2004 Indian Ocean Tsunami in South-West Coast of Sri Lanka and Its Damage

by

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ABSTRACT

The 26 December Earthquake off the west coast of Northern Sumatra generated a terrible tsunami in the Indian Ocean. The number of death and missing persons due to the tsunami rose to 300,000 in the world. The tsunami caused the devastating damage in Sri Lanka which locates far from the epicenter of the earthquake at 1600km, and the death toll of Sri Lanka stood more than 30,000 by the tsunami attack after two hours of the earthquake occurrence. Many houses in coasts, fishery boats, port facilities, railways etc. suffered heavy damage. This paper reports the results of the on-site investigation on the tsunami and its damage in the south-west coast of Sri Lanka.

KEYWORDS: Erosion, Field Survey, Inundation, Tsunami, Tsunami Arrival Time, Tsunami Damage, Tsunami Trace Height

1. INTRODUCTION

A strong earthquake occurred off the west coast of Northern Sumatra, Indonesia around 7:58 in the morning on December 26 of local time (0:58 in the coordinated universal time, UTC). The earthquake generated the mega tsunami which propagated in the Indian Ocean widely and even reached the east coast of Africa, 4500km west of the epicenter. The resulting tsunami devastated the coastal areas of Indonesia, Sri Lanka, India, Thailand and other countries.

Since so many countries and areas suffered terrible damage, many survey teams were organized and conducted post-tsunami surveys. Sri Lankan Island locates far from the epicenter of the earthquake at 1600km, and the death toll of Sri Lanka was more than 30,000 by the tsunami attack without earthquake motion, that is the remote tsunami. The tsunami there was affected by local topography around the island, where the water depth became steeply shallow around the island. Therefore, we conducted on-site investigation in Sri Lanka between January 4 and 6, 2005. The investigation field was from Colombo to Weligama in the south-west coast of Sri Lanka. This report describes the result of our investigation on the tsunami and its damage..

2. OUTLINE OF THE EARTHQUAKE AND TSUNAMI

2.1 Earthquake

The 26 December 2004 Earthquake whose magnitude was 9.0 was the fourth largest earthquake in the world since 1900: the Chilean Earthquake in 1960 (magnitude 9.5), two Alaskan Earthquakes in 1964 (9.2) and 1957 (9.1) and Kamchatka Earthquake in 1952 (9.0). The earthquake occurred between the Indian plate which is part of the Indo-Australian plate, and the Burma plate which is part of the Eurasia plate. The Indian plate has been sliding obliquely beneath the Burma plate, as shown in Figure 1. The aftershock activity was distributed over 1,000km long and 200km wide area, extending to the northward of the epicenter.

2.2 Tsunami

The earthquake caused the most disastrous tsunami so far and the number of people perished in the tsunami rose to 300,000: 220,000 in Indonesia, 43,000 in Sri Lanka, 16,000 in

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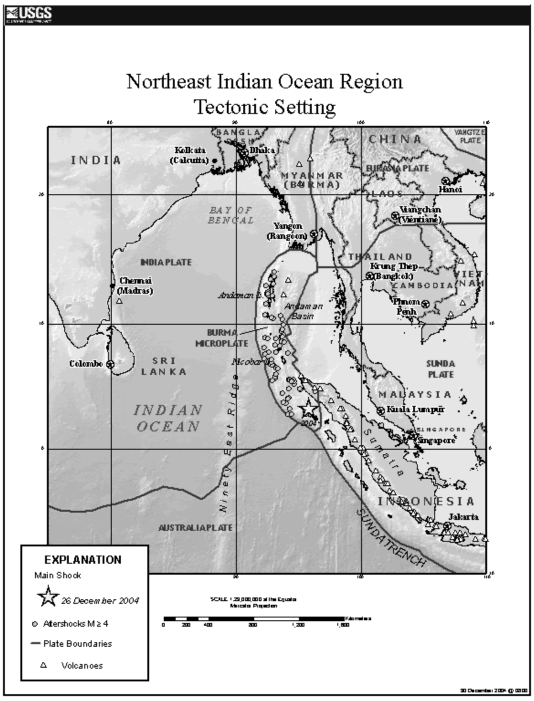

Figure 1: Tectonic setting of the Indian Ocean by USGS[1].

India and 8,000 in Thailand. The earthquake on 26 December 2004 was not the first tsunamigenic earthquake which occurred off the west coast of Sumatra Island. Some previous earthquakes had generated tsunamis, for example, in 1961, 1943, 1936, 1907 and so on. There is a good example to put the experience of the previous tsunami disaster, actually the 1907 tsunami disaster, to save human lives. Only 7 people out of 70000 people of Simeulue Island nearby the epicenter of the earthquake were killed, thanks to the saying of their ancestors ”if there is an earthquake run for your life.”

Because of the fault geometry, the tsunami propagating to the East (towards Thailand) begins with a receding wave, which explains why the sea started to retreat before flooding the coast. On the opposite, to the West (towards India and Sri Lanka) a large wave suddenly hit the coasts. Numerical computation on the tsunami by Dr. Kenji Satake, AIST[2] showed that the tsunami attacked the coasts of Thailand and Sri Lanka in 2 hours and the Maldives within 4 hours. After 10 hours of the earthquake occurrence, the tsunami reached the east coast of Africa.

3. MEASURED TSUNAMI

A tide gauge operated by the National Aquatic Resources Research and Development Agency (NARA) at Colombo measured the tsunami, the data of the water surface variation have been opened to the public by the University of Hawaii Sea Level Center (UHSL) [3]. Figure 2 shows the tsunami on the astronomical tide. The tsunami height was about 2m. The tsunami arrived Colombo around 3:30 UTC (9:30 in local time), and the first peak appeared at 4:00 UTC at which people usually thought the tsunami arrival. As shown in the figure, the tsunami attacked the coast of Sri Lanka near the time of the ebb tide.

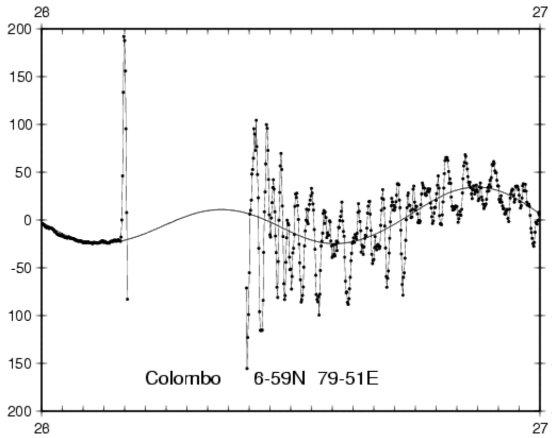

Figure 2: Recorded tsunami [3].

4. FIELD SURVEY

4.1 Tsunami Trace Height

Figure 3 shows the distribution of the tsunami trace heights measured form the sea levels that were measured at each of the investigation sites. The tsunami height is roughly 5m in the south-west coast, although there are locally some tsunami trace marks higher. The location of investigation points are shown in Figure 4 and the numbers in the figure are the tsunami trace heights.

4.2 Tsunami Arrival Time

Based on inhabitant’s stories, three tsunami

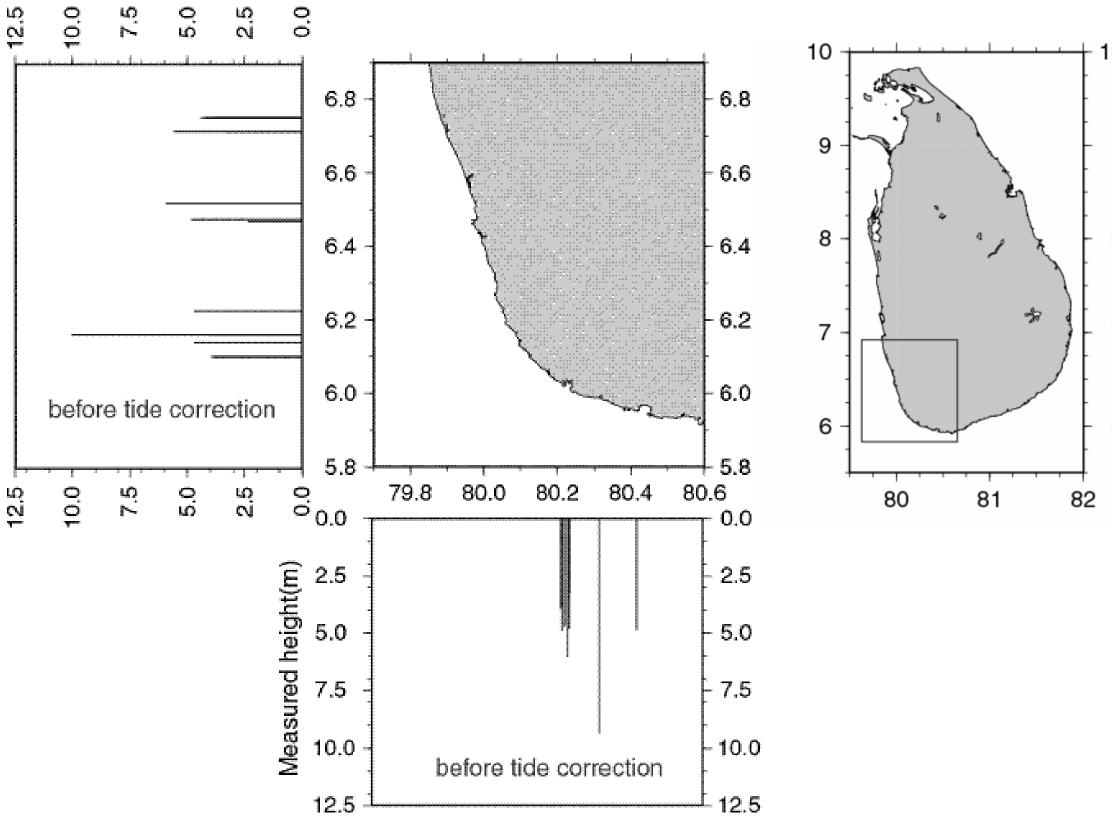

Figure 3: Measured tsunami trace heights.

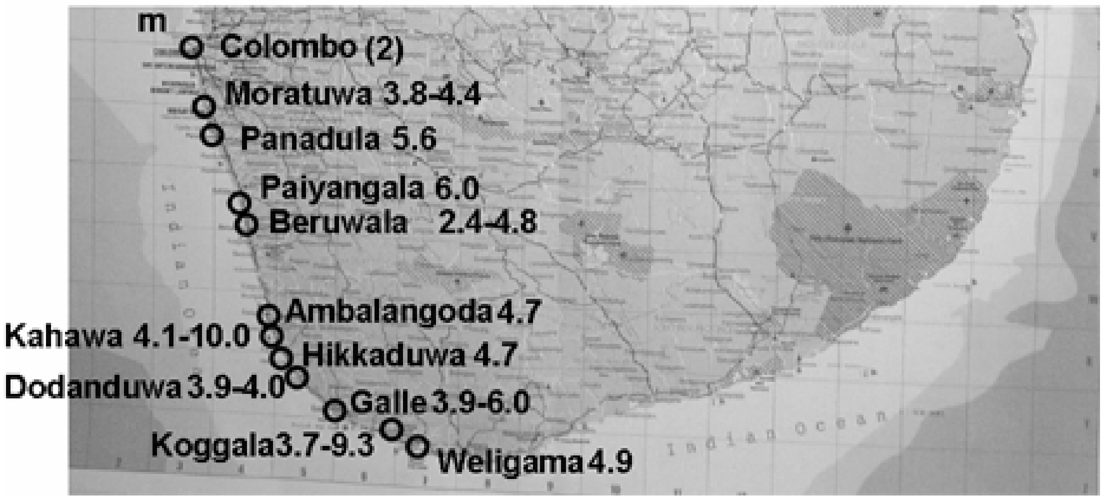

Figure 4: Location of investigation points.

waves attacked in Sri Lankan Island. The biggest wave was the second one at Moratuwa near Colombo in the west coast. The arrival time was around 9:30 in local time (3:30 UTC) there. The time is the same as the measured tsunami arrival time by the tide gauge at Colombo. The traveling time of the tsunami from the epicenter was 2.5 hours, and this value is good agreement with the result of the numerical simulation of tsunami propagation. The time interval between the first wave and second wave was about 30 minutes at Moratuwa, because the second tsunami came at 10:00 in local time.

At Galle Port, the first tsunami started with the small flooding wave, and then the seawater retreated and the sea bottom whose depth was about 12m was able to see. This receding wave made vessels touch bottom. Then, the big second tsunami came. It is necessary to confirm this tsunami feature by the numerical simulation.

4.3 Tsunami Damage

- Inundation of broad low-lying areas

Many low-lying coastal areas were inundated by the tsunami. For example, in Kahawa north of Galle, the train was carried away by the tsunami. The railway was about 190m away from the nearest beach (Figure 5). The inundation due to the first tsunami stopped the train, and then many inhabitants living in the region boarded the train to escape from the tsunami. The first tsunami was not so big as to cause severe damage. However, the second tsunami whose height was bigger then the first one washed out the train (Photo 1). 1500 people were killed in this region.

Photo 1: Passenger car of the train flooded.

Photo 2: Remained building.

A solid and high building (Photo 2), which was a school building, remained near the damaged train, although the buildings were inundated even on the second floor. Such a structure was effective to save human lives in low areas, because tsunamis were able to flow flat areas very easily.

- Wooden and brick houses destroyed

The wooden houses and brick houses were completely destroyed in the low-lying coastal

Photo 3: Destroyed coastal houses.

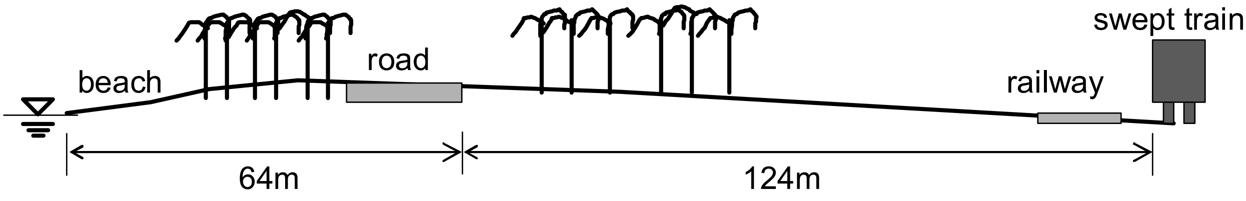

Figure 5: Coastal topography in Kahawa.

areas by the 5m tsunami (Photo 3). On the other hand, the rigid concrete houses suffered a few damage. This result was a good agreement with Matsutomi [4] in which the tsunami of more than 2m destroyed the wooden houses and gave the concrete houses a few damage.

- Damage of port and coastal facilities

Since the heights of watermarks in Galle Port were in the range from 5m to 6m, the 5-6m tsunami attacked there. The quay walls in the most inner part of the port collapsed by the tsunami action (Photo 4), and a dredger (1,169 tons) was lifted on another quay (Photo 5). However, the breakwaters which were made with stones of 1-2m in diameter had a few damage. In other coats, many jetties consisted of stones were still in good condition after the tsunami disaster. The stones of about 50cm in diameter that prevent coasts erosion were flooded onto the land.

On the other hand, the port and harbor facilities like breakwaters and seawalls were able to reduce the tsunami damage in the areas behind the ports and harbors. The wooden houses remained behind the harbors after the tsunami.

- Erosion

Some beaches were eroded by the tsunami flowing. The receding tsunami shaved off land. It also took away the base of structures, and then the structure had severe damage even if there was little damage in the structure. In Ambalangoda the ground under a railway was eroded by the tsunami 0verflowed a river, and the railway tracks were greatly bent (Photo 6).

At Banda Aceh in Northern Sumatra, Indonesia, which was near the epicenter, the 10m tsunami eroded the coast severely (Photo 6) and coastal topography was changed. Although there were protection works by stones in this

Photo 4: Damage of quay wall.

Photo 5: Dredger lifted on the quay.

Photo 6: Damaged railway by erosion.

Photo 7: Eroded beach in Indonesia.

area before the tsunami, the protection works were completely destroyed and the reclaimed areas behind the protection works were eroded more than 1.5m in height. The topographic change can be also seen in Thailand. A sand spit was eroded by the tsunami.

- Extended inundation area by the tsunami climbing rivers and waterways

For example, in Galle a small waterway run into the inner land. The waterway may extend the inundation area beside it, because the tsunami is able to climb rivers and waterways easily.

5. SUMMARY

The Indian Ocean Tsunami on December 26, 2004 caused the devastating disaster in Sri Lanka. Even in the south-west coast of Sri Lankan Island, in which the tsunami did not attack directly like the east coast, almost coastal villages were destroyed and many towns also suffered severe damage, since the coastal low-lying areas were widely inundated. The tsunami height in the south-west coast was 5m in perspective.

The expected all forms of damage from a tsunami were observed in this event. A wide band of the coastal zone was inundated and eroded by seawater. The wave and flooding forces of tsunamis destroyed houses, buildings, coastal vegetation, and some kinds of infrastructures like harbors, roadways and railways. Many humans were also killed.

To prevent and mitigate the disasters from tsunamis especially in the low-lying areas without evacuation places, structural measures are effective to save human lives. They can protect assets as well as human lives. Especially effective tsunami disaster mitigation is to make an integrated defense system which consists of the structural measures to reduce tsunami height and flow velocity and the non-structural measures to support evacuation. For structural countermeasures against tsunamis, high structures are necessary, because it is hard to diminish the energy of tsunamis by wave dissipation works. No structures can block perfectly and always any tsunamis. Therefore, we need to analyze tsunami hazards and to integrate adequate disaster mitigation system which consists of the structural and non-structural measures to compensate each other.

For example, international and national tsunami warning systems are necessary for inhabitants and tourists to evacuate from a remote tsunami. For the remote tsunami, they cannot feel ground motion by earthquake and no one watch the tsunami. Therefore, tsunami warning system based on the international cooperation to transmit tsunami information to countries, and the national warning system to disseminate the information in each country are needed to save human lives. In order to evacuate from a broad low-lying area near a coast, high and rigid structures are necessary for tsunami shelters. Evacuation routes are also needed.

6. ACKNOWLEDGMENT

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