DEVASTATING DAMAGE DUE TO THE 2004 INDIAN OCEAN TSUNAMI AND ITS LESSONS

Fumihiko Imamura [1]

[1] *Professor, Tsunami Engineering, Disaster Control Research Center, Tohoku University, Japan*
Email: imamura@tsunami2.civil.tohoku.ac.jp

ABSTRACT :
A tsunami caused by a great earthquake, M9.2, offshore Sumatra island in the Indian Ocean on December 26, 2004, and devastated more than 10 countries around the ocean including Indonesia, Sri Lanka, India, and Thailand, and killed at least 230,000 people, including visitors from Europe, Australia and North American, also resulting in great economic losses. The whole world was heavily shocked by the precipitate tragedy, that is the worst tsunami damage in our history. Four years are going to pass since the 2004 Indian ocean tsunami happened. It is time to make a comprehensive remarks on disaster and lessons, and to exchange information on the process for the recovery and re-construction including its impact on other countries. Because series of earthquakes followed by the 2004 Sumatra have happened in the Indian ocean, earthquakes followed by tsunamis continues to cause huge damage. The effective tsunami warning system in Indian ocean as well as others are under discussion. The human loss due to each event are quite different, which depends on the tsunami information as well as public awareness at each community.

KEYWORDS:
Indian ocean tsunami, warning system, global disaster

1. GLOBAL DISASTER DUE TO THE 2004 INDIAN OCEAN TSUNAMI

A tsunami caused by a great earthquake more than M=9.2 offshore the north-western Sumatra island in the Indian Ocean on December 26, 2004, and devastated more than 10 countries around the ocean including Indonesia, Sri Lanka, India, and Thailand, and killed at least 230,000 people , including visitors and tourists from Europe, Australia, North American and so on, also resulting in great economic losses. The whole world was heavily shocked by the precipitate tragedy. Four years are going to pass since 2004. Now the establish of tsunami warning system in the Indian ocean and effective countermeasure at each country for structure and non-structure types at each area are discussed. It is time to make a comprehensive report on disaster and lessons, and to exchange information on the process for the recovery and re-construction including its impact on other countries. We have special issues of JNDS(2007), covering papers on the recovery process and countermeasure at the present in the countries of Indonesia, Thailand, and Sri Lanka (Murahari et al,2007, Srivichai et al., 2007, Ratnasooriya et la., 2007).
The severest affected area of Indonesia is the northern part of Sumatra, and it is reported that the coastal areas are completely destroyed by the strong shake and sudden attack of the huge tsunami more than 30 m. It was observed that the tidal surge had reached over 40 meters-height on the hilly area where the tsunami run over the top of the peninsula with a saddle shaped hill. The inland inundation mark at Banda Ache city was found up to 5 km from the coast, and there were lot of debris carried out by the tsunami wave into the center of the city, which should increase the destructive power of the tsunami.
In Thailand and Malaysia, many sightseeing spots were seriously damaged and a large number of foreign visitors also became victim of the tsunami disaster. It was a sudden major disaster to the resorts. This is serious issue to mitigate the tsunami damage in the coastal area because the most of visitors and tourists have large variety on the nation, knowledge, and response for natural disaster. The countermeasure at a tourist area is urgent issue even in Japan, Hawaii et al.. In Sri Lanka, the number of death toll became (raised) nearly 40,000.

The East and South coast in Sri Lanka were totally damaged; besides Colombo, the South-West Sri Lanka had been damaged too, even though the coast is located in the back for the direction of tsunami propagation from the source. In the coastal areas, the community villages were totally destroyed; and the train that stopped for evacuating in emergency basis, had lost more than one thousand of people who were passengers, which is one of new damages due to a tsunami.

Large tsunami waves strongly affect the coastal environments, and damage severely to the agriculture and the fishery activities. For example, ponds for aquaculture are destroyed and trees are fell down by the impact of tsunami waves, and vegetations within the inundation area were blighted due to the salty seawater. Moreover, the sea bottom, coastal topography and river drastically change due to the erosion and re-sedimentation of the sea bottom and the beach sediments. A large amount of sediments are transported landward and cover the wide area of the coastal area to form the tsunami deposits. In order to mitigate damages on the coastal environments and to make a future disaster prevention plan for at-risk countries, detail survey for understanding the damage of coastal environments by the 2004 Indian Ocean tsunami is required (Imamura et al., 2007)

2. NUMERICAL ANALYSIS OF THE TSUNAMI

The numerical modeling of TUNAMI, Tohoku University Numerical Analysis Modeling for Inundation (UNESCO, 1997), has been employed to reproduce the generation, propagation and runup of the 2004 tsunami. The tsunami generated by the displacement of sea floor due to the series of faults in the trench propagating mainly toward east and westward direction because of the wave directivity of energy. When the tsunami reached the coast of Thailand and Malaysia around 500 km far from the source in the east passing through the Andaman sea, one toward the west propagating over the Indian sea arrived at the coast of India and Sri Lanka 1700 km far. Because the sea water depth in Andaman is shallower, 500-600 m in depth, and that in Indian ocean is deeper, 4,000-5,000 m in the depth, which change the traveling speed of the tsunami. In addition, the first tsunami in Thailand was to be pulled down, whereas that in Sri Lanka was to raise, which could be recorded at the tidal stations at each region and are reported by the eyewitness. This is because of the positive initial disturbance of sea bottom in west source and negative in east. Once tsunami waves reach shallow water, they transform dramatically, since the speed of a tsunami is a function of the water depth. But because its energy remains almost constant, the height of the wave grows tremendously in shallow water. The ranging of 10-48 m runup heights in the western shore of the Sumatra, 5-18 m in Thailand, and 10-15 m in Sri Lanka was measured. Surprisingly, the tsunami reached Antarctica, where tidal gauges at Japan Showa's Basement recorded this with oscillation component of up to a meter. Some of the tsunami energy could proceeded for Pacific and Atlantic oceans.

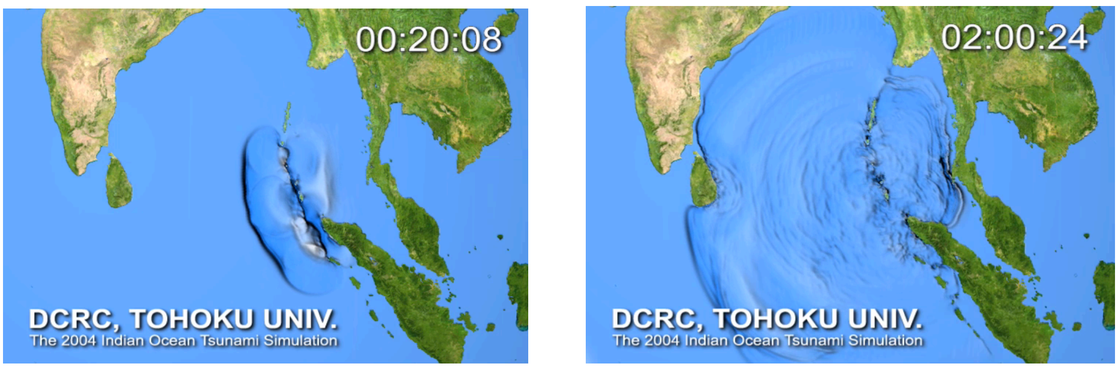

Figure 1 Snapshot of the tsunami propagation at 20 minutes and 2 hours after the generation. The first motion of the tsunami was positive in Sri Lanka and negative in Thailand

The runup simulation is also applied in the case of Banda Ache city where most severe damage was reported in Indonesia (Koshimura et al., 2008). After the tsunami firstly receded offshore the coast, it started to runup into the city of Banda Ache around 25 minutes after the quake. It takes 40 minutes for the tsunami to inundate the half of the city. The length of inundated area from the shore to the end of runup exceeds 4 km. The maximum inundation depth is almost 8 m on the ground, which destroyed the 80 % of house at the area.

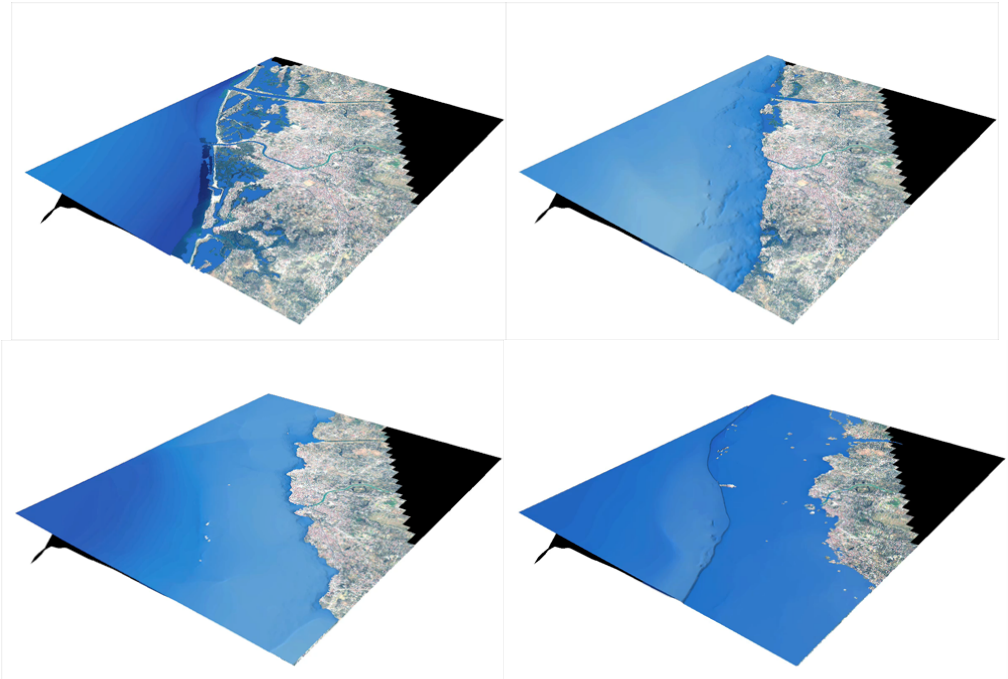

Figure 2 Snapshot of the tsunami propagation and runup into the city of Banda Ache, Indonesia, at 20, 30, 40 and 50 minutes after the generation. The tsunami inundated the most half of the city, causing 70,000 casualties (Koshimura et al., 2008).

3. ACTIVITY OF ESTABLISHING TSUNAMI WARNING SYSTEM IN THE INDIAN OCEAN

The IOC, Intergovernmental Oceanographic Committee, of UNESCO was established in 1960 and has successfully coordinated the Pacific Tsunami Warning System (PTWS) for the Pacific Ocean since 1968. After the Sumatra tsunami on December 26, 2004, the IOC received the mandate to help all UNESCO Member States of the Indian Ocean rim to establish their own Tsunami Early Warning System (IOTWS). It was agreed to in a United Nations conference held in January 2005 in Kobe, Japan as an initial step towards an International Early Warning Programme(IOC, 2008).

The system became active in late June 2006 following the leadership of UNESCO. It consists of 25 seismographic stations relaying information to 26 national tsunami information centers, as well as three deep-ocean sensors. However, UNESCO warned that further coordination between governments and methods of relaying information from the centers to the civilians at risk are required to make the system effective.

In the immediate aftermath of the July 2006 Java earthquake, the Indonesian government received tsunami warnings from the Hawaii center and the Japan Meteorological Agency but failed to relay the alert to its citizens.

At the same time IOC began coordinating the establishment of similar Early Warning Systems (EWS) for tsunami and other ocean-related hazards in the Caribbean (CARIBE-EWS) and the Mediterranean and Northeast Atlantic Ocean and connected Seas (NEAMTWS). To provide immediate interim coverage for tsunami warnings in all other oceans, advisory systems have been established under the aegis of the IOC of UNESCO, in cooperation with the Pacific Tsunami Warning Center (PTWC) from the USA and the Japan Meteorological Agency (JMA) from Japan.

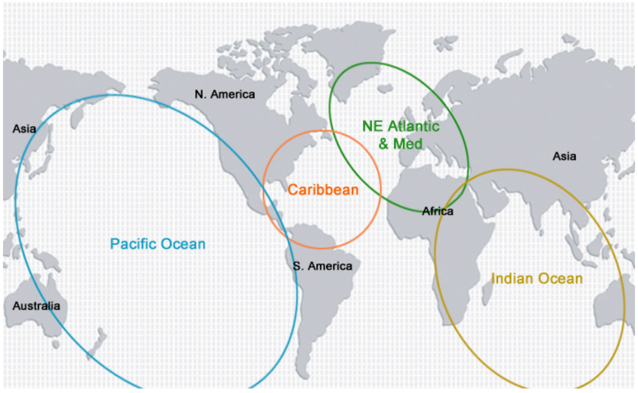

Figure 3 Areas of the Tsunami warning system proposed and discussed by IOC, UNESCO (2008)

4. TSUNAMI INFORMATION AND RESPONSE OF THE PEOPLE

We investigated the tsunami information/warning and response of the people including evacuation in recent tsunamis including the 2004, in order to discuss the essential role of the early tsunami warning. There three stages for carrying out safety evacuation after the earthquake; the first is to collect the information of tsunami warning and natural phenomenon such as strong shakes and abnormal on the coast, the second is to make decision of evacuation based on the risk perception, the third is to select proper route and place for safety evacuation from tsunami attack. Unless the three stages should be completed adequately, people could not be survived.

We found the balance between tsunami warning and risk bias in individual on response. If the risk on the warning overcome the risk bias, they could make the decision of evacuation, which suggest us an idea of proper and essential role of the warning system. Moreover, in diary life, the functions with risk communication and education so on are important to decrease the risk bias.

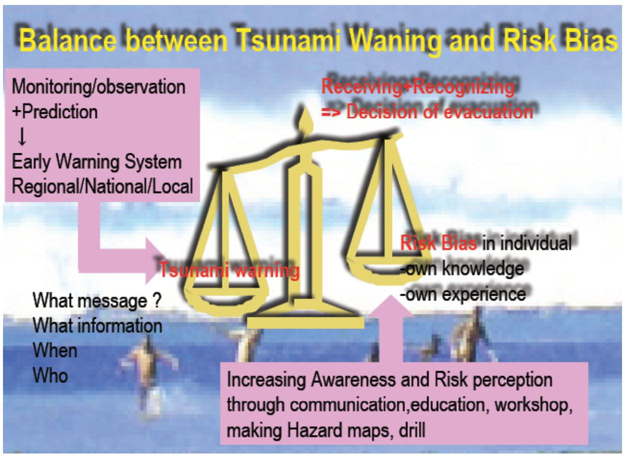

Figure 4 Idea of human response, showing balance between warning and risk bias

5. COMPARISON BETWEEN 2006 SW JAVA AND 2007 S SUMATRA

Since the 2004 Sumatra earthquake, there are a series of earthquakes followed by the tsunamis. The worst of the tsunami damage among those is the 2006 SW Java. Table 6.1 shows the comparison between 2006 SW Java (Imamura, 2007; BAKORNAS, 2006) and 2007 S Sumatra, including the earthquake intensity, tsunami runup and damage on the human and houses. Although the magnitude of the 2006 is smaller than the 2007, the tsunami and its human damage of the 2006 is mush larger than the 2007, on the other hand, the intensity of the 2007 is larger than the 2006, causing the much more houses damage. This suggest that the severe houses damage due to the strong quake by the earthquake of M8.4 in 2007 is significant, however the quick response of the people after the quake and tsunami information on TV and radio based on the awareness of the tsunami after the 2004 could save their lives.

6. REMARKS

Due to the Indian tsunami disaster on December 26, 2004, countries around the Indian Ocean were severely damaged. Rebuilding and recovery processes have been carried out with help from both national and international agencies. Meanwhile, the efforts are still in their initial stages. Many people have yet to re-establish secure livelihoods, and continue to need relief assistance. On country levels, environmental and disaster management programs are required for protection and prevention of future disasters. Lessons of the catastrophe can be summarized into the following:

- Developing the monitoring and warning system with information technology evacuation system
- Integrated disaster mitigation program for each region to mitigate tsunamis as well as typhoons, erosion and flood.
- Data Base to compile the all available data; measured and observed, videos and photos, interview and media in newspaper
- International network for the community for research, education and Hazards map for societ

Table 1 Comparison between 2006 SW Java and 2007 S Sumatra

	2006 SW Java	2007 S Sumatra
Earthquake Magnitude and Max.Mercari Modified Intensity scale	M7.7 , MMI< 5	M8.4, MMI=7-8
Tsunami Runup heights	2-7m	2-4m
Dead	637 Most due to the tsunami	21 No due to the tsunami
Missing	165	0
Heavily injured	624	18
Heavily damaged houses	1,317	>13,000

References:

JNDS,(2007), Special issue of the 2004 Indina ocean tsunami, Catastrophe due to the 2004 Indian Ocean tsunami: lessons learned through the disaster and post –recovery process, http://wwwsoc.nii.ac.jp/jsnds/contents/jsdn_back_number/jsdn_29_1.html

Imamura,F., S.Koshimura,K.Goto,H.Yanagisawa and Y.Iwabuchi(2007), Global disaster: The 2004 Indian ocean tsunami, Journal of Disaster Research, Vol.1.No.1, pp.131-135.

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

IOC(2008), http://www.ioc-tsunami.org/

Muhari,A., S.Diposaptono, and F. Imamura(2007), Toward an Integrated Tsunami Disaster Mitigation: Lessons Learned From Previous Tsunami Events in Indonesia, , J.Natural Disaster Science, Vol.29, No.1, pp.13-19.

Koshimura et al.,(2008),

Ratnasooriya,A.H.R., S.P.Samarawickrama, and F.Imamura (2007), Post tsunami recover process in Sri Lanka, J.Natural Disaster Science, Vol.29, No.1, pp.21-28.

Srivichai,M., S.Supharatid and F. Imamura(2007) ,Recovery Process in Thailand after the 2004 Indian Ocean Tsunami, J.Natural Disaster Science, Vol.29, No.1, pp.3-12.

UNESCO(1997), IUGG/IOC TIME project, Numerical method of tsunami simulation with the leap-frog scheme, manual and guides No.35,SC-97/WS-37.