driven Vertical Piling Breakwater"
- Prof. Koji Fujima (NDA, Japan)
  "Numerical Simulation of Indian Ocean Tsunami Using Linear and Nonlinear Dispersive Wave Theory"
- Prof. Solomon Yim (Oregon State U., USA)
  "Structure-Structure Impact Modeling for Tsunami Debris Flow"

10:30 – 11:00 - Tea

11:00 – 12:30 - Session (3 b) Advanced Technologies of Tsunami Disaster Prevention/ Reduction

- Mr. Susumu Murata (CDIT, Japan)
  "Numerical Model for Estimation of Damages due to Tsunami"
- Prof. Ahmet C. Yalciner (METU, Turkey)
  "Determination of Periods of Free oscillations for the Irregular Shaped Basins by Numerical Technique"
- Dr. Takashi Tomita (PARI, Japan)
  "Development of Tsunami Damage Estimation Tool"

12:30 – 12:40 - Closing Ceremony

- Mr. Susumu Murata (CDIT, Japan)

12:40 – 13:40 - Lunch

Tsunami Hazard Map Seminar

Date

February 13, 2007

Venue

Regency Room, Mount Lavinia Hotel, Colombo, Sri Lanka

Organizers (Japan)

Ministry of Land Infrastructure and Transport
Port and Airport Research Institute

Organizers (Sri Lanka)

University of Moratuwa
National Science Foundation
Disaster Management Centre

Objectives

A tsunami hazard map provides a visual reference identifying historical and expected tsunami risks, and is a useful tool to prevent and mitigate future tsunami disasters. The seminar will focus attention on the outline of tsunami hazard maps and issues for its usage and promotion. Future direction of development of tsunami hazard maps and their relevance in developing countries will also be discussed.

Agenda

February 13, 2007

14:00 – 14:15 - Opening Ceremony
- Mr. Masahiko Furuichi (MLIT, Japan)

14:15 – 16.00 - Presentations
- Dr. Takashi Tomita (PARI, Japan)
  "Hazard Map to Build the Understandings and Awareness of Tsunami Disasters"
- Mr. Kentaro Kumagai (NILIM, Japan)
  "Utilization and Promotion of Tsunami Hazard Map"
- Dr. Nimal Wijayaratna (University of Ruhuna, SR)
  "Hazard Mapping - A Sri Lankan Experience"
- Dr. Subandono Diposaptono (MMAF, Indonesia)
  "Tsunami Risk Map in West Sumatera Indonesia"

16:00 – 16:30 - Discussion

16:30 – 16:40 - Closing Ceremony

- Dr. Shigeo Takahashi (PARI, Japan)

Contents

The 3rd International Workshop on Coastal Disaster Prevention

Tsunami Hazard Map Seminar

THE THIRD INTERNATIONAL WORKSHOP ON COASTAL DISASTER PREVENTION

DEVELOPMENT OF THE INDIAN OCEAN TSUNAMI WARNING SYSTEM

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Aftermath of the Indian Ocean Tsunami the need for a reliable tsunami warning system similar to that operating in the Pacific Ocean was identified. The UNESCO/ International Oceanographic Congress (IOC) in collaboration with the Indian Ocean states and other stakeholders initiated the establishment of a tsunami early warning system in March 2005. The initial task was to reach agreement on the structure and operation of such a warning system.

An effective tsunami warning system must include four key components, namely,

1) detection of hazard
2) assessment of risk
3) issuing the warning
4) dissemination of the warning
5) community preparedness to respond as advised in advance

It was agreed that the Indian Ocean Tsunami Warning System (IOTWS) will comprise a coordinated network of national systems and capacities, and will be part of a global network of early warning systems for all ocean related hazards. Therefore within the IOTWS, each Member State will have the responsibility to issue warning within their respective territories. For this purpose the respective warning centres of individual nations must be well equipped to receive and analyse information, detect the hazard, assess the risk and issue the warning to the community who have been adequately trained and coached on how best to respond to the specific type of warning issued. The UNESCO/IOC initiatives led to the establishment of the Intergovernmental Coordination Group (ICG) which meet regularly to report, discuss and monitor the initiatives and actions taken by the nations individually and jointly to contribute to the establishment of the IOTWS. A reliable tsunami warning system requires information arising from three instrumentation networks, namely, an improved seismographic network, a real time sea level observation network covering the Indian Ocean basin and the deployment of advanced deep-sea pressure sensors capable of detecting the tsunami as it travels over the deep ocean. It also requires the availability of well equipped national warning centres which are able to detect the hazard, analyse, assess the risk and issue an appropriate warning. The nations must educate its people on disaster preparedness and how to respond to a specific type of warning.

In order to achieve the specified objectives related to the establishment of the IOTWS based on national and international contributions, the ICG agreed on the establishment of Working Groups covering critical areas of the IOTWS. The said working groups comprising representatives of the nations and international experts are jointly contributing to the establishment of the IOTWS.

At present there are six working groups namely,

1) Seismic Measurements, Data Collection and Exchange
2) Sea level data collection and exchange, including deep ocean tsunami detection instruments
3) Risk Assessment
4) Tsunami hazard identification and characterization, including modeling and prediction
5) Establishment of a System of Interoperable Centres
6) Mitigation, Preparedness and Response

During the course of 2005/6 progress has been made in improving seismographic networks, sea level observation networks and the capabilities of national warning centres. There have been considerable efforts in identifying and providing access to wide range of relevant data bases and networking. Of significant interest is the fact that India, Indonesia, Malaysia, Thailand and Australia are planning the deployment of deep sea buoys which are currently being developed. The deep sea buoys which form a key element of the IOTWS will enable the detection of tsunamis arising in Sunda arc and provide early warning to the Indian Ocean states. It is expected that around 10 buoys will be in place by the end of 2006. The presence of these buoys will be of great advantage to countries like Sri Lanka which are located at a considerable distance from the potential fault line providing them a warning of the order of 1.0-1.5 hours. Through the respective working groups the nations maintain a working relationship on all issues related to each group.

One of the key areas of research and development refers to scenario modelling of tsunamis which have occurred previously and potential tsunamis which are most likely to occur in the future. Previous tsunamis have been modeled successfully providing a broader understanding of exposure of Sri Lanka to the hazard. In the absence of near-shore bathymetric data, the models have not covered areas closer to the shoreline. In effect the near-shore transformation processes and interactions that amplified the wave have not been incorporated. It is evident that simulations for a range of possible scenarios, incorporating the combined influence near-shore transformation and inland dissipation processes should be implemented in order to understand the exposure and impact on the coastal zone. For this activity to be implemented it is necessary to have quality data of the near-shore bathymetry and land topography. The results from this exercise should be stored in a relational database. In the event of a tsunami this database will provide initial information on the potential exposure to the hazard and impacts. Modelling should then be carried out as soon as information is available on the earthquake and should be further refined by remodeling with data available from the deep sea buoys when they are in place. By doing so it would be possible to assess the potential exposure and impacts of the tsunami if it was to occur and will greatly enhance the early warning process and its dissemination to the people to be affected.

TSUNAMI DISASTERS AND THEIR MITIGATION IN JAPAN

Shigeo TAKAHASHI

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1. Introduction

Disaster prevention technologies developed from experience with many tsunamis in Japan are reviewed in this paper. Also introduced is recent research on the prediction of disasters, real-time tsunami prediction and new countermeasures following the devastating Indian Ocean Tsunami.

2. Recent Tsunami Disasters in Japan and development of countermeasures

(1) Tsunamis and their disasters

In Japan, tsunami disasters occur very frequently. Historical tsunami disasters can be found in many old documents including the first documented tsunami in 684. Tsunami disasters occur approximately once every 10 years, and huge disasters once in a 100 years due to the active movement of tectonic plates around the Japanese Islands.

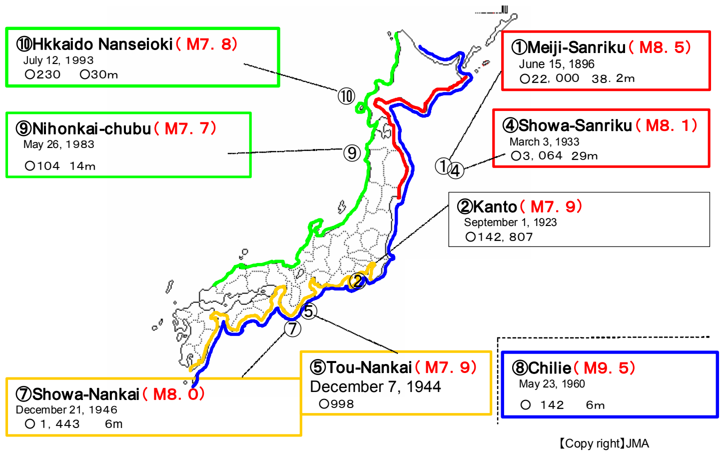

Fig. 1 Recent major earthquakes in Japan (The figure is from reference paper of Ports and Harbor Bureau of MLIT modified from the original figure of Japan Meteorological Agency.)

Figure 1 shows the recent major tsunamis in Japan. Tsunamis attack not only the Pacific Ocean coastline but also the Japan Sea coastline. The Meiji-Sanriku Tsunami in 1896 killed 22,000 people, which is the largest casualty in modern-age Japan. A tsunami arising from an earthquake off the Chilean coast attacked various locations in Japan and killed more than 100 people in 1960. The tsunami reached Japan after about 22.5 hours, traveling approximately 18,000 km with a speed of about 800 km/h.

The Nihonkai-Chubu Tsunami disaster, which occurred 20 years ago which killed about 100 in 1983, and the Hokkaido Nanseioki Earthquake Tsunami killed more than 200 people in 1993.

(2) Development of Countermeasures

From the 1950's, many administrative measures for disaster prevention have been taken, including those against tsunami disasters. In 1952, a tsunami warning system was established in Japan and after the Chilean Tsunami disaster, international cooperation for a distant tsunami warning system was established. In 1956, the Seacoast Law was implemented from the viewpoint of management of seacoasts including countermeasures against tsunamis and storm surges. In 1961, the Disaster Countermeasures Basic Act was established and a Central Disaster Management Council has been established in 1962, and in 1963, a

Basic Disaster Management Plan was prepared.

After the coastal disasters, the research on coastal disasters was promoted and the construction of coastal defenses was accelerated throughout Japan.

3. Current Countermeasures

In the very near future, earthquakes have been predicted for the Tokai, Tonankai and Nankai regions in addition to the area off the Miyagi coast. The central and local governments in these regions are preparing for expected tsunamis in various ways.

Non-structural measures are being prepared to mitigate expected tsunami disasters including 1. Tsunami warning system, 2. Dissemination of tsunami knowledge, 3. Land usage planning, and 4. Effective evacuation measures for low-lying areas(hazard maps, evacuation towers etc.) In addition, many structural countermeasures are being prepared against calculated tsunami heights, including tsunami seawalls, river water-gates, and on-land water gates.

The Central Disaster Management Council of the Cabinet Office is responsible for disaster mitigation. The Ministry of Land Infrastructure and Transport is implementing countermeasures against natural disasters including tsunamis.

4. Research on New Integrated Tsunami Countermeasures at PARI

Intensive studies have begun to establish integrated disaster mitigation measures in various research institutions around the world after the Indian Ocean Earthquake Tsunami. The Port and Airport Research Institute (PARI) which had made studies on tsunami since the Chilean Tsunami, established a tsunami research center to develop new integrated countermeasures for expected huge tsunamis in Japan, which includes:

1. Disaster prediction with ‘dynamic hazard maps’
2. Vertical evacuation in tsunami-resistant buildings
3. Real-time tsunami prediction with monitoring
4. New structural countermeasures (Tsunami gates)
5. Greenbelt

5. Concluding Remarks

The Indian Ocean Tsunami caused devastating disasters. People in the world experienced the disasters directly and indirectly, i.e. visually through TVs, which will contribute greatly to reduce tsunami disasters in the future. But they will disappear gradually from the memories of people. Not just the experiences of the disasters but the analyses of the disasters are important, and we should learn from the experiences. They should be integrated into advanced disaster mitigation technologies.

For example, to enable safe evacuation, people should be given adequate information on actual tsunami inundation disasters, which includes the actual risk of human casualties and potential of damage to houses and facilities in the coasts, in addition to information on tsunami height. The technology to provide more specific and concrete information (scenarios) on tsunami disaster is needed. The advance technologies should be developed with an international cooperation including researchers from Sri Lanka.

TSUNAMI DISASTERS AND THEIR MITIGATION IN JAPAN

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ABSTRACT: Disaster prevention technologies developed from experience with many tsunamis in Japan are reviewed in this paper. Also introduced is recent research on real-time tsunami prediction and the prediction of disasters following the devastating Sumatra Earthquake Tsunami.

1. INTRODUCTION

Civil engineering research on the coastal zone is very active in Japan as this zone is very heavily populated and economically very important. Recent research has been directed toward disaster prevention and environmental preservation.

Intensive research is being done on disaster prevention in the coastal zones of Japan. Research on typhoon disasters started after the Isewan Typhoon in 1959, which killed about 5,000 people. After the Chilean Tsunami disaster in 1960, research began on tsunami disasters, with significant progress after the Nihonkai-chubu Tsunami in 1983 and the Hokkaido-Nanseioki Tsunami in 1993.

On December 26, 2004, the devastating Indian Ocean Tsunami disaster occurred, killing about 300 thousand people [1-5]. Studies have been focused on clarifying the factors of the tsunami disaster and also to establish integrated disaster mitigation measures around the world.

The contents of this paper are as follows:

1. Introduction
2. Recent Tsunami Disasters in Japan and development of countermeasures
3. Current Countermeasures
4. Research on New Integrated Tsunami Countermeasures
5. Concluding Remarks

Sections 2 briefly reviews recent tsunami disasters and development of countermeasures against expected tsunamis in Japan using reference documents reported by the Ports and Harbor Bureau of the Ministry of Land, Infrastructure and Transport, Japan. Section 3 introduces the current countermeasures in Japan Section 4 introduces integrated research being conducted at the Port and Airport Research Institute. New disaster mitigation measures are needed to reduce the casualties due to huge tsunamis.

2. RECENT TSUNAMI DISASTERS IN JAPAN AND DEVELOPMENT OF COUNTERMEASURES

"Tsunami" is a Japanese word written using two Chinese characters. 'Tsu" means harbor and "nami" means wave, and therefore "tsunami" means "harbor wave" in Japanese. Although tsunami is not apparent in deep seas but it become violent in coasts. Especially people can find tsunami in harbors. This is the reason of the name.

It became internationally popular after the Meiji-Sanriku Tsunami in 1896 and the Showa-Sanriku Tsunami in 1933. News reports of devastating damages appeared around the world.

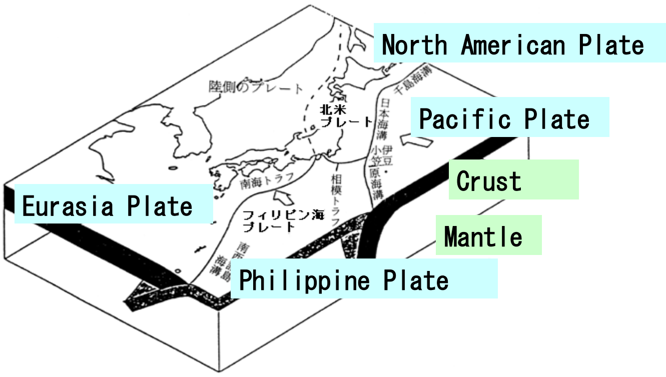

Fig. 1 Subduction zones and plates around Japan

In Japan, tsunami disasters occur very frequently. Historical tsunami disasters can be found in many old documents including the first documented tsunami in 684. Tsunami disasters occur approximately once every 10 years, and huge disasters once in a 100 years. This is due to the active movement of tectonic plates around the Japanese Islands. The vertical displacement of plates due to subduction zone earthquakes results in tsunami generation[6,7].

Figure 2 shows the recent major tsunamis in Japan. Tsunamis attack not only the Pacific Ocean coastline but also the Japan Sea coastline. All of these tsunamis were generated from seas near the Japanese Islands, except that from the Chilean Tsunami in 1960.

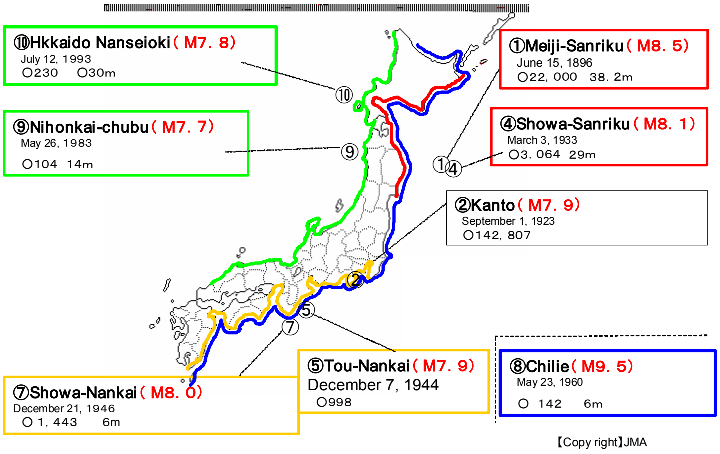

Fig. 2 Recent major earthquakes in Japan (The figure is from reference paper of Ports and Harbor Bureau of MLIT modified from the original figure of Japan Meteorological Agency.)

Figure 3 shows a picture about the Meiji-Sanriku Tsunami in 1896 which killed 22,000 people, the largest casualty in modern-age Japan. The shaking due to the earthquake was not significant along the coast, and therefore the people did not realize that there was a risk of a tsunami attack and did not evacuate. The tsunami hit at night (8 o'clock at night, 35 minutes after the quake) at heights exceeding 10 m (maximum recorded runup height 38.2 m).

This disaster can be considered to be similar to that of the Indian Ocean Tsunami since no warning (no evacuation) and almost no coastal defenses existed against such a large tsunami. In 1933, the Showa-Sanriku Tsunami attacked the same region again but the number of casualties was greatly reduced to 100 due to evacuation before the tsunami attack.

Figure 3 A picture of the Sanriku Tsunami Disaster

From the 1950's, many administrative measures for disaster prevention have been taken, including those against tsunami disasters. In 1952, a tsunami warning system was established in Japan. In 1956, the Seacoast Law was implemented from the viewpoint of management of seacoasts including countermeasures against tsunamis and storm surges. In 1961, the Disaster Countermeasures Basic Act was established and in 1962, an act went into effect concerning special financial support to deal with designated disasters of extreme severity. A Central Disaster Management Council has been established and in 1963, a Basic Disaster Management Plan was prepared.

Figure 4 shows an inundation disaster caused by the Chilean Earthquake Tsunami arising from an earthquake off the Chilean coast. The tsunami reached Japan after about 22.5 hours, travelling approximately 18,000 km with a speed of about 800 km/h. The tsunami attacked various locations in Japan from Hokkaido in the north to Okinawa in the south. People could not comprehend the tsunami danger from such a distance and the tsunami warning system did not work. After this disaster, international cooperation for a distant tsunami warning system was established.

Just before the Chilean Earthquake Tsunami disaster, a devastating storm surge attacked the Isewan Bay in 1959 killing about 5,000 people. After these two coastal disasters, the research on coastal disasters was promoted and the construction of coastal defenses was accelerated throughout Japan.

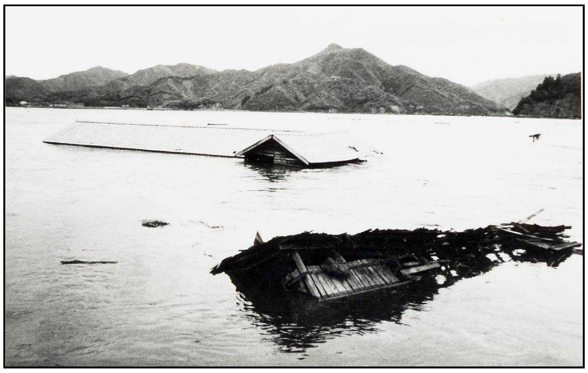

Fig.4 Inundation in Suzaki due to Chilean Tsunami

Fig. 5 Inundation due to Nihonkai-chubu Tsunami in Iwasaki Village

Fig. 6 Wave runup at Matsuzaki Port

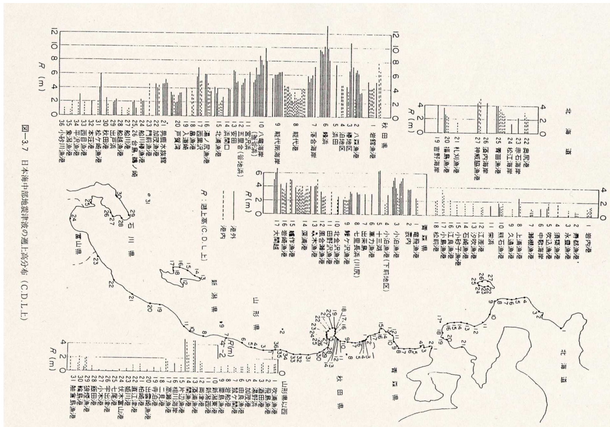

Fig. 7 Tsunami height along Japan Sea coasts

Fig. 8 Aonae in Okushiri Island just after Tsunami attack

Figure 9 Damaged houses and ships

Figure 5 shows a photo of the Nihonkai-Chubu Tsunami disaster, which occurred 20 years ago. Figure 6 shows a photo of the tsunami running up to 5 m near Matsuzaki Port; it was taken by a construction worker. Due to the warning system, the number of casualties was reduced to about 100. Also, coastal defenses against the storm waves were effective. The casualties included children who were on a picnic on the coast and people working in the sea, such as fishermen and marine construction workers. The transmission of the warning to these people was difficult. Figure 7 shows the distribution of tsunami heights along the Japan Sea coast. It should be noted that significant damage appeared where the tsunami height exceeded 4 m and devastating damages occurred where the tsunami height was near 10 m[8].

Figure 8 is a photo of the Aonae district of Okushiri Island just after the Hokkaido Nanseioki Earthquake Tsunami[9], which is known as the Okushiri Tsunami, because the most serious damage was to Okushiri Island. The maximum tsunami run-up height was more than 30 m and more than 200 people were killed.

3. CURRENT MEASURES FOR TSUNAMI DISASTER PREVENTION

(1)Okushiri Island

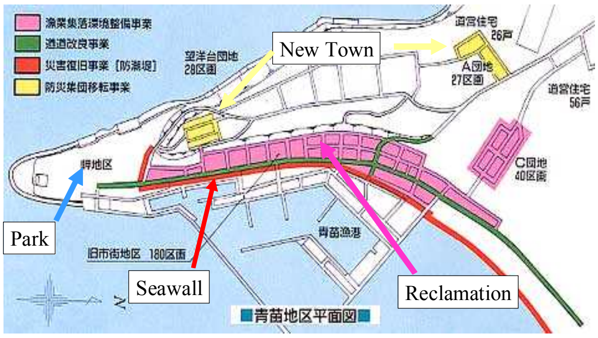

Figure 10 Land use planning in Aonea district

Fig. 11 Completed tsunami mitigation works

After the disaster, construction work was implemented to establish a total disaster prevention system for Okushiri Island. Figure 10 shows a map of land use planning, where houses in the most severely damaged areas were to be moved to high land areas and some land reclamation would be done to create higher land areas. Figure 11 shows the seawalls in front of the reclaimed lands and an artificial high ground in the fishery port where fishermen can work daily on the first floor and use the second floor for evacuation.

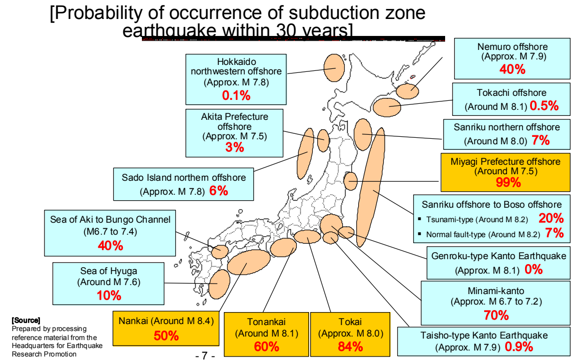

Fig.12 Expected earthquakes(from reference material of the execution office of the Earthquake Research Committee)

(2) Expected Tsunamis

Figure 12 shows the occurrence probabilities within 30 years of subduction zone earthquakes around the Japanese Islands. In the very near future, earthquakes have been predicted for the Tokai, Tonankai and Nankai regions in addition to the area off the Miyagi coast. The central and local governments in these regions are preparing for expected tsunamis in various ways.

The Central Disaster Management Council of the Cabinet Office is responsible for disaster mitigation. The Ministry of Land Infrastructure and Transport is implementing countermeasures against natural disasters including tsunamis. To prepare for the expected earthquakes and tsunamis, the Large-Scale Earthquake Countermeasures Special Act was passed in 1978, which encourages having basic plans for earthquake disaster prevention including the definition of jurisdictions and responsibilities for disaster management, a disaster management system and plan, disaster preparedness, emergency actions and recovery, financial measures, state of emergency plans, etc. A new law, the Tonankai and Nankai Earthquake Countermeasure Special Act, was passed in 2002.

(3) Non-structural Countermeasures

The disaster caused by the Nihonkai-chubu Earthquake Tsunami showed that not only hardware measures but also software measures are needed to mitigate expected tsunami disasters. Software measures include:

a. Tsunami warning system
b. Dissemination of tsunami knowledge
c. Land usage planning
d. Effective evacuation measures for low-lying areas.
(hazard maps, evacuation towers etc.)

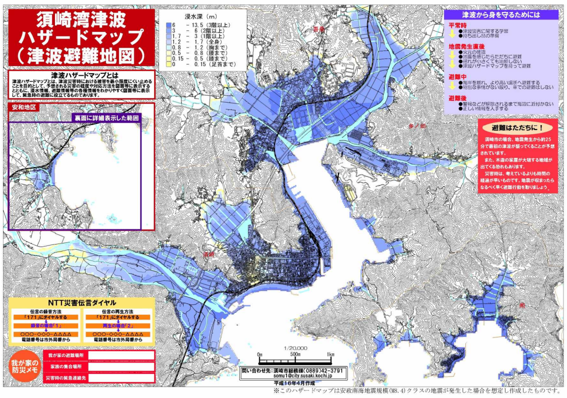

Fig. 13 Hazard map for Suzaki City

The Japan Meteorological Agency developed a new warning system for local earthquake tsunamis from 1999 to issue a warning within 3 minutes using a tsunami database of 100,000 calculated tsunamis. The agency also has a warning system for distant earthquake tsunamis that was established with international cooperation.

Figure 13 shows a hazard map prepared for Suzaki City. The 'Manual for Tsunami and Strom Surge Hazard Maps[11]' has been used by some local governments to prepare hazard maps in collaboration with engineers and local citizens. Such a map can be useful for effective evacuation of the residents and also aid in the planning of disaster mitigation.

(4)Structural Countermeasures

Many structral countermeasures are being prepared against calculated tsunami heights, including tsunami seawalls, river water-gates, and on-land water gates.


Fig.14 Tsunami breakwater in Suzaki

Figure 14 shows a tsunami breakwater which is under construction at a baymouth in Suzaki Port, Japan. Tsunami breakwaters were and are being constructed in expected tsunami areas (especially areas affected by major tsunamis in the past) to reduce the intrusion of a tsunami into the harbor. Ordinary breakwaters can also prevent a tsunami to some extent, especially reducing a direct attack of the tsunami wave front, as has been observed in recent tsunamis in Japan[10].

4. RESEARCH ON NEW INTEGRATED TSUNAMI COUNTERMEASURES

Intensive studies have begun to establish integrated disaster mitigation measures in various research institutions around the world after the Indian Ocean Earthquake Tsunami. The studies include

1. Generation of Earthquake
   Generation mechanism of earthquake, Prediction and Early warning method of earthquake
2. Generation and Propagation of Tsunami
   Numerical simulation of generation and propagation of tsunami, Early warning method of tsunami,
3. Run-up of Tsunami
   Numerical simulation (prediction of water current and height)
4. Tsunami Disaster
   Prediction(Numerical simulation) of Tsunami forces
   Prediction(Numerical simulation) of Failures of buildings and facilities
   Prediction of behavior of floating objects
   Prediction of human safety
5. Non-structural Countermeasures
   Hazard map making, Evacuation simulation, Dissemination of tsunami knowledge
   Real time prediction of incident tsunami
6. Structural Countermeasure
   Tsunami breakwaters and seawalls, Tsunami gates, Green-belt, Evacuation tower
7. Disaster Prevention Policy and Administration
   Risk management (Planning of evacuation, recovery and reconstruction, Evacuation drill)

Coastal management (Land-use planning ,

The Port and Airport Research Institute (PARI) has been working for many years since the Chilean Tsunami to mitigate tsunami disaster. Just after the Indian Ocean Tsunami PARI established a tsunami research center to develop new integrated countermeasures for expected huge tsunamis in Japan. This section explains four current research projects at PARI:

1. Disaster prediction with 'dynamic hazard maps'
2. Vertical evacuation in tsunami-resistant buildings
3. Real-time tsunami prediction with monitoring
4. New structural countermeasures(Tsunami gates)
5. Greenbelt

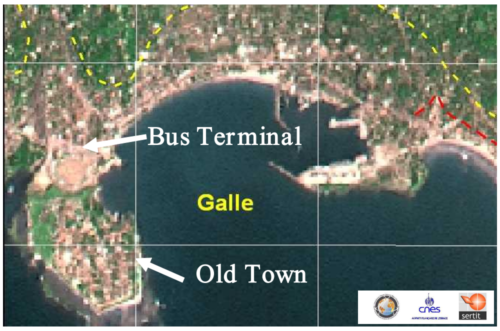

Figure 15 Galle city

4.1 Disaster Prediction with Dynamic Hazard Maps

People around the world were shocked by videos taken during the Indian Ocean Tsunami attack. Having people be aware of the danger of a tsunami disaster is very valuable.

Figure 15 shows a map of Galle City in southern Sri Lanka. Figure 16 shows pictures from the video which was given to a Japanese government survey team that visited there. The video was taken at the bus terminal and shows the tsunami attacking the area. The tsunami came from the southeast, washed the old market place and came into the bus terminal area. Watching the video led me to reconsider the current tsunami mitigation technologies.

1. The tsunami current on land is very strong and includes various kinds of debris. This phenomenon was unexpected and is difficult to be reproduced numerically in a simulation.
2. If I had been there I probably would not have been able to find a way to escape from the tsunami.
3. Engineers do not really understand what will actually occur during a tsunami attack.
4. Videos and photos can be easily understood by the public. We need the technology to disseminate images of disasters like these videos to make people fully aware of what can occur.

Fig. 16 Pictures from a Tsunami Video in Galle

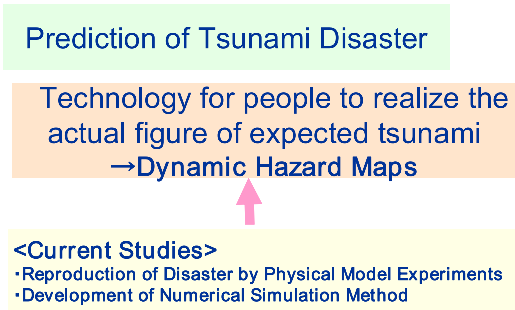

Fig. 17 Studies for tsunami disaster prediction

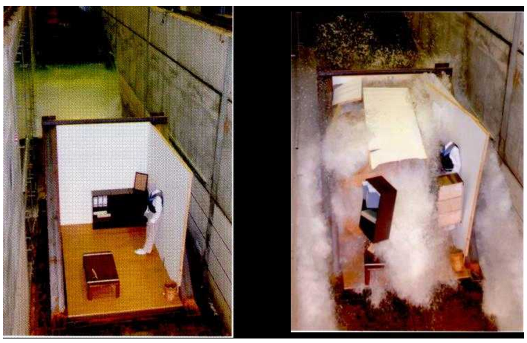
Fig. 18 Large scale tsunami experiment

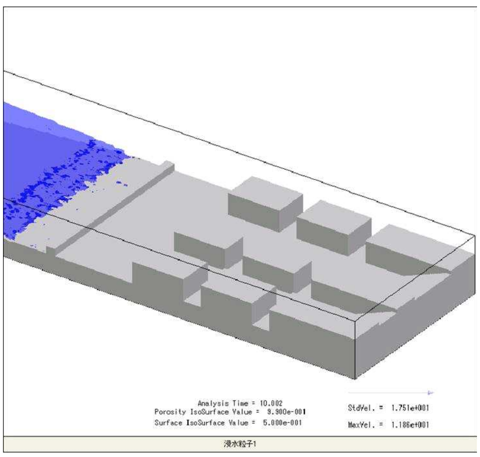
Fig. 19 STOC calculation

Figure 17 explains a research project to develop tsunami disaster prediction technologies. We are conducting model experiments and developing a new numerical simulation method to prepare dynamic hazard maps. The dynamic hazard map is for the local people to visually understand what will actually occur during a disaster.

Figure 18 shows a model experiment to investigate the damage to an ordinary house during a tsunami attack. It was conducted at the Large Hydo-Geo Channel of PARI measuring 184 m in length, 3.5 m in width and 12 m in depth. It was constructed in 2000 to conduct prototype wave experiments using 3.5 m waves. The wave maker was modified to produce 2.5 m tsunamis in the channel. Various experiments are underway to investigate the actual tsunami damage to buildings and coastal facilities.

Figure 19 shows a picture produced by STOC[12], a numerical simulation for tsunami. STOC can calculate tsunami behavior from its generation to on-land run-up using 3-D direct fluid simulation. A dynamic hazard map can be made with visualization of the calculated results by STOC.

]
Fig. 20 Stability tests of human bodies against currents

Figure 20 shows an experiment to examine what happens when people are caught in currents. This was done to observe the danger of overtopping waves from seawalls and breakwaters[13]. Figure 21 shows a result of the experiments which allow us to identify the unstable condition due to the current and the water level. For example, if the water level is 55 cm and the current speed exceeds 150 cm/s, then people cannot remain standing. The fundamental behavior of tsunami-induced current is the same as that of waves.

Cooperative studies should be done considering accumulated research results on tsunami and ordinary waves[14-19].

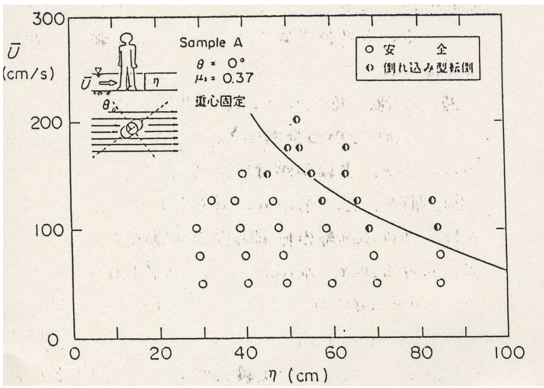

Fig. 21 Stability of human bodies against currents

4.2 Vertical Evacuation in Tsunami Resistant Buildings

The predicted Tokai Tsunami is expected to attack the coastline within several minutes. What must be considered are the dangers to encounter the tsunami current during evacuation. As mentioned in 4.1, it is very dangerous to walk in the inundated area. Rather than trying to escape, it could be safer to seek refuge in a tall strong building nearby.

Figure 22 shows a temporary evacuation place for the neighborhood in Tanabe Town, Wakayama Prefecture. People in this small community will first escape to this high land from tsunami and then to move to a large city-designated evacuation place located more than 1 km away. At first, it would be better to evacuate to a high place like this or a high building nearby. The temporary evacuation building should be reinforced to resist a tsunami attack.

Figure 23 shows an evacuation tower in Japan. If high buildings are not available nearby, such an evacuation building should be prepared or public buildings should be modified and reinforced with anti-tsunami design to provide those in the neighborhood with shelters in case of an emergency.

Fig.22 Temporary evacuation place

Fig. 23 Evacuation tower

4.3 Real-Time Prediction of Tsunami with Monitoring

Even if there are tsunami warnings, the actual tsunamis are sometimes not as large as predicted. If such "false warnings" are repeated, the number of people who evacuate will decrease. Therefore, it is very important to increase the reliability of the warning by monitoring tsunamis and basing their real-time prediction on such data. Research is in progress to directly measure the tsunami in offshore area using new systems including pressure gauges, GPS devices and HF radars.

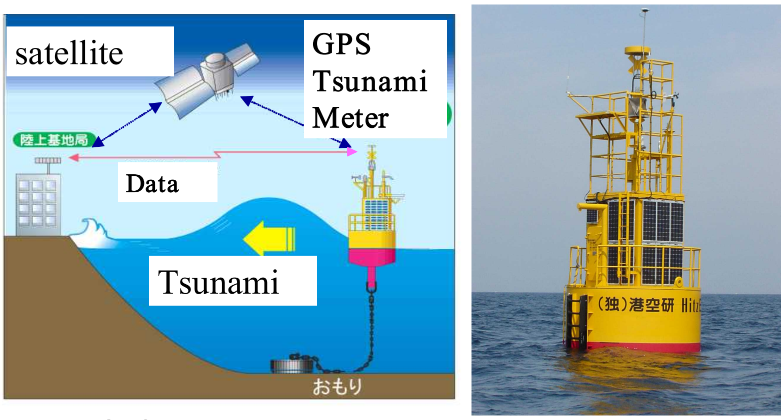

Fig. 24 GPS tsunami meter

The Port and Harbor Bureau of the Ministry of Land Infrastructure and Transport has a nationwide surveillance network named 'NOWPHAS' to observe waves[20-22]. NOWPHAS has more than 50 stations along the Japanese coasts with mainly ultrasonic wave gauges. NOWPHAS has succeeded in measuring some tsunamis, but its measurements are limited to areas relatively near the shore. Figure 24 shows a new device called a 'GPS tsunami meter' which was installed 13 km off Kochi Port and successfully measured the Tokaido-Oki Tsunami that occurred last year. The tsunami was small but was clearly measured 9 minutes before arrival at Kochi Port. The Ministry is planning to install GPS tsunami meters near the subduction zones to have real-time prediction of tsunami.

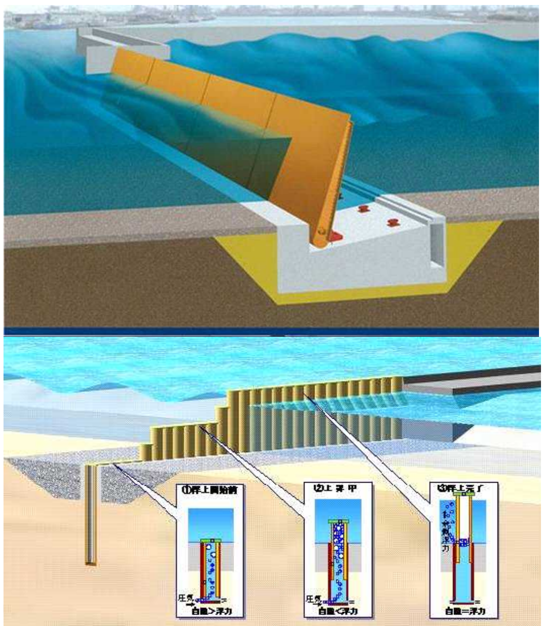

Fig. 25 New Tsunami gates

4.4 New Structural Countermeasures

In Japan, the population is very dense and economical activities are very intensive in coastal zones. It is not enough to simply have people evacuate from the area.

Facilities in the coastal zones must also be protected. Hardware countermeasures such as seawalls and breakwaters are necessary to prevent failure of vital facilities in coastline areas.

Figure 25 shows new water gates to be installed at a breakwater mouth for protection against tsunami intrusion. They are being developed as cooperative projects with private companies. The breakwater can prevent tsunami intrusion, and closing the breakwater mouth is very effective to reduce intrusion. A tsunami has tremendous energy and is very difficult to stop. Therefore, it is important to develop economically feasible and technically effective protective hardware measures.

4.5 Green-Belt

Damages due to the Indian Ocean Tsunami were significantly reduced in the coastal areas protected by natural barriers of coastal forests. Figure 26 shows an artificial forest named 'green-belt' to protect the coastal area behind. The artificial forest can dissipate the tsunami energy reducing the speed and height of tsunami. This effect is being investigated at various institution including PARI.

Fig.26 Greenbelt

5. CONCLUDING REMARKS

It is said that the dissemination of knowledge of tsunami is essential. This is true and we can now provide general knowledge of tsunami to people. However the tsunami disasters are very different depending on places. For example, to enable safe evacuation, people should be given adequate information on actual tsunami inundation disasters, which includes the actual risk of human casualties and potential of damage to coastal buildings and facilities, in addition to information on tsunami height. The technology to provide more specific and concrete information (scenarios) on tsunami disaster is needed. This should be done with an international cooperation including researchers from Sri Lanka.

ACKNOWLEDGEMENTS

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DEVELOPMENT OF DESIGN GUIDELINES FOR BUILDINGS AGAINST TSUNAMIS

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Abstract

Three different types of structural failure were observed in various structures during the tsunami of December 2004, namely sliding, overturning and undermining through scouring. Guidelines have been drawn up for low cost single storey buildings at risk from the natural disasters of coastal flooding, cyclones and earthquakes, covering zoning and siting issues in addition to building planning and structural recommendations. Finally, engineering calculations have been performed for three case studies, namely a school building that has lost a corner column due to undermining, the same school building subjected to tsunami loading (Fig 1 & Tab 1) and a boundary wall experiencing a lateral water load. These calculations help to identify strategies for designing efficiently against the very large effects of tsunamis.

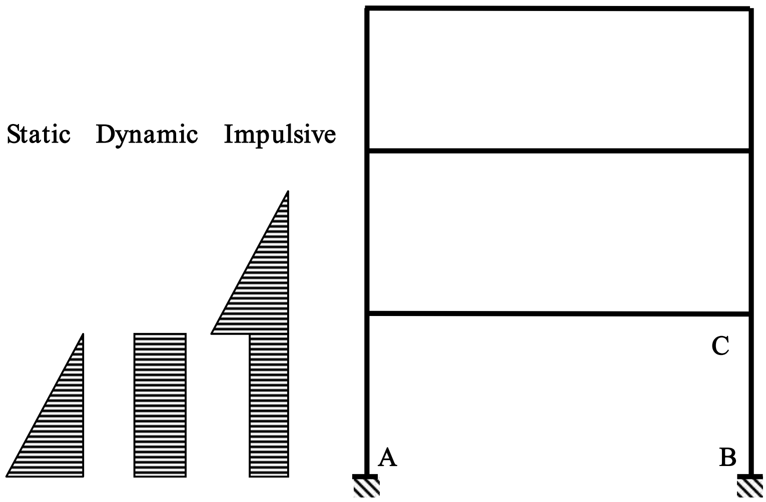

Figure 1 – Typical school building frame used for computer simulation

Table 2 – Maximum bending moment (kNm) at base for frame under tsunami loading

No. of storeys	Infill wall?	Loading width (m)	Column position	Duration of Impulse (s)				Static load
				0.1	0.25	0.50	1.0	
1	No	0.225	Rear	10.89	12.50	13.23	13.67	14.29
2	No	0.225	Rear	15.54	20.64	22.96	24.30	24.18
3	No	0.225	Rear	17.92	23.42	26.11	27.70	28.20
2	Yes	3.10	Front	21.42	26.24	28.70	30.33	35.28

STRATERGIC APPROACH AND INVESTIGATIONS ON MITIGATORY MEASURES

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1. Introduction

Post-disaster planning has been undertaken in the context of overall coastal hazards such as tsunamis, however remote the chances of a very extreme event taking place. In particular, when planning for reconstruction it is important to assess scientifically the basis and criteria on which such an exercise is undertaken. Planning based on observations arising from a single extreme event without scientifically analyzing the true character of its impacts and future threats and risks should be avoided.

2. Planning Countermeasures

There are many countermeasures that could be adopted in coastal zone management when planning for a tsunami and other coastal hazards that accompany high waves and high inundation. These include early warning systems, regulatory interventions in the form of extending existing setback defense line and physical interventions such as protection structures and utilizing the full potential of coastal ecosystems. These have to be supplemented with efficient evacuation procedures, incorporating planned evacuation routes and structures that effectively integrate with the overall planning process.

In this respect the countermeasures can be broadly classified into two categories and respective measures are listed below.

- Countermeasures that promote successful evacuation from tsunami
    1. Early Warning Systems
    2. Public Warning Systems
    3. Hazard Maps for Vulnerability
    4. Set Back defense line
    5. Evacuation Routes and Structures

- Countermeasures that mitigate the impact of tsunami

1. The implementation of artificial measures for protection including tsunami breakwaters, dikes and revetments
2. The effective use of natural coastal ecosystems including Coral Reefs, Sand Dunes and Coastal Vegetation (Mangrove Forests)
3. Tsunami Resistant Buildings and Infrastructure

In the above context three types of physical interventions are identified depending on their location and function in protecting the coast. These interventions may be achieved not only by artificial methods via Coastal Engineering Design but also by harnessing the full potential of natural coastal ecosystems. The types of interventions and typical examples for each category are listed below.

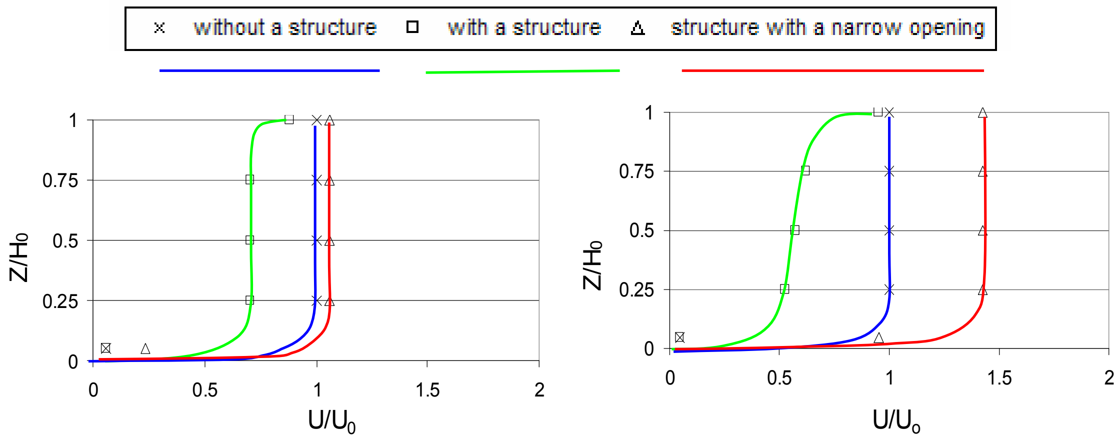
(i) Reduce the impacts of tsunami waves prior to reaching the shoreline.
(eg. Tsunami Breakwaters, Coral Reefs)

(ii) Protect the coastal zone by preventing the inland movement of tsunami waves.
(eg. Tsunami Dike, Sand Dunes)

(iii) Mitigate the severe impacts of tsunami waves on entry to the shoreline.
(eg. Tsunami Dikes, Revetment, Coastal Vegetation)

On many occasions both methods can be adopted in parallel to develop well-integrated hybrid solutions satisfying environmental concerns.

Although corals, rock reefs and mangroves are believed to provide shoreline protection against waves, currents and storm surges solid evidence for such through scientific studies is remarkably little and has been mostly accidental or circumstantial. The paper presents the results of the physical modelling carried out to understand the impact of Coral Reefs and Coastal Vegetation. The experiment was carried out in a 0.8 × 1.8 × 32 m long wave tank with a programmable paddle wave generator. Figures 1 includes the normalized velocities for the conditions of: (i) no structure, (ii) structure without an opening and (iii) structure with a narrow opening for the testing of coral reefs for solitary waves of 2€ = 10cm, ω = 0.4Hz.



(a) 50% porosity (b) 20% porosity

Figure 1: Normalized Velocity as a function of normalized height

2€ = 10cm, ω = 0.4Hz

MITIGATING TSUNAMI HAZARDS : AN INDONESIAN CHALLENGE

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Abstract

The rate of population growth and magnitude of economic development along Indonesian coasts presents many challenges. One of these challenges is to ensure the safety and security of the human population and physical facilities that are periodically subjected to catastrophic tsunami disasters. Significant initiatives are under way to minimize the impacts from tsunamis through better preparedness and a more informed public.

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

INTRODUCTION

Indonesia is both blessed and threatened by nature. Due to our size, extending over 3 times zones and more than 6.000 km from east to west, and to our geologic setting, we are blessed with what is considered by some to be the greatest marine biodiversity within a single nation. We are tasked with being good stewards of this global resource whose importance and management are just beginning to be understood. This blessing is balanced by nature as we are also threatened with almost every natural disaster known, including earthquake and tsunamis, most of which directly impact our coastal populations and resources. Our culture has accepted this dichotomy with nature, reflecting her diversity in our traditions and acknowledging her might during natural disasters.

One of the explanations often provided for the significant increase in the amount of disaster damages is the population increase in disaster-prone locations, especially coastal areas. Every year, more and more Indonesian are at risk from a variety of natural disasters that affect the coastal environment. In the past 20 years, there has been such explosive growth along the nation's coastal margins that today more than 60 % of the Indonesian population lives in coastal areas. More than 80% of industries, 75% of cities with a population of more than 100.000 people and 60.000 villages are located in the coastal area. Most development activities take place in the coastal area including fisheries, agriculture, industry, transportation, tourism, urban development, and are particularly vulnerable to catastrophic and chronic coastal disasters, such as tsunamis.

The rate of population growth and magnitude of development along our coast presents many challenges and a significant initiatives are under way to minimize the impacts from tsunami disasters through better preparedness and a more informed public.

TSUNAMI DISASTER IN INDONESIA

The world was made frighteningly more aware of the danger associated with population centres located in coastal areas by the devastating loss of live and setback of economic development due to the December 2004 tsunami disaster. Most of tsunamis that happen in Indonesia are caused by tectonic earthquakes along the subduction zone and active seismic area. As recorded, from 1600 – 2005 there were 107 tsunami events with 90% of them caused by tectonic earthquakes, 9 % by volcanic eruptions, and 1 % by landslides.

The most catastrophic tsunami was caused by the Sumatera Earthquakes 2004. The Sumatera Earthquake (26 December 2004) generated giant tidal waves which hit coastal areas not only in NAD (Nangroe Aceh Darussalam) and North Sumatera provinces of Indonesia, but also Malaysia, Srilangka, Thailand, India, Maldive, and Africa. Its run-ups were reported higher than 30m, and more than 300,000 lives were lost.

The 26 December 2004 Tsunami disaster in Indonesia was massive with record breaking earthquakes and tsunami waves. There was very short almost no time for alert and evacuation.

Other examples of tsunami include Flores (1992) with more than 1950 dead, East Java (1994) with 240 death, Biak (1996) with 107 death, and West Java (2006) with 668 death. The most famous catastrophic tsunami was caused by the eruption of Krakatau in 1883. The Krakatau Eruption generated giant tidal wave that hit coastal area and small islands around the Sunda Strait. Its run-ups were reported higher than 30m, and more than 36,000 lives were lost.

Some of Indonesian coastal areas that are routinely threatened by tsunami include west coast of Sumatra, South coast of Java, North and south coast of Nusa Tenggara, islands of Maluku, North coast of Papua, and most of Sulawesi (Celebes) coast. Table 1 shows tsunami cases in Indonesia from 1960-2005

Table 1. Tsunami cases in Indonesia during 1960-2005

NO	YEAR	EPICENTRUM	MAX RUN -UP (m)	TOTAL IMPACT (died/injured)	LOCATION
1.	1961	8,2 Lat. S; 122 Long.E.	NA	2 /6	NTT, Central Flores
2.	1964	5,8 Lat. N; 95,6 Long.E	NA	110/479	Sumatra
3.	1965	2,4 Lat.S; 126 Long.E	NA	71 died	Maluku, Seram, Sanana
4.	1967	3,7 Lat.S; 119,3 Long.E	NA	58/100	Tinambung South Sulawesi
5.	1968	0,7 Lat.N; 119,7Long.E	8 – 10	392 died	Tambo Central Sulawesi
6.	1969	3,1 Lat.S; 118,8 Long.E	10	64/97	Majene South Sulawesi
7.	1977	11,1Lat.S; 118,5Long.E	NA	316 died	NTB, Sumbawa Island
8.	1977	8 Lat.S; 125,3 Long.E	NA	2 /25	NTT, Flores, Atauro Island
9.	1979	8,4 Lat.S; 115,9 Long.E	NA	27/200	NTB,Sumbawa, Bali,Lombok
10.	1982	8,4 Lat.S; 123 Long.E	NA	13/400	NTT,Larantuka
11.	1987	8,4 Lat.S; 124,3 Long.E	NA	83/108	NTT, East Flores, P. Pantar
12.	1989	8,1 Lat.S; 125,1 Long.E	NA	7 died	NTT, P. Alor
13	1992	8,5 Lat.S; 121,9 Long.E	11,2 – 26,2	1952/2126	NTT,Flores, P. Babi
14.	1994	10,7Lat.S; 113,1Long.E	19,1	38/400	Banyuwangi East Java
15.	1996	1,1 Lat.S; 118,8 Long.E	NA	3/63	Palu Central Sulawesi
16.	1996	0,5 Lat.S; 136 Log.E	13,7	107 died	P. Biak, Irian Jaya
17.	1998	2,02 Lat.S; 124,87 Long.E	2,75	34 died	Tabuna Maliabu Maluku
18	2000	1,11 LS; 123,5 BT	3	4 died	Banggai, Central Sulawesi
19	2004	3,298 LU; 95,779 BT	34,5	>200.000 died	NAD, North Sumatera,
20	2005	2,065LU; 97,010BT	3,5	N/A	Nias North Sumatera
21	2006	9,4LS; 107,2BT	7,6	668	West Java (Tasikmalaya, Ciamis), Central Java (Cilacap, Kebumen), Yogyakarta

POLICIES, STRATEGIES, AND OPERATIONAL BASED COASTAL DISASTER IN THE COASTAL ZONE AND SMALL ISLANDS

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

The program also emphasized the implementation of Integrated Coastal Zone Management (ICZM). In ICZM we will try to make a balance between the natural resources, human utilization, and disaster mitigation aspects (Figure 1).

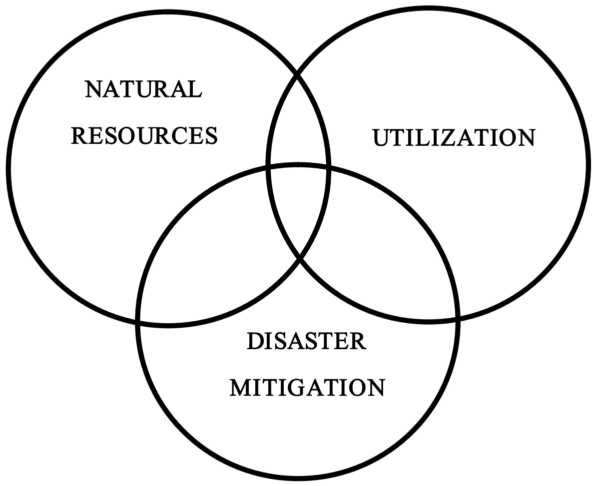

Figure 1 - The components of ICZM (Natural Resources, Human Utilization, and Coastal Disaster Mitigation)

Disaster mitigation is an important component that should be considered by all coastal planners. Economic development in coastal areas that has resulted from years of effort can disappear just in a minute with a disaster such as tsunami.

Furthermore, viewing disaster risks as mainly coming from a hazard has been expanded to include a community's vulnerability. The shift in risk reduction strategies has, in addition to being reactive - utilizing early warning, preparedness and emergency management tools, to becoming more proactive - utilizing awareness raising, risk management and risk reduction strategies. Both strategies, when combined, are expected to immensely reduce deaths, as well as social, economic and environmental losses. The framework put forth by UN-ISDR encompasses both with sustainable development as the overarching principle. It can now be appreciated that disaster risk reduction and other management programmes like integrated coastal management, poverty reduction and good governance have mutually supportive objectives. As with other programes, disaster risk reduction acknowledges both the social and physical dimensions of the risks, calls for a stronger political commitment and puts significant importance to changing human behavior and attitudes. Strategies are geared towards management of the physical environment (e.g., zoning, mangrove, coastal forest and habitat restoration); promotion of sustainable livelihood, poverty alleviation and promotion of public participation.

Directorate General for Marine, Coasts and Small Islands is responsible for integrating vertical and horizontal coastal management plans, and to support the sustainability of fisheries development. Based on the Marine Affairs and Fisheries Policies, Directorate General of Marine, Coasts and Small Islands will implement the four national programs. These programs were elaborated into 8 (eight) main activities that will be implemented in our annual plan. One of the activities is related to coastal disaster mitigation, and will be briefly explained in the following section.

Structural Counter Measures

Although, Indonesia has suffered from a large number of tsunami attacks since an ancient time, until now there is no effective countermeasures against the tsunami. Tsunami countermeasures using hard structure (seawall, breakwater, etc) is quite expensive for Indonesian. Yet, tsunami countermeasure using hard structure will arise aesthetical and environmental problems. Another countermeasure alternative is to evacuate the people who lives in the dangerous area, though it is very difficult to persuade them to live in the high land of safety from the tsunami. Most of the people who live in the neighbor of the coast earn their breads from fishery work, where 70 % of them are under the aleviation line. Therefore they complain of the inconvenient for their works because they have to transport for longer distance (Takayama, 1997). Even if they are forced to live in the high land, they will finally return to the previous convenient place near sea in spite of the danger of tsunami. Through the study conducted by International Organization for Migration (IOM) on March 2005, showed that most of the refugees (72%) want to return to the previous place. The attack of tsunami is very rare like once 100 years. It is comprehensible that they want to take the daily convenience in spite of the very rare danger of their lives. The other problem is in the time limitations for issuing tsunami warning. Since Indonesia is island country, the tsunami very often attack to the coast in very short time. So there is not enough time to warn the people.

Since the scale and hazard level of tsunami disaster depends on the population, the land usage, and countermeasures in the affected area, the effective combination of soft structural and non-structural countermeasures, which is suitable for the environment, social, and economic conditions in the region should be developed. Therefore, the countermeasures should be in harmony with daily lives of the people. Countermeasures using soft structure might be recommended in this case, such as mangrove green belt, coastal forest, and land use arrangement. Experimental survey shows that green belts and coastal forests significantly reduce the tsunami energy (Hiraishi, 2000; Harada and Imamura, 2003).

Structural counter measures using natural protection methods (soft structure), such as casuarinas Sp plantation/green belt along the coasts for tsunamis threat are being developed. This activity covers planting of casuarinas Sp (cemara laut), hibiscus tiliaceus (waru laut), and ketapang, .

This activity site is located on the coasts of Indonesia which experienced environmental degradation and are located in tsunami prone coastal areas. This site was originally a pristine forest that was then subjected to commercial cutting and conversion to settlement. These activities led to tsunami attack.

The overall goal of the activity is to establish the greenbelt to reduce the rate of tsunami impact. The degree or success of greenbelt in reducing the tsunami impact is not a straightforward case as it depends on a number of factors, e.g. the distance from the tsunami and the spatial extent and structure of greenbelt.

The concept that was developed in consultation with the community was to establish three lines of defence :

- Planting of greenbelt seedlings in coastal area, where they will be protected; and,

- Planting greenbelt seedlings in the beach.

Training was given to the community to educate them about how important of the forest is both in economic and ecological aspects, and in methods of planting greenbelt seedlings.

Greenbelt are important in reducing the impacts of the Indian Ocean tsunami based on preliminary environmental assessment, anecdotal evidence, and satellite photography before and after the tsunami event. For example, in the Aceh coastal area, houses protected by greenbelt did not suffer damage compared to those without greenbelt..

In the field of structural countermeasures, the Department on Marine and Fisheries had and is doing also activities in structural mitigation by building disaster friendly houses in forms of stage houses. All of the activities is being done through integrated coastal management.

Non-structural Counter Measures

Public awareness

Education, training and awareness building should be considered as an integral part of pre-disaster assessment and mitigation activities. The building of disaster awareness in the general population, starting with the individual, was essential in reducing casualties. Raising public awareness is achieved through various public campaign activities. Workshops are used as the main information dissemination media, covering different target groups such as decision makers and practitioners. The objective of this workshop are :

1. To increase public awareness and knowledge.
2. To strengthen links among key agencies who are responsible for the tsunami and disaster management.
3. To share experiences and expertise on tsunami disaster.
4. To introduce to the people the links between the scientific value of tsunami and national plan.
5. To evaluate the progress of the tsunami monitoring system.
6. To evaluate the knowledge of the people around the tsunami prone area to the disaster.

And to complement those efforts, for children education we have published a comic book entitled TSUNAMI. The comic was made based on the real story of local wisdom to evacuate people in Simelue island, NAD province of Indonesia. Simelue is small island located between $2^{o}15$"-$3^{o}00$" Latitude and $95^{o}40$"-$96^{o}35$" Longitude, approximately 130 km southwest of Sumatera island in Indian Ocean and about 50 km southeast of the earthquake Epicenter. Simelue was hit by the tsunami generated from Sumatera Earthquake 2004. The tsunami wave height varied between 2-15m. It took 5-10 minutes after the receding of sea levels until the first tsunami waves arrival followed by a second wave, which was the highest according to witnesses. All villages in Alafan district on the northeast coast and facing to the source of the earthquake and tsunami were destroyed. The second wave reached maximum height of 15m. At Labuhan Bakti villages on the south end of the island, the maximum wave height was measured at 4 m but also destroyed all the villages.

However the toll was only 7 people dead and 1 missing from a population of 78.000

people. There is a story that has always been told by the people of these islands about ‘SMONG” a local word referring to a tsunami that happened in 1907. They said if you feel a quake and the sea levels drop, you should immediately run to the hills. This story saved their lives on 26 December 2004. According to historical tsunami databases, there was a tsunami in this region in 1907.

There are many ways to Rome. That is also with mitigation, many ways can be done. It is very heavy to mitigate the whole tsunami prone coastal area in the vast Indonesia.

Prioritizing should be done for areas in the V-shape bay and river mouth because this area will be the most suffering when the tsunami hits. The tsunami generated by a submarine earthquake is not so big in its source, but it is amplified as it approaches to the shore. The Input and output tsunami energy flux should be balanced each other without energy loss and supply. Consequently, tsunami become bigger in a narrower bay. In bay of V-shape incident tsunami is also reflected from the shores of both sides and concentrates at the intermost part of the bay. Consequently, tsunami is amplified so much there. Well saying that the V-shaped bay is dangerous for the tsunami.

This condition is made more difficult with a mild slope topography with no protecting greenbelt such as cemara laut, waru, ketapang, mangrove or other sea forests.

Since 2003, the Ministry of Marine and Fisheries has been advocating and socializing tsunami in several areas, but still in the province level and district level with a not so significant effect for the community.

Starting in the year 2006, the public awareness extends to remote bay areas and river mouth with high population density and in prone to disaster, the method should be done more interestingly.

Because one of the alternative in being done through community based media i.e puppet show, live music or other local entertain. Public awareness by using their root culture can help them understand tsunami better. The Department of Marine and Fisheries had done outreach activities in several areas, formally through fisherman organization, religious meeting and through live music entertain.

Development of Strategic planning and Spatial Use Planning Models for Provinces, Districts, Cities and Small Islands.

The Spatial Use Planning Documents where the exist have never taken into account coastal disaster risks. Policy for coastal spatial use planning is being developed that will incorporate disaster mitigation measures. Strategic planning for tsunami hazard mitigation is also developed in several cities/districts. The strategic planning consists of the following element :

- Identifies issues
- Cralifies goals
- Sets detailed objectives
- Establish vision and mission
- Establish and action plan

Development of National Policy and Guidelines.
This main activities include:

- Formulating national guidelines for Integrated Coastal Zone Management
- Formulating national guideline for Coastal and Small Islands Hazards Mitigation.
- Formulating national guidelines for Coastal and Small Island Spatial Use Plan.
- Formulating Bill for 'Indonesian Coastal Management Act'.

The guidelines for Coastal and Small Islands hazards Mitigation are aimed at educating local governments, and communities in disaster management. The goals of the guideline are (i) to enhance mitigation efforts in coasts and small islands, (ii) to motivate participation of local governments, private sectors and communities in developing mitigation efforts, (iii) to promote public awareness of disaster mitigation.

The last but not the least is our new Marine and Coastal Resources Management Program that will apply Integrated Coastal Zone Management Policy in 15 Provinces and 43 Districts/Cities.

The background of doing the Marine and Coastal Resource Management Project is the increase of the ecosystem destruction and the weak organizational capacity in the local level to manage their coastal resources after the regional autonomy. The usage of the coastal resources has lead to the widening of the decrease of the ecosystem quality (i) integrated approach in planning and managing coastal zones, (ii) information and date as basis for decision making in managing resources, (iii) openness in the allocation of resources, and (iv) the involvement of local government and local community in managing resources. The pressure to the coastal resources is worsen by the monetary and economical crisis. Deppletion of coastal resources and the decrease of the quality of the marine flora and fauna has bad effects toward coastal community, especially the fishermen.

The MCRMP project is inserted to enhance the sustainability of the management of the coastal resources to preserve the sea's flora and fauna and develop social economy based on the frame of the regional autonomy in 15 provinces. It can be reach through: (i) strengthening the local capacity to plan and manage coastal and sea resources that sustain, (ii) increasing the availability and access of information and city planning data with quality and various data available for planning, (iii) enforce the law and regulation in managing the resources, and (iv) small scale investment to enhance socio economic and the quality of coastal areas in certain location

In drafting an integrated coastal management plan, issues in natural disaster is inserted in the national strategy of coastal management. Also the zoning plans is paying attention to disaster prone zones.

The ICZM process starts with the identification of management issues, goals and objectives (strategic plan), establishment of zonation plan, formulation of management plan, and establishment of action plan. The coastal environment is very sensitive and dynamic, therefore all development activities should be designed and planned based on the ICZM concept because they can alter the stability of fragile ecosystems, change the socio economic situation, and have negative impacts. The ICZM concept will include disaster mitigation in the hierarchial planning process. In this program, a risks and hazards thematic map including tsunami is being developed in 15 Provinces.

A hazard map was developed using technical data from the historical data and numerical forecasting of tsunami. All information was translated to the GIS platform, significantly refining areas which could easily be inundated and where specific households, in times of emergencies, need to be evacuated immediately. They now use GIS as an effective tool for upland and urban planning; and on the drawing board are plans for appropriate coastal zone development.

Tsunami hazard map shows the information necessary for residents to take refuge to high place or shelters alocated by local government. The tsunami hazard map usually indicates the inundation area, infrastructure, land use, evacuation route, and location of safety places. An example of tsunami hazard map is shown in Figure 5, which is for Padang city, West Sumatera Province. The map is given by one sheet of paper, of which shows the tsunami inundation state in whole city. The map has been completed after several discussions with stakeholders.

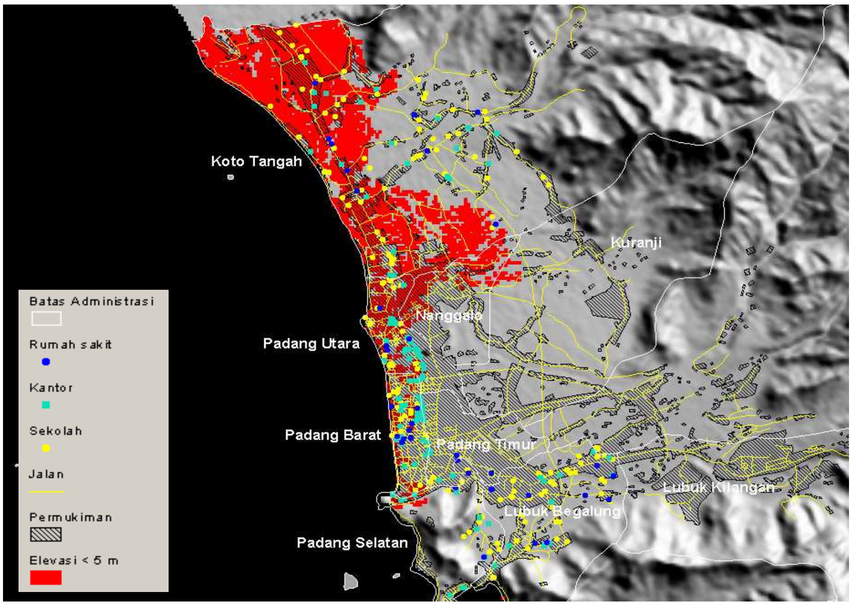

Figure 2 - Tsunami Hazard Map in Padang City, West Sumatera Province of Indonesia

Tsunami Research in Indonesia

Research is fundamental to tsunami disaster mitigation strategies. Recent research agendas have become multidisciplinary, which look not only at comprehensive knowledge about disaster, but also on their likely impacts to societies and how communities interact and find solutions given knowledge of potential disasters affecting them. Research data are important inputs that drive policy directions and significantly affects how governments formulate informed decisions. It also feeds into the other components of tsunami disaster mitigation such as continuing education, public awareness, advocacy and information management.

After the 1992 Flores Tsunami, scientists in Indonesia became involved actively in tsunami research. Several tsunami surveys and laboratory work have been done in Indonesia. An International Tsunami Survey Team with experts from Indonesia, USA, Japan, UK, Korea, and other countries surveyed the 1992 Flores Earthquake Tsunami, 1994 East Java Earthquake Tsunami, 1996 Irian Jaya Earthquake Tsunami, 2004 Sumatera Earthquake Tsunami and 2006 West Java Tsunami. They gathered data of maximum tsunami run-up heights, and distances, average run-up height and areas of inundation, flow pattern of run-up and run-down, eyewitness accounts, and observations of subsidence and uplift. Therefore, the tsunami data was well reported and documented for these events. They also performed investigation both by numerical modeling and physical modeling e.g. tsunami generation, propagation, and run-up; effect of mangrove greenbelt to reduce tsunami etc. Many agencies and universities in Indonesia have done tsunami research, including

- Bandung Institute of Technology (ITB), Bandung
- Sepuluh Nopember Institute of Technology (ITS), Surabaya
- Gadjah Mada University (UGM), Yogyakarta
- Hasanudin University (UNHAS), Makasar
- Agency for Meteorological and Geophysics (BMG)
- Geological Research Development Center (PPGL)
- Agency for the Assessment and Application of Technology (BPPT)
- Ministry of Public Work
- Ministry of Marine Affairs and Fisheries (MMAF)
- Ministry of Energy and Mineral Resources.

Establishment of Indonesia Tsunami Early-Warning System

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.

a. Strengthen the Indonesian TEWS to function as a regional TEWS for Indian Ocean.
b. Increasing Public awareness and preparedness in the disaster affected regions.
c. Encourage and facilitated the capacity building of national research institutions in disaster mitigation.

The basic principles of the Indonesian TEWS are as follows :

a. Issue warning within 5 minutes.
b. Real time, automatic, and compatible with national and international standard.
c. The components are : observation and integration of data; dissemination of information; and community preparedness.

MMAF is also involved in the working group for preparing TEWS. The team is coordinated by the Ministry of Research and Technology.

Integrated Coastal Zone Management Law, Indonesia's New Beginning

The effort to optimize the management of coastal and resources should be supported by regulation, especially those related to the setting of coastal and environmental environment. The support of a regulation is hoped to be able to harmonize inter sector and inter area policies to create equality between usage aspects and conservation aspects. In this regards, the Department of Marine and Fisheries has initiated to make a draft bill on coastal and small island management. The document that is ready is the white paper of the coastal management law and will be handed over to the parliament using their initiatives right.

The goal of the law is to:

(a) protect, conserve, rehabilitate, use and manage coastel resources based on sustainability; (b) Enhance the management of coastal resources through integration, coordination and delegating authority (c) Restore and enhance community based coastal resouce management and (d) law inforcement

The key of a successful sustainable management lies in the ability of the community and the local government to plan and use the coastal resources as needed. The community means that it is not totality the rights of the government but how they can represent the interest of the public. More widely, community are all primary stakeholders that is involved in the management process of resources as a system. Based on those premises, generally there are three focuses of the draft bill: (i) pushing communities and local government initiatives to manage their coastal resources based on sustainability and voluntarily; (ii) having a standard in coastal management in the nation wide level, such as the management of coral reef ecosystem and what is associated with it; and (iii) organizing mandatory management such as resolving conflict and law enforcement.

First, to certify the program and giving voluntary incentive, the draft will regulate the voluntary action of local government to follow or not follow the program. The initiative has to come from the local government or community, not top down. For interested areas, they can draft a coastal management plan and propose it to the Bappeda/Local Government of Fisheries and Marine to be certified in the district or provincial level. Those ho had been certified voluntarily to have the coastal management program will be given proper incentive. There are two main fund source for the incentive: MMAF has allocated part of its budget to implement the integrated Coastal and Small Island Management program. The government can use their national budget for a project revolving fund. The source of fund will relatively be small and not efficient as a government incentive for the local government.

Second, the norms of coastal, small island, and the management of the ecosystem is regulated by its own standard that is in the fourth part of the law draft. One of the management strategy is to give opportunity for damaged nature to rehabilitate naturally, and also preserving the other ecosystem. So that the damaged coral and seagrass due to destructive fishing can be rehabilitate, letting the fishes procreate in the area.

The third, enhancing effectiveness in managing coastal area should be done with the role of all stakeholders in conflict resolution, monitoring, supervision and law enforcement. Those who made destruction should be punished, law enforcement should be done consistently and correctly based on the existing regulation. Monitoring activities will push compliance and law enforcement openly, whereas the community is participating as 'reef watchers' and private sector will get the benefits by also funding the activities of monitoring and supervising and enforcement.

In the bill draft, articles on mitigation has been included, those physically and structurally.

The Sumatera 2004 earthquake and tsunami were a rude awakening from a long sleep in Indonesian coastal management systems. They shook us to the realization of how exposed we are to various disasters. They demonstrated how vulnerable Indonesia is to socio economic impacts of disasters, and that our capacity is simply to low to meet the ever increasing challenges. One element is the creation of a Integrated Coastal Zone Management Law which include tsunami and other coastal hazards.

The Indian Ocean tsunami will create a shift in coastal management paradigm. We have learnt coastal management principles from mid-latitude countries, but seldom in relation to natural hazards. In tropical coastal management, we must now include tsunamis and other coastal hazards. In relation to reducing the risks, integrated coastal management (ICM) needs to re-examine the role of the coastal ecosystems in relation to aquaculture and paddy cultivation, selective development of beaches and islands for tourism, appropriate design criteria and setback lines for tourist infrastructures, marine parks for the protection of coral reefs, etc.

It is true that the law alone would not prevent tsunamis from devastating our shores, prevent deaths, on halt economic damages. The law would – however - provide the legal foundation and legitimacy for our government to undertake the necessary steps to reduce the scale of disasters in coastal area, and thus to extend better protection to its people.

The coastal management bill would require among others: a) to enforce regular hazards identification, assessment, and monitoring; b) to mitigate the hazard of disasters; and c) to ensure the preparedness of community and emergency responders.

With regard to enforcement, the Bill set sanctions for violation of its regulations, it imposes penalties and punishments for faults by omission and by commission, and it even enables people to file lawsuits against government and other entities in relation to protection and disaster risk matters.

The Draft Bill were presented to the House's Plenary and, the House established a Special Commission to bring the draft bill into the political processes. It has been resolved that the Bill will be approved by the House, to be, referred to the Executive Branch, and to be signed off before the end of 2007.

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Effect of Tsunamis on the Eastern Coast of Thailand

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1. Introduction

The infrastructures in the Gulf of Thailand, for example, gas pipelines and platforms can be affected by tsunamis that are generated by earthquakes in the western part of the Philippines. In this study, the simulation of tsunamis in the Gulf of Thailand is conducted to obtain the arrival time, wave height, and current velocity.

2. Analytical Conditions

Six cases of fault ruptures are considered for earthquakes with magnitudes of 8.0, 8.5, and 9.0 corresponding to earthquake return periods of 63, 205, and 667 years, respectively. The linear shallow water wave theory in spherical coordinate system is used for tsunami simulation in the large area covering Southeast Asia while the nonlinear shallow water wave theory in Cartesian coordinate system is used for tsunami simulation in the Gulf of Thailand.

3. Analytical Results

From the simulation of the tsunami generated by the Mw 9 earthquake, the tsunami arrives Narathiwat in 11 hrs, Trat in 15 hrs, Prachuapkhirikhan in 16.5 hrs, Phetchaburi in 19 hrs, and Bangkok in 20 hrs. It is found that the arrival time is slightly affected by the earthquake magnitude.

For an earthquake magnitude of 9.0, the tsunami height is 0.97 m at a sea depth of 4.4 m and the current velocity is 0.27 m/s at a sea depth of 15.6 m in Narathiwat. And the tsunami height is 0.38 m at a sea depth of 5.4 m and the current velocity is 0.15 m/s at a sea depth of 17.5 m in Trat. At the central coast of Vietnam, the tsunami height is 3.8 m and the current velocity is 1.7 m/s at a sea depth of 20 m. The large difference of tsunami height and current velocity is due to the diffraction of waves into the Gulf of Thailand.

The effect of earthquake magnitudes on tsunami height and current velocity is investigated (Figure 1). As the earthquake magnitude increases from 8.0 to 8.5, the tsunami height increases by 3 times and the current velocity increases by 2 times. And when the earthquake magnitude increases from 8.5 to 9.0, the tsunami height and the current velocity increases by 2 times. It is obvious that the earthquake magnitude significantly affects tsunami height and current velocity.

4. Conclusions

The tsunami arrival time, wave height, and current velocity are analyzed in this study. The Gulf of Thailand is less affected by the tsunamis generated by fault ruptures off-shore the Philippines. The effect is lessened by the diffraction of tsunamis at the southern part of Vietnam. However, lifeline facilities in the Gulf of Thailand should be well prepared for the disaster.

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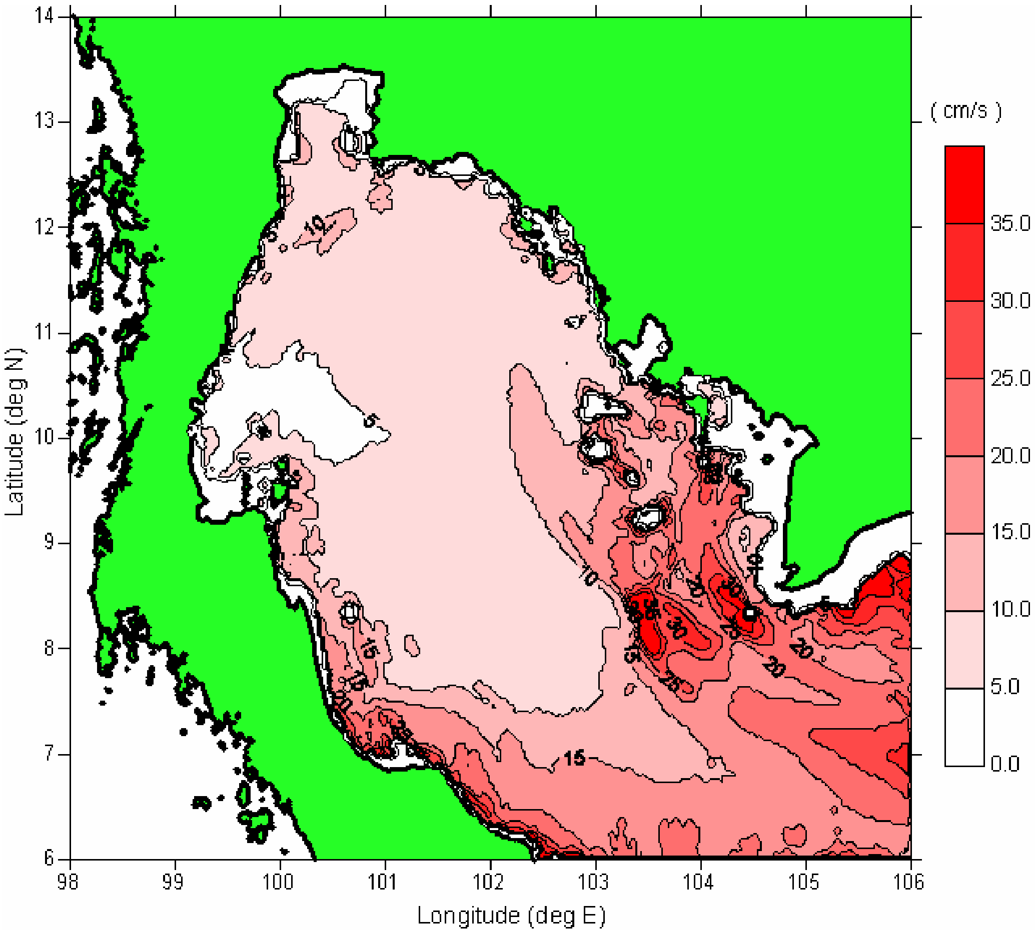

Figure 1: Current velocity from the Mw 9 earthquake

EFFECTS OF TSUNAMIS ON MOORED & MANUEVERING SHIPS

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1. Introduction

The Boxing Day Tsunami of 2004 impacted at least two major commercial harbors, namely Colombo in Sri Lanka and Chennai in India. While the impacts of the tsunami on the ports were not significant, the event highlighted the threat that tsunamis pose to moored and maneuvering ships. Specifically, maneuvering ships in both harbors were overpowered by velocities produced by the tsunami and ships were broken from their moorings at Chennai (Figure 1). The author has been involved in evaluating the potential impacts of tsunami events on the Ports of Los Angeles and Long Beach in Southern California, USA. This paper presents methods for examining the impact of tsunamis on moored/maneuvering vessels.

Figure 1- Moored Vessel During Tsunami, Port of Chennai, India

The approach taken here is to use harbor hydrodynamic results to force mooring and maneuvering dynamic models. The TERMSIM model was used to simulate mooring dynamics, the SHIPMA model, maneuvering dynamics.

2. Analysis

Moored vessels are subject to three physical phenomena during a tsunami: (1) vertical lifting of the vessel due to rise in water level (VWL) which cannot be accommodated by typical mooring line arrangements, (2) horizontal forces due to accelerated currents (HAC) which can be quasi-static or dynamic, and (3) dynamic horizontal forces from leading tsunami waves (HLW). While HLW loads can be approximated by the HAC approach, more research is necessary to fully develop the HLW case. An example static VWL analysis of the mooring arrangement in Figure 2 is presented below for a typical Post-Panamax container ship in Figure 3 which shows lines will part with 3-4 m tsunami heights.

Dykstra et al (2006) report tsunami modeling results for the Port of Long Beach and Los Angeles. Figure 4 shows, for a hypothesized Palos Verde landslide scenario with an approximate return period 10,000 years, that the maximum tsunami height at any berth location in the port complex is 3m or less with the exception of a very isolated area. Thus a very small portion of the berths would be vulnerable to excessive VWL.

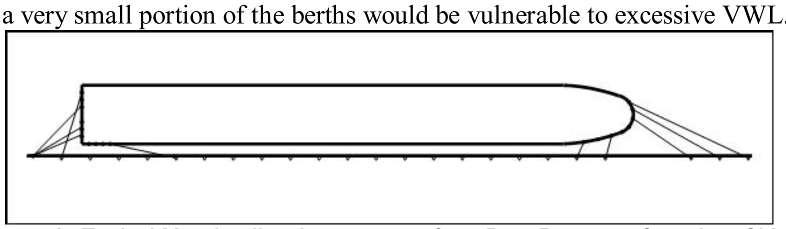

Figure 2. Typical Mooring line Arrangement for a Post-Panamax Container Ship.

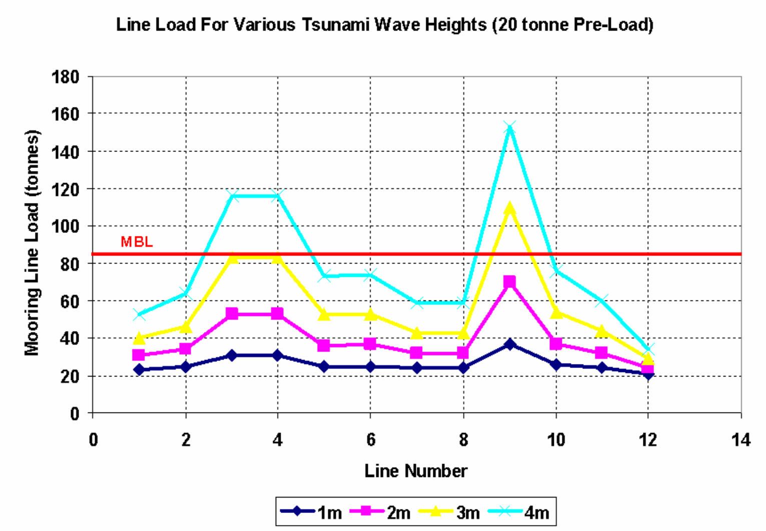

Figure 3. Mooring Line Analysis For Various Tsunami Heights (VWL).

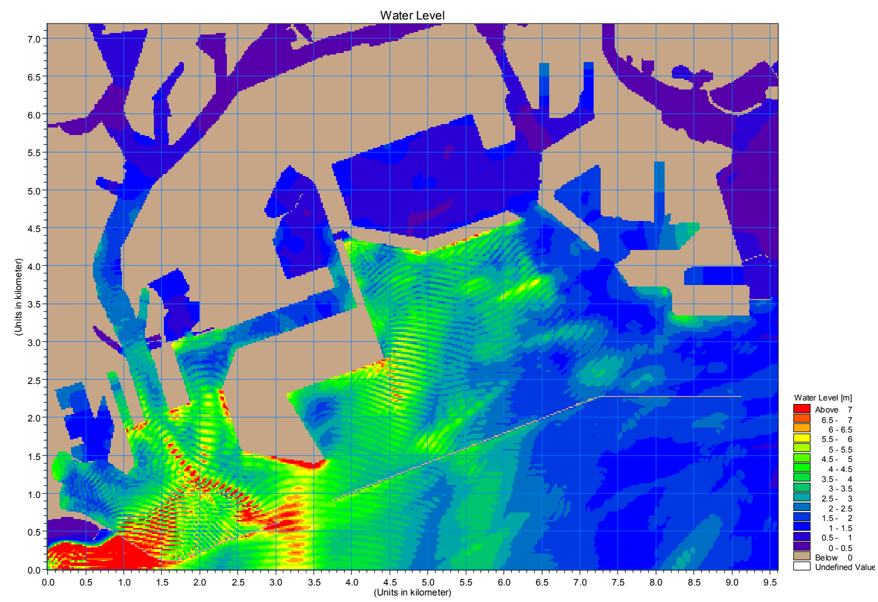

Figure 14. Tsunami Height Within the Ports of Los Angeles and Long Beach For A Hypothetical Event.

Ship motions were computed using the TERMSIM model developed by MARIN. While not developed for tsunami analysis (it cannot simulate a rapid rise in water level), it can perform a full dynamic analysis of the tsunami-induced currents. The same vessel/mooring arrangement used above was modeled here. The hypothetical tsunami currents were not sufficient to part the mooring lines.

Experience indicates that accelerated tsunami-induced currents pose very considerable threat to maneuvering vessels as well as vessels that have broken from their moorings. The SHIPMA maneuvering model developed by MARIN was used to demonstrate the impact of tsunami currents. For the case of LA/LB, tsunami currents were not sufficient to cause a vessel passing through one of the harbor entrances to lose significant control.

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

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In many researches focusing on the mega-thrust earthquakes around the Nankai Trough in southwestern Japan, the structural researches using refractions and reflections seismic has succeeded to image the key structures to understand recurrences of mega-thrust earthquakes around the Nankai Trough. Moreover, results of earthquake recurrence cycle simulation show that the first ruptures seems to occurred around the Tonankai earthquake rupture zone in each recurrence cycle, and the clear segment boundary between the Tonankai and Nankai earthquake rupture zones off the Kii peninsula was analyzed using tsunami data.

The 1944 Tonankai and the 1946 Nankai earthquakes, each hypocenter was located off the Kii peninsula. So, imaged irregular structures seem to be as key structures at the segment boundary between the Tonankai and Nankai earthquake rupture zone. By the advanced simulation study of recurrence cycles of mega-thrust earthquakes around the Nankai Trough, these irregular structures seem to act as a controller of recurrence cycle and pattern of mega-thrust earthquakes in the Nankaki Trough.

Based on these researches, we proposed and have been starting to deploy the dense ocean floor observatory network system equipped with multi-kinds of sensors such as seismometers, pressure gauges etc., focusing on the understanding of crustal activities off Kii peninsula including the Tonankai/Nankai earthquake rupture zones.

This observatory system will be the one of most advanced scientific tools to understand the mega-thrust earthquakes around the Nankai Trough.

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 earthquakes and tsunamis.

Especially, these are most important functions for disaster reduction of 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

4) Understanding of the interaction between the crust and upper mantle around subduction zone. In this paper, we will explain the advanced dense ocean floor observatory network system in detail and emphasize the purpose and importance of this system.

In this presentation, we would like to introduce this advanced ocean floor network system in detail.

TSUNAMI WARNING SERVICE IN JAPAN

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1. Introduction

Japan is located in the circum-Pacific tectonic zone where seismic activity is extremely high. More than ten percent of earthquakes in the world take place in and around Japan. Japan, surrounded by seas, is one of the most tsunami-prone countries in the world, and has suffered from serious tsunami disasters. Considering such circumstances, the Japan Meteorological Agency (JMA) initiated tsunami warning service for local tsunamis in 1952, and that for distant tsunamis in 1962.

2. Procedure for issuance of tsunami warring/advisory

JMA continuously monitors seismic activity in and around Japan. When a large earthquake occurs in/around Japan, JMA immediately determines the hypocenter and the magnitude of the earthquake. If the earthquake occurs in ocean area with tsunamigenic potential, JMA conducts the tsunami forecast operation using the database containing tsunami amplitude and travel time constructed by numerical simulation. Tsunami forecasts are categorized into two: Tsunami Warning and Tsunami Advisory. Tsunami Warning is divided into two grades: Major Tsunami and Tsunami, depending on the estimated amplitude of the tsunami as shown in Table 1. JMA issues Warnings and/or Advisories for 66 coastal regions which cover all of coastal areas of the country. These tsunami forecasts contain the estimated maximum tsunami amplitude and estimated tsunami arrival time. JMA provides Warnings and/or Advisories for the national and local authorities for disaster prevention and broadcasting stations. Governors of municipalities are responsible for giving their residents directions to evacuate from tsunami hazardous areas. Warnings and/or Advisories are cancelled when JMA concludes that the dangerous situation is over, namely, when the observed amplitude of the tsunami diminishes and becomes lower.

When a large earthquake occurs distant from Japan, JMA also determines the hypocenter and magnitude using seismic data from global seismological observation network as well as domestic ones, and exchanges information on the earthquake with PTWC and USGS. In case there is a possibility of tsunami generation, JMA immediately conducts the tsunami forecast operation in the same manner and criteria as the local tsunami procedure.

Table 1: Types of Tsunami Forecast Bulletin

Tsunami Forecast Bulletin		Value of Tsunami Amplitude to be issued
Tsunami Warning	Major Tsunami	"3m", "4m", "6m", "8m", "over 10m"
	Tsunami	"1m", "2m"
Tsunami Advisory	Tsunami Attention	"0.5m"

(Tsunami amplitude is measured from the ordinary tide levels)

3. Application of advanced technologies for tsunami warning

For advance actions to mitigate damages caused by strong motions of earthquakes, JMA has built the "Earthquake Early Warning" system (EEW system), which quickly determines the hypocenter and the magnitude from the seismic waveform data observed at the seismic stations near the hypocenter, and transmits warning with estimated seismic intensity and arrival time of strong ground motion at each region before the strong ground motion arrives as possible. This technique is also expected to contribute to reducing elapsed time for the issuance of tsunami warning. JMA applies EEW technique to tsunami warning to be issued in 2 minutes at earliest after the occurrence of the earthquake.

Previously it was technically difficult to derive earthquake mechanisms quickly after occurrence of an earthquake. Therefore, JMA assumed reverse faults with dip angle of 45 degree, which generate tsunami most efficiently, in order to make the tsunami database for local tsunami warning operation to ensure disaster prevention. Now, JMA developed a new system to calculate Centroid Moment Tensor (CMT) solution automatically about 10 minutes after an earthquake occurrence in order to use them for tsunami forecast. However, it is not available for the first warning, which is issued 3 to 5 minutes after the earthquake occurrence. Therefore, JMA will apply it to re-evaluating the grade of the warning based on the derived CMT solution. JMA will start to use the CMT solutions for tsunami warning operation soon.

4. Northwest Pacific Tsunami Advisory and Tsunami Watch Information for the Indian Ocean

In the Pacific Ocean region, the earthquake of magnitude 9.5 occurred near Chile in 1960. The tsunami generated by the earthquake caused disasters to many countries around the Pacific Ocean. As a lesson of the tsunami disasters, International Coordination Group for Tsunami Warning System in the Pacific (IGC/ITSU), which was renamed to Intergovernmental Coordination Group for the Pacific Ocean Tsunami Warning and Mitigation System (ICG/PTWS) in 2005, was established in 1965. Pacific Tsunami Warning Center at Hawaii is responsible for the provision of tsunami warning for the whole Pacific region to member states of ICG/PTWS. In addition to that, establishment of the regional tsunami warning center has been discussed by ICG/ITSU since 1978. JMA established the Northwest Pacific Tsunami Advisory Center (NWPTAC) as the regional center in the Northwest Pacific region and started to provide tsunami advisory to countries around the Northwest Pacific Ocean in March 2005. The 2004 Sumatra earthquake and the tsunami caused unprecedented disasters in the Indian Ocean region. Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWS) as well as the Pacific Ocean region was established in 2005 and discussion for establishment of tsunami warning system has been continuing. Therefore, JMA has been providing countries around the Indian Ocean with Tsunami Watch Information (TWI) on an interim basis since 2005, and will continue until tsunami warning system will be fully operated in the Indian Ocean region in order not to repeat such disasters.

When an earthquake of magnitude 6.5 or greater occurs in the coverage area, NWPTA or TWI is provided to relevant countries in 20 to 30 minutes. NWPTA and TWI contain source parameters, evaluation of tsunamigenic potential and estimated tsunami arrival times or travel times. Moreover, information with regard to estimated tsunami heights is also provided in NWPTA. When a tsunami is actually observed at tidal stations, information on tsunami observations is subsequently provided.

HYDRAULIC CHARACTERISTICS OF BUOYANCY-DRIVEN VERTICAL PILING BREAKWATER

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1. Introduction

A breakwater must protect a harbor from rough sea damage while allowing ships to moor in safety. But it has been very difficult to guarantee calm water in the harbor because the entry route of fairway is always open. So, new innovative breakwater is developed, that is always at the bottom of the sea, and surfaces at times of high waves, storm surges and tsunamis, as needed to protect the inside of the harbor.

The new breakwater is a wall structure that is formed by upper and lower steel piles (see Figure 1). There is the slit between two piles structurally.

Compressed air is supplied from the bottom of the lower pile into the upper pile. The upper pile rises to the surface because of the relative increase in buoyancy. When air is expelled from the upper pile, its buoyancy drops causing the upper pile to sink back into its resting position.

This research investigates hydraulic characteristics of this breakwater by using the large-scale experiments and numerical simulations and reports the development project.

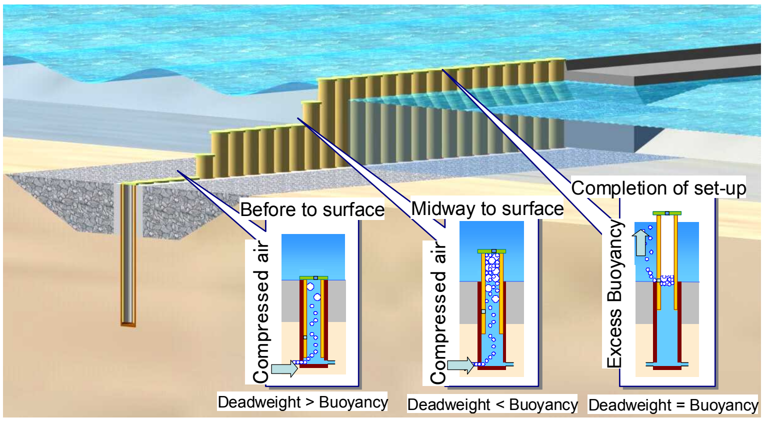


Figure 1 - Concept of the new breakwater

2. LARGE SCALE EXPERIMETS

The 1/5 model scale tests was conducted in the Large Hydro-Geo Flume. This wave flume is 184m long, 12m deep and 3.5m wide. The stroke of this wave flume is 14m. 7 Steal piles, which diameter is 40cm, were set up in the flume (see Photo 1).

The pressures on the piles, velocity in the slit and height of waves are measured while changing the distance of the opening. The wave period is changed from 3.6s to 26.8s and the wave height is 0.4m and 0.8m. Figure 2 shows the transmission coefficient of one case. The result shows that the transmission coefficient is 0.4 to 0.6 when the ratio of the opening distance to diameter and indicates that the coefficient is not depend at the wave period. Pressures on the piles and velocity in the slit are also measured.

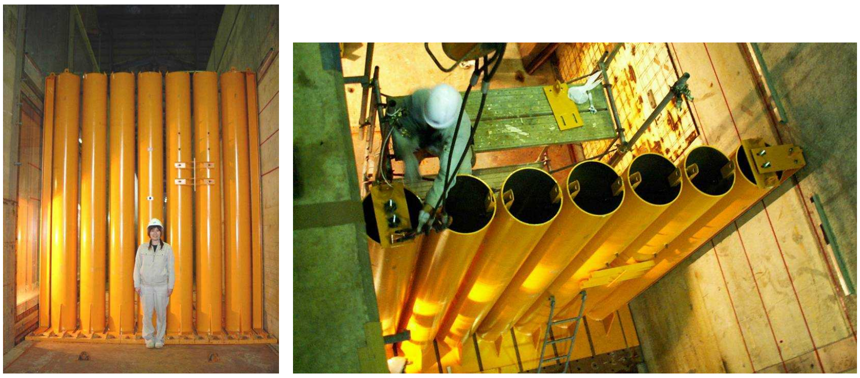


Photo 1 – Experimental set up

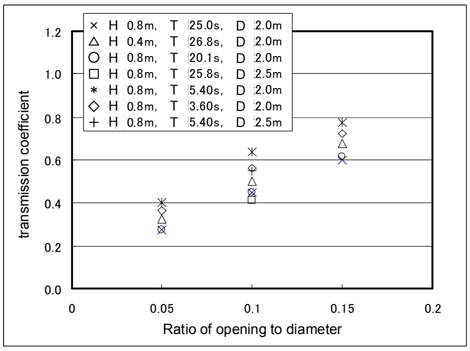
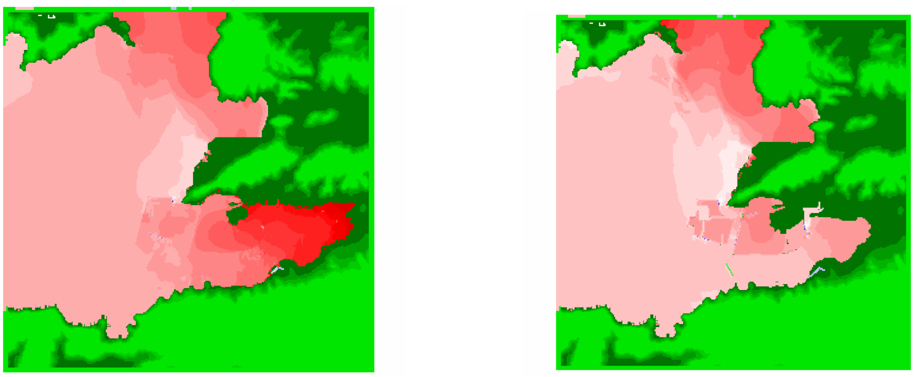


Figure 2 - Results of transmission coefficient

3. NUMERICAL SIMIULATIONS

3 dimensional Navier-Stokes Numerical simulator is developed to evaluate the velocity and pressure on the piles. The results of this simulation are good agreement with the results of experiments.

By using these results, this simulator applied to the locale with lager grid size. Figure 3 shows the comparison of Tsunami height in the Wakayama shimotsu port due to Tokai, Tonankai and Nankai earthquakes. The right hand side figure is installed the buoyancy-driven vertical piling breakwater at the mouse of the port. This result shows that this new breakwater decreases Tsunami height and inundation area. This breakwater delays the inundation time for five minutes in this case.



without new breakwater with new breakwater

Figure 3 - Comparison of Tsunami height

NUMERICAL SIMULATION OF INDIAN OCEAN TSUNAMI USING LINEAR AND NONLINEAR DISPERSIVE WAVE THEORY

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1. Introduction

In tsunami propagation over a long distance on a deep sea, the frequency dispersion effect plays an important role in the wave transformation. In addition, if the wave propagates on a long shallow shelf, soliton waves are generated by the interaction between nonlinearity and dispersion effect. The authors (2006) had performed the numerical simulation of the Indian Ocean Tsunami, and made clear that the frequency dispersion effect was appeared significantly in the southwest direction of the tsunami source. This conclusion suggests that the dispersion effect is not important in the numerical simulation of the Indian Ocean tsunami in Sri Lanka. However, the simulation of the previous work had ended at 6 hours after the earthquake, although the reflected wave from the Maldives attacked Sri Lanka 5 hours after the earthquake. In the present paper, the new simulation, in which the reproduction time is set as 8 hours, is conducted to check the contribution of the dispersion effect on the reflected waves from the Maldives. In addition, the effect of the nonlinear dispersion is examined in the shallow water area in the southwest coast of Sri Lanka.

2. Numerical Method and Condition

The numerical procedure is same as the previous work (Shigihara and Fujima, 2006). The initial condition and the bathymetry data are same as those used by Tomita and Honda (2006). However, the reproduction time is set as 8 hours.

3. Results and Discussions

The time history of water surface elevation at h=10m point is recorded at some locations along the southwest coast of Sri Lank drawn in Figure 1 (P1 to P6). The result at P1 and P4 is shown in Figure 2 and 3, respectively.

At P4, the leading wave is the maximum wave, and the third wave is the maximum at A1. This difference may be caused by the topography effect. In addition, at P4, the waves after 4 hours from the earthquake have the short wave period; however the long-period waves are appeared after 6 hours after the earthquake at P1. The long-period waves 6 hours after the earthquake recorded at P1 are the reflected waves from the Maldives. These waves propagated the long distance, although the numerical result by the dispersive wave theory is very similar to that by the long wave (non-dispersive) theory. Thus, it is concluded that the dispersion effect is not important in the numerical simulation of the Indian Ocean tsunami in Sri Lanka, even if the reflected waves from the Maldives have an important role in the tsunami waveform in Sri Lanka.

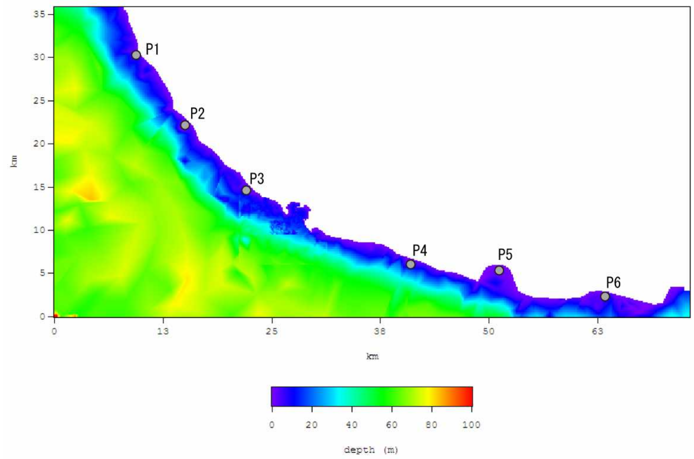

Figure 1: Output Point and bathymetry off the southwest coast of Sri Lanka.

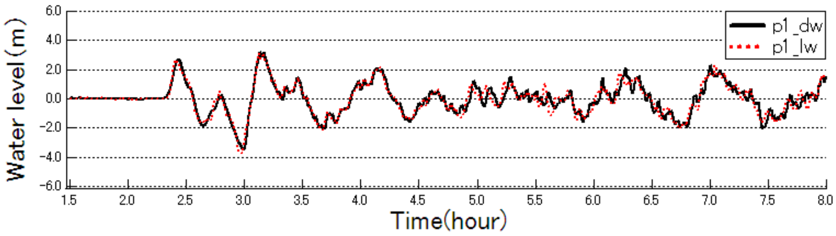

Figure 2: Water surface elevation at P1.

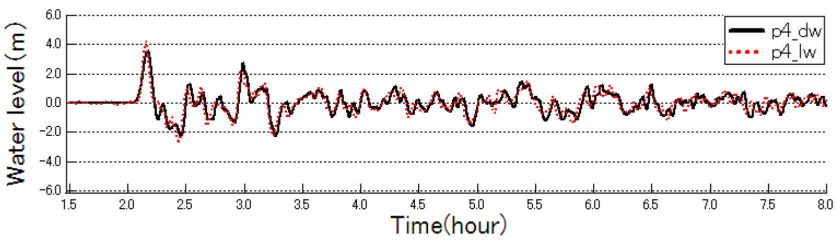

Figure 3: Water surface elevation at P4.

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STRUCTURE-STRUCTURE IMPACT MODELING FOR TSUNAMI DEBRIS FLOW

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Abstract

In a large tsunami, sea or land-based structures such as boats, barges and vehicles may become debris that flow with the tsunami in land. Video footages from the 2004 Indian Ocean Tsunami clearly showed that potential damages on coastal structures such as resort hotel buildings and highway bridges close to the shoreline due to debris flow may be significant. Additional evidence include photographs of boats, barges and vehicles found kilometers in land in Indonesia, India, Sri Lanka and Thailand. The large amount of debris (boats and vehicles) on Okushiri Island after the 1993 tsunami is but another collaboration of debris flow occurrence. Thus, in predicting tsunami effects tsunami on coastal structures, it is important to take into account the associated debris flow and impact of large (flexible) objects. This paper focuses on the modeling of structure-structure impact behavior in free-surface flow and addresses some issues including:

- Interaction between boundary layers around the structures for both low and high Re flows
- Cavitation occurrence in high Re flow
- Free surface interaction with structural boundary layers
- Free surface interact with cavitation

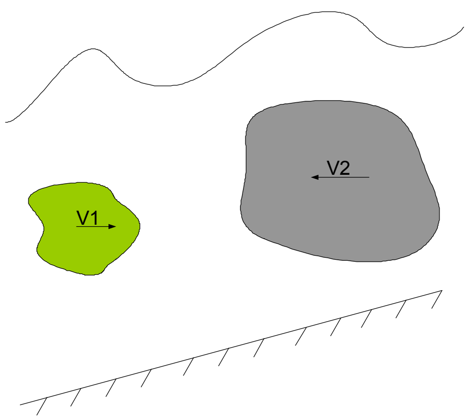

Fig.1. Basic model for Structure-Structure Impact

The Basic model, shown in Fig.1, represents two flexible structures moving in opposite direction in the fluid medium with free surface and bottom wall. The fluid domain can be described by the Navier-Stokes equation (NSE) or Reynolds-Averaged Navier-Stokes (RANS) equation with k-epsilon closure model. The near wall region of the flow containing the structures can be sub-divided into three different regions. Due to the complexity of the buffer layer and defect layer, there is currently no general method for applying a turbulence model with the first computational interior node located in these layers. Instead, the common practice is to place the first near-wall node either in the viscous sub-layer (Low-Reynolds-Number (LRN) models), or in the inertial sub-layer (High-Reynolds-Number (HRN) models). For the LRN turbulence models, which use a refined mesh close to the wall, damping functions are used to solve the whole domain down to the solid wall. For the HRN turbulence models, wall functions are used to bridge the near wall region. When two structures are far away, the computation for a point located in the fluid can be handled normally. However, when these two structures approaches and become very close to each other, their boundary layers will overlap. After the two structures impact each other, they will become separated and a reversed flow will happen. When two structures approach with a high relative speed (High Re), the boundary layer near the surface of the two structures is turbulence. Similarly with the Low Re case, fluid “jets” in both orthogonal directions happens and singular point appears during approach with a fast relative velocity. When two structures approach and become very close to each other, their boundary layers will overlap. After two structures impact each other, they will be separated immediately and a reversed jet flow will happen. If the separation speed is high enough, cavitations may occur in their wake regions because of negative pressure. When free surface exist, the pressure on the surface will be constant. As two structures approach with a high relative speed, the fluid jet will flow in a preferred direction, i.e., the free surface direction, and a dome will occur in the free surface because of the jet. When the two structures are very close to the free surface, the turbulent boundary layer maybe interacted with the free surface. As two structures separate in a high speed, the free surface will be pulled downward because of negative pressure. When cavitation occurs, the free surface will be interacted with the bubbles floating up. The free surface will be changed. When implementing the computation, the following questions need to be resolved:

- Which normal distance is valid when using damping functions?
- When the solid is very close to the wall, i.e., when two boundary layers overlap, how will the boundary effects be determined (calculate)?
- After the contact elements are generated in the numerical code, can the boundary layer be neglected?
- How will the cavity interacting with free surface be modeled?

These questions will be addressed in future follow up papers.

Reference:

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Numerical Model for Estimation of Damages due to Tsunami

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1. Introduction

Tsunami damage is usually estimated by computing the inundated area. However, the out-flow of vehicles, drifting of ships, drifting objects colliding with buildings and the damage of buildings by the tsunami's flow pressure, all cause serious damage to the society. Therefore, to make an accurate plan for damage reduction it is useful to utilize a numerical model which can estimate various types of damage due to tsunami. This report shows tsunami simulation models which also consider energy in the water level, its velocity and results of simulation computed for Sendai port and Kesennuma Bay.

2. Study flow and Digitizing of Topography

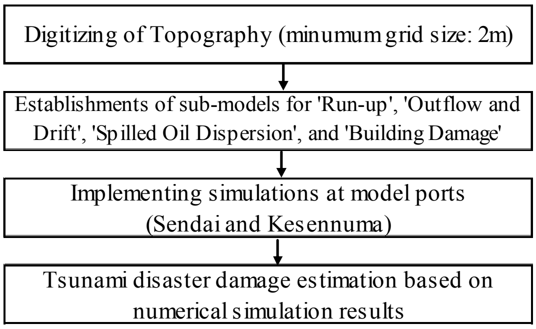


Figure 1 : Study flow

Figure 1 shows the flow of this study. For the calculation of tsunami propagation, special grid size is set into 6 zones (1,350m to 2m), with grid size decreasing as the tsunami approaches from the origin to the objective port. The 'Run-up' sub-model mainly covers the land with 2m grid, in order to precisely consider the topography and scale of building.

3. Numerical Simulation Model

The model is composed of 4 sub-models;

1) 'Run-up' sub-model

This sub-model is based on the two-dimensional non-linear long wave theory and the Leap-Frog method is used for the time differential scheme.

2) 'Outflow and Drift' sub-model

This sub-model is based on an advection-diffusion model considering drag force and the additional mass of drifting objects, i.e. automobiles, timber, containers, vessels and aqua cultural floats, following Goto (1983).

3) 'Spilled Oil Dispersion' sub-model

In this simulation, it is assumed that storage tanks are damaged by the quake causing oil spill in the spilled-oil protection compound. And then the spilled oil is dispersed by the tsunami which overflows the barrier into the compound. The oil diffusion is simulated by the same method as that of Goto(1985).

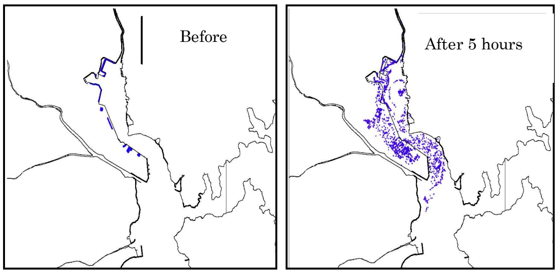
4) 'Building Damage' sub-model

Damage of building is estimated by comparing building strength with drag force based with estimated inundation based on the research by Iizuka and Matsutomi (2000).

4. Simulation Results

Major results of simulations are as follows;

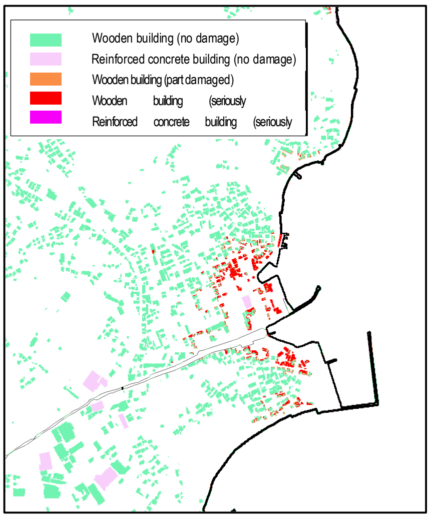
1) 'Outflow and Drift' simulation results



In Kesennuma Bay many of vehicles, vessels and aquacultural floats flow out in 5 hours after the earthquake as shown in Figure 2, while at Sendai port no container or timber out flow from the land side, except for some vehicles, due to the limited depth of inundation.

Figure 2: Drift of vehicles in Kesennuma Bay

2) 'Building Damage' simulation results



At Sendai port, buildings within the inundated area are all RC structures and the depth of water is limited. No destruction of buildings occurred.

In Kesennuma Bay area many buildings are destroyed as shown in Figure 3 because there are many wooden buildings and water depth of inundation is 3 meters.

3) 'Oil Dispersion' simulation results

At Sendai port, the incoming tsunami did not overflow the oil protection compound, thus no oil dispersed into the sea.

However, at Kesennuma port, the tsunami overtopped the oil protection compound and the spilt oil dispersed outside the compound barrier.

Figure 3: Building destruction simulation at Kesennuma port

5. Conclusion

In this study, run-up height on land, water depth and velocities are used as parameters to calculate the tsunami's energy. The model revealed not only of the inundation, but also damage to buildings as well as outflow and drift of materials on land in addition to vessels in the port. Therefore, this simulation model is useful for predicting probable damages of tsunamis and for formulating effective countermeasures.

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DETERMINATION OF PERIODS OF FREE OSCILLATIONS FOR THE IRREGULAR SHAPED BASINS BY NUMERICAL TECHNIQUE

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1. Introduction

The subject of oscillation inside harbors, bays, or any other semi-enclosed or closed basins is a problem that can have direct influence on the management of harbors, shipping and coastal utilization in the case of tsunami events. The waves entering the basins cause water surface fluctuations dependent on the characteristics of the incoming waves and the boundary conditions of the basins. Short period waves entering continuously to the small basins such as harbors in general may generate abnormal wave conditions and cause unexpected damages. Response of the basin, together with the wave characteristics may result in amplification of these waves and in higher surface fluctuations. Response of the basin depends on reflection and energy dissipation characteristics of the boundaries and the geometric properties of the basin. The wave periods that result in higher water surface fluctuations are the periods of oscillation of that basin. Periods of free oscillation depend on the dimensions of the basin; larger basins have higher periods of oscillation.

Resonance, when occurs, may cause difficulties in harbor operations, result in crashing of small crafts in marinas, and give significant damage to the coastal structures in the basin. If the basin is larger such as bays or enclosed seas, then the periods of free oscillations will be larger and may result with higher amplitudes. The sudden energy transfer to the sea related to the fault break or submarine and/or subaerial landslides may generate tsunamis and propagate towards shore and cause disturbances inside the semi-enclosed basins for a long time. The amplitudes of the disturbances are also dependent on the amplitude of the waves and the characteristics (shape, depth and boundary conditions) of the basins.

Long waves, especially tsunamis, may have highly destructive effects on coastal structure and mooring crafts. Their effects become much higher and may continue longer duration when the wave period coincides with the period of free oscillation of the basin, harbor or bay.

Scope of this study is to investigate the behavior of the basins under the disturbances caused by long waves, and to develop a short cut numerical method for determining the periods of free oscillations of the irregular shaped enclosed or semi-enclosed large basins and/or bays.

The numerical method used in this study has been given in Yalçıner et. al. (1993, 1995). In the method application, a single wave is inputted to the basin as an initial impulse, and the propagation of this wave in the basin is computed by using the numerical method solving the nonlinear form of wave equations. The time histories of water surface fluctuations at different locations due to propagation of the waves in relation to the initial impulse are stored and analyzed by the Fourier Transform Technique and energy spectrum curves for each location are obtained. The periods of free oscillations are determined from the peaks of the spectrum curves. The method is tested by using the regular geometrical shaped basins; i) rectangular shaped basin with two different horizontal and inclined sea bottom profiles ii) and a cylindrical shaped flat bottom basin with different water depths. The computed periods of free oscillations are compared with the theoretical values. The effect of the bathymetry and the characteristics of the numerical method on the computed frequencies of the modes of free oscillations are also discussed.

The method is also applied to the problem of determination of free oscillations for the earthquake generated waves in the irregular shaped basins of uneven bathymetry such as the sea of Marmara and Izmit bay. The results obtained for these basins are presented and discussed.

2. Method

The method used in this study was tested by Çakıroğlu (1997), for regular shaped basins whose resonance periods are known analytically. The procedure to determine the periods of free oscillation of an arbitrary basin is straight forward by this method. Long wave equations for shallow water describe the motion of long waves inside the basin. These equations can be solved using the appropriate boundary conditions with the existence of a single wave as the external force. For duration of time, the solution can be applied to determine the water surface elevation fluctuations for selected locations of the basin. Fourier Transformation Technique is used to obtain the frequency spectrum curve for each location of the basin. Peak values of the frequency spectrum curve will show the periods of free oscillation of the selected location. The periods of free oscillations of the whole basin is obtained by examining and comparing the occurrences of each period of oscillation.

3. Application to the sea of Marmara

Several runs are carried out for the test, by using two different initial impulses. In the first application, the impulse having the crest along East-West direction, which makes the wave propagation along North-South direction. In the second application, the impulse having the crest along North-South direction, which makes the wave propagation along East-West direction.

The periods where the spectrum curve shows peaks are listed for each location for each test as the periods of free oscillations of that location. The most common periods are selected to represent the periods of free oscillations. It was found that 218.min, 72. min., 36min., 31min, 26min., 15min., 12min., 105min., 9min. are some of the periods of free oscillations of the sea of Marmara. The accuracy of the results of any numerical method is dependent on the grid spacing, size of time step, and the duration of the simulation. In this method for more accurate results, it is recommended that the grid spacing and time step in the simulation must be sufficiently small, and the simulation duration must be sufficiently long.

Acknowledgements

This research is supported by INTAS (03-4286) and RFBR (05-05-64265) for Russian author. METU Basic Research Fund is acknowledged by its support to Turkish author for developing and application of the model with the research number AFP-2001-03-03-06. The depth data is developed by TUBITAK-YDABCAG-60 Basic Research Grant in Turkey. The sincere gratitudes are also extended to both Prof. Fumihiko Imamura and Prof. Costas E. Synolakis for their long term endless collaboration with the authors in modeling of tsunamis. The long wave propagation model TUNAMI-N2 used in this paper is a registered copyright of Professors Imamura, Yalciner and Synolakis.

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DEVELOPMENT OF TSUNAMI DAMAGE ESTIMATION TOOL

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1. Introduction

As many historical tsunamis did so, the 2004 Indian Ocean Tsunami taught us that tsunamis had devastating forces and caused various damages such as destruction of structures, beach erosion, etc which resulted in many human losses. The most important and essential measure to minimize human loss is evacuation. However, many people do not evacuate immediately even when they feel earthquake motion in a tsunami prone area, because they wait information of the earthquake and its induced tsunami to decide whether they should evacuate or not. Moreover, even if they catch a tsunami warning by a responsible organization, some people do not evacuate, because they misunderstand characteristics of tsunami and vulnerability against tsunamis in their living-areas. To encourage evacuation, the people who live in tsunami prone areas should understand the disasters caused by the tsunami expected to attack there. Actually many people evacuated in Sumatra at the tsunami event on March 28, 2005, because they had the experience of tsunami disaster caused by the Indian Ocean Tsunami on December 26, 2004.

If we can estimate the expected tsunami damages actually, we can also construct holistic defense system against the tsunamis, which combine structural measures to reduce the tsunami and non-structural measures to support evacuation. At present, numerical simulations are the most useful tool to predict and understand the tsunami attacking coasts, and actually numerical models based on nonlinear/linear shallow water theory have been used to estimate tsunami height, tsunami arrival time and inundation areas. Moreover, Fujima et al. (2002) and Yoneyama et al. (2002) showed that three-dimensional and non-hydrostatic models are effective to estimate the tsunamis interacting with structures and local topography, respectively, through the comparison with experimental results. The authors have also developed another tsunami numerical model named STOC (Storm surge and Tsunami simulator in Oceans and Coastal areas) which is an integrated models based on the combination of three models. Such models can estimate the tsunami running up lands and resultant various damages as well as tsunamis propagating in the oceans, because they can calculate the complicated tsunami flow interacting with structures and tsunami forces acting on the structures.

2. Numerical Models to Estimate Tsunami Damages

The numerical model of STOC is composed of three different sub-models: STOC-ML, STOC-IC and STOC-VF, in order to calculate the tsunamis interacting with structures as well as propagating in the oceans.

STOC-IC is a three-dimensional and non-hydrostatic model, which is developed to estimate the tsunami affected by structures in a wide area whose spatial scale is more than dozen square kilometer like a coastal city and town. It connects to STOC-ML through overlapping zones in which the physical quantities such as the water surface displacement, velocities, pressure, etc. in each computational area of STOC-IC and STOC-ML are adjusted using the interpolation technique. The governing equations of STOC-IC are Reynolds-Averaged Navier-Stokes equations and continuity equation for incompressible fluid in three dimensions, including eddy viscosity models. A technique to reduce computational efforts is to use the vertically-integrated continuity equation to detect the free water surface duce computational effort. This brings wide computational area to which the three-dimensional model is applied.

STOC-ML is a multi-level model in which water bodies are divided vertically into some horizontal layers. The governing equations are almost same equations as STOC-IC, although the assumption of hydrostatic pressure is applied in each layer. No calculation of Poisson equation of water pressure results in reduction of computational effort and then STOC-ML is applied to wide areas such as the oceans.

STOC-VF is also fully three-dimensional and non-hydrostatic model. The difference from STOC-IC is the detection technique of the free water surface. This model applies the Volume Of Fluid (VOF) method to do that. Since the VOF method can calculate the waves breaking and overtopping structures, STOC-VF provides the estimation of destruction due to the tsunami striking impulsively.

3. Application to the 2004 Indian Ocean Tsunami

Combination of STOC-IC and STOC-ML is applied to the Indian Ocean Tsunami in Galle, Sri Lanka, using a nested grid system based on bathymetry data from GEBCO 1-minute global bathymetric grid, and nautical charts, and topography and structure data. Comparing the result by the traditional tsunami simulation which considers roughness instead of buildings on land, the computational result taking into consideration the existence of buildings and using STOC-IC provides less difference on the maximum inundation depth in the hinterland of no coastal facilities to protect waves and tsunamis. However, there is much difference in the inundation process of the tsunami running up. Existence of buildings has the effect of delaying the tsunami propagation behind them, because the tsunami has to run around them and go to another path in some areas.

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TSUNAMI HAZARD MAP SEMINAR

HAZARD MAP TO BUILD THE UNDERSTANDINGS AND AWARENESS OF TSUNAMI DISASTERS

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1. Introduction

Activities for tsunami risk reduction would start form the understandings and awareness of tsunami disasters. If the disaster can be figured out, some measures can be required: measures to protect social and individual properties, measures to save human lives, and etc. In fact, Japan has constructed many kinds of and a lot of measures to prevent disasters in coastal areas which suffered tsunamis damage actually in history. The effect of countermeasures makes the number of devastating disasters and the degree of damage be reduced recently. However, the 1993 Hokkaido Nansei-Oki Earthquake Tsunami caused severe disaster again in the Okushiri island which suffered the disaster by the 1983 Sea of Japan Earthquake Tsunami. The 1993 tsunami of 10 meters or more in high overtopped the seawall that was constructed after the 1983 tsunami. The height of the 1983 tsunami was 4 meters smaller than the 1993 tsunami. As indicated by this repeated disaster, natural forces such as a tsunami can sometime exceed the estimated level based on historical damage. For disaster management to minimize the tsunami disaster, decision-makers, disaster management officials, and inhabitants should understand the feature of tsunami and its induced damage, and prepare the next disaster.

2. Tsunami hazard map

The tsunami hazard map provides a graphical indication of the areas predicted to be influenced by possible tsunamis. The most fundamental tsunami hazard map would indicate the inundation areas by the historical tsunamis. In many tsunami-prone areas, tsunami inundation maps have been made as a tsunami hazard map. They are much useful to build the understandings and awareness of the vulnerable areas to the possible tsunamis. The inundation map together with the indication of historical disasters would be more effective in understanding the possible damage.

The accuracy of computed inundation area depends on the resolution of topography and bathymetry as well as the fault model of the earthquake which defines the initial condition of the tsunami form. Especially, fine topography data yields better estimation of tsunami inundation. Development of leaser scanning technology provides the detailed survey of topography.

It has pointed out that there is difficulty to understand the indication of the inundation map. In the map, the areas without the inundation are also shown in the contrast of the inundated areas. Are the not-inundated areas always safe to all tsunamis? For example, in the Ofunato bay of Japan, the inner bay coast had less damage by historical tsunamis generating near the coast while it suffered hardly damage by the Chilean Tsunami which propagated from far filed. This difference results from the resonance of tsunami by the bay. The inundation map gives just one or some numerical simulation results of the possible tsunamis and/or the historical disaster results. The next tsunami could inundate the areas beyond the border of the inundation in the hazard map. Therefore, we should consider how to draw the results in the hazard and inhabitants also learn the meanings of the indication in the hazard map. To overcome the problem, the damage by the tsunami striking actually should be estimated in real-time.

3. Advanced hazard map

The 2004 Indian Ocean Tsunami showed us tsunami destruction as well as inundation. It also produced many kinds of drifting objects including debris which caused damage additionally. Estimation of such damage brings an advanced hazard map which provides more practical disaster management. Recently, three-dimensional and non-hydrostatic numerical models began to be applied to the estimation of tsunami. Estimation of the complicated tsunami features interacting with structures starts with such a numerical model.

4. Tsunami disaster management using the hazard map

Tsunami disaster management should start with the hazard map. Part of the tsunami disaster can be prevented by existing structures, sand dunes and so on, and other part would be reduced by new structures if their construction is possible. Such things are discussed on the hazard map. Regardless of whether the structures exist or not, the evacuation is a priority measure to save human life. Addition of evacuation routes and places into the hazard map provides an evacuation plan map resulting in effective evacuation from the tsunami. The indication of the location of the persons who require any supports for evacuation also make the preparedness of community support system. Effective information and data to reduce the tsunami risk into the hazard map would depend on the characteristics of the area and country: religion, culture, poverty, and etc.

UTILIZATION AND PROMOTION OF TSUNAMI HAZARD MAP

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1. Introduction

It is important to estimate the tsunami inundation height and to draw the tsunami hazard map, but also is important to utilize the map in order to imagine the practical situation of the tsunami and stimulate inhabitants into evacuation. It is not completed only printing the maps or distribution of the maps to the inhabitants. But the Inhabitants have to understand the meanings of the symbols, lines, hatching colors and figures printed in the map and to know what to do before tsunami arrival at the shore. Local administrative bodies which are responsible for tsunami damage mitigation therefore have to make plan for utilization and promotion of the Tsunami Hazard Map.

2. Examples of Utilization and Promotion of the Tsunami Hazard Map

The Tokai, Tonankai and Nankai areas are located on the coastline of Japan faces the Pacific Ocean. Figure 1 shows their locations. They have high risk of tsunami due to the magnitude eight class earthquakes around the Nankai and Suruga troughs. It is estimated by the government council that the earthquake can be triggered off by anytime in the Tokai area, and the earthquake will generate in the next 60 years in the Tonankai and Nankai areas. Shima City is an attractive resort for its beautiful scenery of seashore and marine sports points in the middle of Mie Prefecture in the Tonankai area. A fishery is also the main industry of the city. Kochi City is the capital of the prefectural government of Kochi Prefecture. These cities suffered the tsunami damages for many times in the past and are taking the measures against the tsunami. Effective utilization of the Tsunami Hazard Map is one of the main measures in these cities. The measures below are related to the utilization and promotion of the Tsunami Hazard Map:

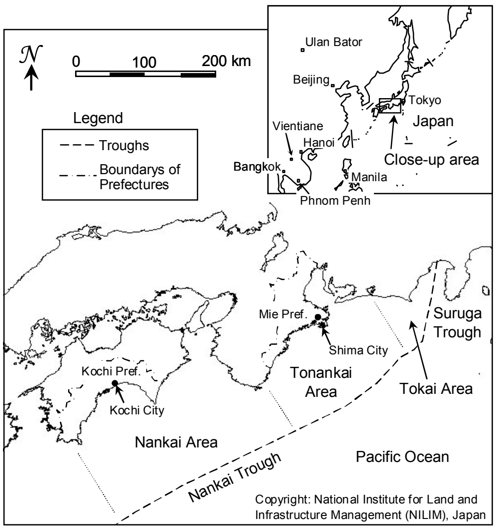

Figure 1: Pacific Ocean and Coastal areas of Japan

- Regulation established by the local government

Utilizing a Tsunami Hazard Map, one can easily judge if his or her home would be suffered from tsunami inundation or not. But it is difficult to make the inhabitants act and evacuate at their own initiatives. A regulation is enacted by Mie Prefecture in 2006. It provides personal commitments for citizens and private companies before, in and after the earthquake. All inhabitants and visitors must evacuate oneself to the safe area from inundation or to shelters in no time of delay if earthquake occurs, tsunami-forecast is announced, or tsunami arrival is estimated. The significant point of this regulation is the request for the immediate evacuation after the earthquake with no waiting for any kind of advisories, instructions or orders for evacuation by the municipal. Self-decision-making for evacuation is required for every inhabitant. Traffics of four-wheel-automobiles are also restricted in the city area. Personal traffic by car for evacuation will be forbidden in the city areas of Mie Prefecture other than special occasions.

- Orienteering from one's home to the tsunami shelter and Drawing the additional close-up map

The inhabitants are recommended to participate in an orienteering game, a walk event from one's home or place of work to the nearest tsunami shelter, held in a local community block. It is planed and organized by the municipal and representatives of inhabitants from the community. Figure 2 shows the orienteering in Mie Prefecture. The main objective of the orienteering is to learn the routes to the nearest shelter. But it is also important to find risks that will make the evacuation route impassively. Numbers of problems on evacuation will be found inevitably from the viewpoint of inhabitants, such as collapse of houses, fire, landslide, wreck of structurally-weak walls, darkness in the night, lack of the sense of a direction for the strangers, and others. These practical knowledge and critical information have to be reflected in the Tsunami Hazard Map. Inhabitants write the special signs for them in the map. A Close-up Map can be made additionally if it is necessary. The Close-up Map is useful because it can expresses details including shapes of houses and open spaces, the locations of structurally-weak walls, sites for fire hydrants and chemical fire extinguishers and others. Figure 3 is a Close-up map draw by inhabitants in Mie Prefecture. There are 367 local communities along the coastline of the Mie Prefecture and 197 communities of them already finished to develop their plan for tsunami evacuation by March 2006.

Figure 2: Orienteering *Mie Pref.

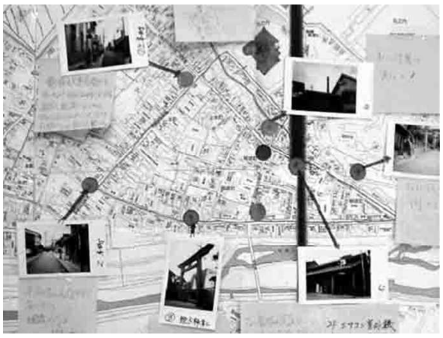

Figure 3: Close-up map *Mie Pref.

- Agreement for cooperation between private company and local government

Figure 4 is a flow diagram regarding the agreement for cooperation between the local telecom company and Mie Prefecture, concerning the utilization existing buildings as a tsunami evacuation shelters. This agreement was concluded between Mie Prefecture and the telecom company in 2004. Prefectural government, Mie Prefecture,

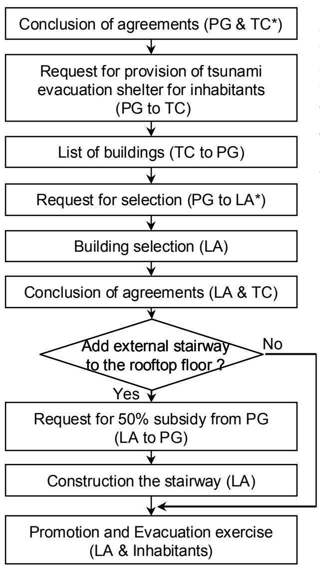

Figure 4: Flow diagram of utilization existing buildings as tsunami evacuation shelters

*PG: Prefectural Govornment
TC: Telecom Company
LA: Local Authority

Data source: Department of Disaster Prevention and Crisis Management, Mie Prefecture requests the telecom company to make a list of buildings which could be utilize as tsunami evacuation shelters. With the list revealed by the telecom company, the local authority selects a building. And the agreement is concluded between the local authority and the electric company for utilizing the selected building as a tsunami evacuation shelter. If necessary, an external stairway is constructed by the local authority. Figure 5 is an external stairway, newly constructed and attached telecom company building which was declared as a tsunami evacuation shelter by local authority of Mie Pref. in 2004.

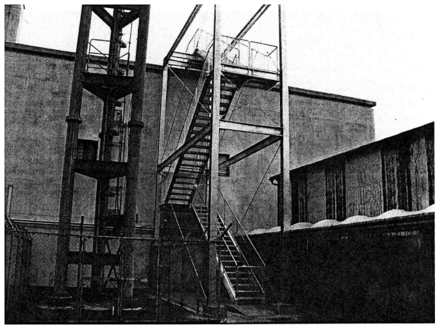

Figure 5: External stairway *Mie Pref.

Cabinet Office of Japan Government edited a guideline for tsunami evacuation shelters in 2005. The guideline stated the requirements for the tsunami evacuation building and its location, method for estimation of the number of evacuee and others.

- Annual village festival to strengthen up the social power of the local community

Figure 6: Village festival *A. Hirota

In Kochi City, annual one-day village festival is hold in order to strengthen up the social power of the local community. It is planed and organized by the municipal and representatives of inhabitants from the community. It is unique because of the joint style of a festival and an event for disaster prevention. Figure 6 is the people participated in the festival in 2006.

3. Conclusions

In this paper, practical methods of utilization and promotion of the Tsunami Hazard Map are introduced. But an effective method for utilization and promotion is not uniform because of characteristics of the local communities. Local government should take the most proper measures according to their surroundings. And, in any case, cooperation between the local authority and inhabitants is essential for the planning of safety evacuation and tsunami damage mitigation.

Acknowledgments

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HAZARD MAPPING – A SRI LANKAN EXPERIANCE

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1. Introduction

There are no clear guidelines or standards for the preparation of tsunami hazard maps in Sri Lanka. Confusion is there about the exact procedure that should be followed to prepare a hazard map which has all necessary information to recognize the degree of risk, means of escaping from the danger and how the information should be presented so that it is easily understandable to the end users. Guidelines used in other countries are very useful, however they should be adjusted to suite the local conditions. Preparation of a hazard map for the city of Galle, Sri Lanka using the guidelines adopted in Japan is discussed in the paper highlighting the necessity of a set of local guidelines.

2. Manual for Tsunami and Storm Surge Hazard Maps

Manual for Tsunami and Storm Surge Hazard Maps, Coastal Development Institute of Technology, Japan was used as a guideline to prepare the tsunami hazard map for Galle city. The hazard map discussed in this paper was prepared for safe evacuation of people and some special features of tsunami hazard maps for administrative purposes suggested by the manual were not used. Therefore an evacuation plan is included in the map but it lacks information such as the number of evacuees in evacuation centers, conditions of evacuation centers etc. which are of administrative importance.

3. Hazard Map for Galle City

According to the manual, inundation prone areas should be set based on the most critical potential tsunami event. However there had been only one recorded tsunami event in Sri Lanka and simulating hypothetical tsunami events is also difficult. Therefore the inundation area during the 2004 Indian Ocean tsunami was used as the inundation prone area during a future tsunami. A buffer zone was introduced to cover any additional inundation during a more critical tsunami event. Facility risk level evaluation was not done in preparing the hazard map even though the manual recommends that. Evacuation information was collected from the residents in the inundation area. No formal gatherings were organized but an evenly distributed sample of households was interviewed to collect information. According to the manual, there should be several meetings with all stakeholders to verify and correct the information in the map. However this was limited to collecting the feedbacks from a few selected stakeholders due to the limitation of resources.

4. Conclusions

It is not practicable to exactly follow the guidelines adopted in other countries due to various differences and limitations. Therefore a set of local guidelines is necessary for the preparation of hazard maps.