Effects of *M* 9 Sumatra earthquake and tsunami of 26 December 2004-A Review

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ABSTRACT

The great mega thrust M 9 Sumatra earth-quake on 26 December 2004 at 06:28:53 am IST created the most devastating tsunami in the known history. The deadly tsunami waves lashed low-lying towns adjoining the coastline of eleven countries, including Indonesia, Thailand, Malaysia, India and Sri Lanka, causing more than 150,000 deaths. Tsunami is a water wave caused due to tectonic activities under water and travels across oceans with very high speed and can inflict great damage to life and property at the shores. Many regions around the globe, especially the Pacific Ocean have witnessed many damaging tsunamis in the past. Countries around the Pacific Ocean have developed an early warning system that has been very effective for the last 50 years. Tsunamis have not been so frequent in the Indian Ocean, therefore lack of awareness has been a major cause for the great devastation caused by the tsunami of 26 December 2004. This paper gives a brief back- ground about tsunamis.

KEY WORDS: ***Earthquake; Tsunami***

INTRODUCTION

Tsunami is a word of Japanese language meaning harbour wave', which is used to de- scribe the large waves produced by an abrupt shifting of the sea floor which results in vertical displacement of the overlying water. When these waves reach the land by travelling distances across the ocean, they cause devastation on the coasts.
These waves move at a speed, V, that is equal to the square root of the product of the acceleration of gravity, g, and the water depth, D, that is $V = (\sqrt{Dg})$. With typical water depth in ocean at about 3000 to 4000 m, a tsunami travels at about 200 m/s, or over 700 km/h. Typically, in deep ocean tsunami has very large wave length (distance from crest to crest) running into 100-200 km and the wave height of less than 1 m. As the rate at which a wave loses its energy is inversely related to its wave length, tsunamis not only propagate at high speeds, they can also travel great trans-oceanic distances with very little energy losses.
As a tsunami approaches land and propagates into the shallow water near the coast, Fig 1, its speed reduces because of two reasons:

(i) the speed of a tsunami is directly related to the water depth and it reduces as water depth reduces

(ii) the friction of the continental floor slows down the front of the wave.

Thus, not only the waves slow down, they get closer to
each other. Due to conservation of energy, decrease in distances between individual waves leads to increase in amplitude of the waves and therefore the waves rise up to 10 m or more near the coasts. This phenomenon is also known as "Shoaling Effect".

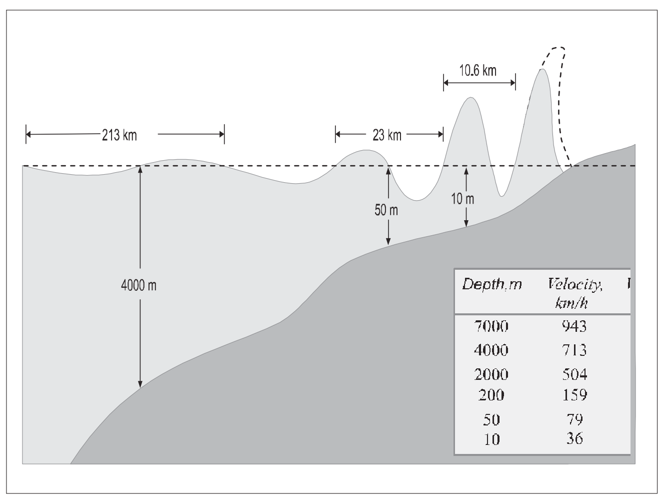

Fig.1 Shoaling effect of tsunami

GENERAL OBSERVATIONS

Due to the subduction of the Indo- Australian plate under the Eurasianplate, the Andaman and Nicobar Islands experienced uplift on the western coast and subsidence on the eastern coast as seen from the field evidence. At Port Blair, located on the east coast, water level has risen by about 1 m, Fig 2. Western coast of the middle Andaman
islands showed emergence of new shallow coral beaches suggesting an uplift.

Fig .2 Sea water level at Port Blair with respect to land has gone has up by about 1 m.

Damage to buildings and other structures were primarily due to tsunami (as against due to ground shaking) on the mainland India. In Little Andaman and other islands south of it; and structural damage in islands north of Little Andaman were primarily due to ground shaking.

The earthquake occurred along the plate boundary marked by subduction zone between the Indian plate and the Burmese micro-plate. The subduction zone is charac- terized by NNW–SSE arcuate trench running parallel to the western side of the Sumatra and the Andaman–Nicobar Islands. As a result of this movement of tectonic plates, the Andaman and Nicobar Islands have experienced uplift and subsidence at different places as seen from the field evidence. At Port Blair, the sea water level has risen by about one meter, suggest- ing a subsidence of the landmass, whereas in Middle Andaman Islands emergence of new shallow coral beaches suggests uplift (Fig. 3). The implications of rise in water level by 1 m with respect to the land are rather severe: the buildings and roads at lower elevations and the dry docks are being flooded during high tide, making them non-functional and disrupt- ing normal activities even weeks after the event. In Middle Andaman Islands, at Baratang an older mud volcano became active again after the earthquake and also several new small mud volcanoes erupted along with large ground deformation(Fig. 4). Damages to buildings and other structures were primarily due to tsunami (as against due to ground shaking) on the mainland India, and in Little Andaman and other islands south of it (Fig. 5); structural damage in islands north of Little Andaman was primarily due to ground shak ing.

Fig. 3. *a*, Up-throw of coral beds and rock strata due to uplift on the western coast of middle Andaman Island near Flat Island *b*, Seawater flooded Andaman Trunk Road at Sipi Ghat area near Port Blair during high tide, suggesting subsidence of the landmass.

Fig.4 Eruption of a mud volcano near Jarawa creek at Baratank Island Middle Andaman 105km north of Port Blair

Fig. 5. RC frame building (MES Inspection Bungalow) now stands in waters at the Military Residential Colony south of Malacca on the east coast of Car Nicobar Island.

Tsunami created giant waves as high as10–12 m; in several instances, objects were found on top of the trees after the tsunami. In the islands of Great Nicobar, Car Nicobar and Little Andaman, buildings constructed on the coast were washed away by the great waves, while those located on high grounds survived. When a num- ber of rows of buildings existed on the coast, buildings in the first row from the sea suffered extensive damage, those in the rear rows did better due to the shielding provided by the front row. In general, constructions circular in plan (e.g., circular water tanks, light house) did better under the onslaught of tsunamis as the water could easily flow around such objects. At Car Nicobar about 100 personnel of air force (including the family members) lost life or are missing. However, the operational area and the air-strip survived enabling rescue and relief operations by the air force after the event.

Due to the ground shaking, the wooden buildings suffered less damage compared to the more modern RC frame and concrete block masonry buildings. The latter sustained extensive damage when the seismic codes were not complied with. For instance, the Passenger Terminal Building at the Phoenix Bay in Port Blair was recently constructed but did not comply with the seismic codes. This rather expensive building has been irreparably damaged. A number of houses built by local people using reinforced concrete but without proper engineering supervision and seismic detailing collapsed. A three-storey apartment building in Port Blair on stilt columns, not complying with the codal requirements, collapsed (Fig. 6). Similar dam- ages were also observed in Rangat, and Mayabandar in northern islands as well.

Fig. 6. Collapse of a three-storey reinforced concrete frame building at Port Blair

A number of jetties collapsed were severely damaged in a number of islands which severely affected the sea traffic and hence the relief operations (Fig. 7). A new 268 m long bridge between North Andaman and Middle Andaman at Austen Strait had to be closed to even the light vehicles. The superstructure has moved on the substructure by a substantial amount and middle three spans fell off from the bearing (Fig. 8*a*).

Fig. 7 Collapse of the 80 m segment of approach in Great Nicobar Island jetty at Campbell Bay.

On the mainland India, the fishing community living along the shore suffered the maximum damage: to its housing, to its boats and fishing equipment, and in terms of loss of life. The other major sufferers were the tourists on some of the beaches. Most houses along the coast had been non-engineered. In general, quality of construction had a major influence on the level of damage sustained by the buildings. Buildings with low foundation depth, those with poor building materials, poor integrity and poor workmanship were worst sufferers. Several bridges suffered serious damages. Superstructure of all four spans of a bridge at Melmanakuddi came off the substructure and two of the spans were washed away to large distances (Fig. 8*b*). A good connection between the superstructure and the substructure and the additional provision of restraining upstands, recommended fea- tures for seismic design, would have helped the bridge. Infrastructure in Nagapattinam, Tamil Nadu was significantly affected: a railway line on the shore, telecommunication tower and control panel room were irreparably damaged. Compound walls up to300 m inside the shoreline were extensively damaged.

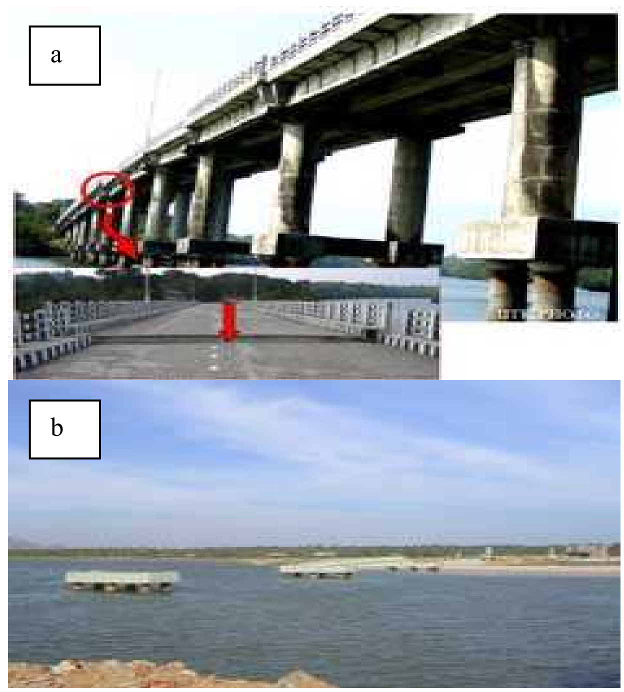

Fig.8. *a*, Three middle spans of Chengappa Bridge over Austen Strait connecting Middle Andaman and North Andaman Islands, 230 km north of Port Blair fell off from the bearing to ground shaking *b*, Complete loss of spans of the four-span RC bridge at Melmannakudi due to tsunami

Tsunami caused by the earthquake resulted in heavy death tolls in a large number of countries. As of January 13, 2005 (18 days after the event) the total number of deaths (approximate) as reported from various countries was: 159,484. The break-up is as follows:

Table. 1 Total no. of deaths country wise

Name of the Country	No of deaths
Indonesia	113,306 (3,598 missing)
Sri Lanka	29,825 (5,806 missing)
India	10,672 (5,711 missing - 5625 on the Andaman and Nicobar islands)
Thailand	5,309 (3,396 missing)
Somalia	150
Myanmar	59
Maldives	82 (26 missing)
Malaysia	68 (6 missing)
Tanzania	10
Bangladesh	2
Kenya	1

DETAILS OF OTHER PAST TSUNAMIS:-

Not only India but some other countries have been plagued by more frequent tsunamis for centuries.

Table.2 Detail of tsunami of other country

Date	Country	No. of deaths
November 1, 1755	Lisbon, Portugal	60,000
August 27,1883	Java and Sumatra	37,000
1896	Japan	27,000
1946	Hawaii and Alaska	159
1960	Chile	1500
	Hilo Hawaii	61
	Japan	150

The first reported tsunami that hit the Indian coast[redacted]dates back to April 2, 1762. An earthquake at Bangladesh-Mya[redacted]ar border triggered a tsunami in the Bay of Bengal. Wate[redacted]in Hoogly at Kolkata rose by 2 m; rise in water at Dhaka[redacted]s reported to have capsized hundreds of boats and drowned many people. On December 31, 1881, an earthquake of magnitude 7.9 at Car Nicobar region generated tsunamis with maximum crest height of 0.8 m which were recorded The Krakatoa volcano eruption of 1883 mentioned earlier had caused a tsunami that was felt at Indian coasts also. In twentieth century also, Indian coasts have witnessed two major tsunamis. On June 26, 1941, an 8.1 magnitude earthquake at Andaman Islands generated a tsunami of about 1 m in height. The cellular jail in Port Blair was also damaged, and the earthquake was felt even in Madras and Colombo. Even the land of certain islands was reported to have sunk by about 60 cm. On November 28, 1945, Makran coast of Pakistan had an earthquake of magnitude 8.0. This earthquake was accompanied by generation of tsunamis and mud volcanoes. The tsunamis were as high as 12 m at some of the Makran ports, causing tremendous damage. The height of tsunami reached 11 m at Kachch coasts and about 2 m at Mumbai. About 15 persons were reported dead at Mumbai due to the tsunami. About 4,000 people died due to the earthquake and tsunami.

CONCLUSION

The extent of unpreparedness in India to handle tsunami canbe understood from the fact that IS1893 (Part 1) does noteven mention tsunamis among the other secondary effects of earthquakes. For instance, Foreword of the code states – “Earthquake can cause damage not only on account of the shaking which results from them but also due to other chain effects like landslides, floods, fires and disruption to communication. It is, therefore, important to take necessary precautions in the siting, planning and design of structures so that they are safe against such secondary effects also”. Therefore, in Indian scenario, the solution is not only to develop a warning system, but also to launch a massawareness campaign. Unless the local governments and the public can effectively react, the warning system may not be effective. Unlike an earthquake mitigation plan where we need to educate only a certain group of people who are directly related to the construction industry and enforce code compliance, in case of tsunamis, we need to educate everyone who is likely to be directly affected in case of any such calamity.

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