

# **DAMAGE TO ANDAMAN & NICOBAR ISLANDS DUE TO EARTHQUAKE AND TSUNAMI OF DEC. 26, 2004**

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## **INTRODUCTION**

A great Tsunamigenic earthquake measuring 9.3 on Richter Scale ( $M_w = 8.2$ ) having a focal depth of 10 km struck Northern Sumatra, Indonesia at 00:58:50 UTC on Dec. 26, 2004 accompanied by several strong aftershocks having magnitude ranging from 5.0 to 7.3 and with epicentral locations ranging from west coast northern Sumatra to Andaman-Nicobar islands, Indian region. The main shock near Sumatra generated tsunami that hit the Andaman and Nicobar Islands and caused extensive damage to lives and property. The official death toll in India has risen to more than 15500.

A technical survey from Department of Earthquake Engineering, IIT Roorkee, Department of Civil Engineering, IIT Madras and Officials from Andaman Harbour Works, Port Blair visited various damage affected islands of Andaman and Nicobar areas from Dec.28 to 31, 2004. The Andaman and Nicobar island group consists of 572 islands, out of which only 38 are inhabited. The buildings in the Andaman and Nicobar islands are mostly reinforced concrete framed structures and traditional wooden tribal houses. The port and harbour structures are the lifeline structures as the travel between the islands and mainland is through the ferries and ships.

The islands were subjected to earthquake shaking and damage was caused to buildings and other infrastructures. The main earthquake shock also generated tsunamis which hit the islands and east coast of mainland India at different intervals of time and with different wave heights. The buildings near the coast have also been damaged severely. The residential colony and offices of Air Force station at Car Nicobar was first severely damaged by ground shaking and liquefaction and then completely washed away by tsunami waves. The passenger hall building at Haddo wharf has been damaged beyond repair. The buildings away from the shore have been subjected to only ground shaking and developed minor non-structural cracks. The bearings of the bridge at Mayabandar in northern Andaman have also been damaged.

## **SEISMICITY OF ANDAMAN AND NICOBAR**

It lies on the southern part of the Great Alpine-Himalayan seismic belt and is known for seismic activity. Earthquakes of Richter Magnitude greater than 8 have occurred in the region. Generally, epicenters are in the sea. Major earthquakes in Andaman & Nicobar island generally characterized by aftershock sequences and foreshocks have not been common. Brief detail of some major earthquakes that hit in this regions are described.

### **DECEMBER 31, 1881 EARTHQUAKE**

An earthquake of magnitude M 7.9 occurred beneath the ocean which caused damaged to some masonry buildings at Port Blair. Tsunamis triggered by this earthquake are reported to have caused a 1.2m run up on the east coast of India.

### **JUNE 26, 1941 PORT BLAIR EARTHQUAKE**

An earthquake of magnitude M 8.1 struck Port Blair. It was the strongest recorded earthquake from the Andaman. The tower of the cellular jail broke down, killing the chief warden. The Tsunamis triggered by this earthquake is reported to have inundated the west coast of Andaman. The region was inhabited mostly by the Jarawa tribes, who had no means of reporting. However, the earthquake was well recorded on the east coast of India.

## JANUARY 20, 1982 GREAT NICOBAR EARTHQUAKE

An earthquake of magnitude  $M_s$  6.3; occurred at 4h 25m 12.7s GMT at a focal depth of 28 km located at East coast of Great Nicobar Island. The maximum intensity observed – VIII. Caused wide spread damage to civil engineering structures. Caused great panic among the ex-servicemen settlers (300 - 1969).

The earthquake caused Ground failure. The ground particularly the road failure was seen upto 12 to 15 km from Campwell Bay on both E-W & N-S roads. The damages were mainly due to the failure land slopes. The failure along the cost line was also observed. A dominant fissure runs 300-400m and width measuring 2.0 cm with depth more than 75cm occurred along the cost line.

The houses of Nicobares and Shompens founded on wooden plies with floors about 1.5m above the ground were not damaged. The timber cum hollow block masonry (THBM) construction faired well. Chimneys damaged invariably. The Campbell Bay School in THBM damaged due to differential settlement of the ground. Damage to buildings located on filled up soil was more. The double storey buildings of the Andaman Harbour Works performed very well.

## SEPTEMBER 13, 2002 NORTH ANDAMAN EARTHQUAKE

An earthquake of magnitude  $M_L$  6.0 (IMD),  $M_L$  6.8 (USGS) occurred in North Andaman. It caused considerable damage to property – Diglipur; collapsed walls, toppled overhead tanks, ruptured water pipes, reinforced construction around Diglipur sustained considerable damage. There were no casualties.

## TSUNAMIS

Tsunamis are generated by any large displacements at sea level which could be due to earthquakes. Earthquakes generate tsunamis by vertical movement of the sea floor as in normal faulting or thrust faulting. If the sea floor movement is horizontal, tsunamis are not generated as in strike slip earthquake. Tsunamis are also triggered by marine landslides into or under the water surface, and can also be generated by volcanic activity and meteorite impacts. Tsunami velocity is dependent on the depth of water.

Damage due to tsunami to the habitat along the coast is widespread. The buildings were badly damaged by the tsunami waves and flooding that was caused by it. In Andaman Island the tsunami wave height is observed to be 1 to 2 m and in Car-Nicobar the height is estimated to be about 10m. The waves swept away structures on its way. It uprooted trees and thrown far away. Both inward and receding wave front caused huge damage.

## DAMAGE TO BUILDINGS

Figure 1 shows an Arial view of earthquake damage to buildings. Two types of building constructions have been prevalent in Andaman and Nicobar islands: (i) Buildings with load bearing walls of concrete block masonry and sloping tiled or sheet roofs, and (ii) RC frame buildings. Buildings have suffered damage due to ground shaking, as well as due to tsunami waves. The buildings near the coasts have suffered more damage, compared to those away from the coast, due to the following reasons:

- (i) The buildings near the coast have been subjected to tsunami wave pressure after having damaged by the earthquake ground shaking.



*Fig. 1 Arial view of damage in Port Blair*



**Fig. 2 - Damaged Passenger hall Building at Haddo Wharf, Port Blair, Andaman Island**



**Fig. 3 - Liquefaction at Haddo Wharf, Port Blair, Andaman Island**

- (ii) Near the coast, the buildings have been founded either directly on the reclaimed land on isolated footings or on piles. Many buildings have more than one type of foundation systems for integrally connected super structure. The different types of foundation systems have resulted in differential settlement and damage to the superstructure. Columns having isolated footings on reclaimed land have been observed to undergo excessive settlement. Figure 2 shows the damage to Passenger hall Building at Haddo Wharf, Port Blair, Andaman Island. Due to sandy soils and high ground water table near the sea shore, liquefaction has taken place resulting in damage to the structures. Figure 3 shows the liquefaction at Haddo Wharf, Port Blair, Andaman Island.
- (iii) Reinforcement in buildings near the shore was corroded due to high concentration of chlorides, resulting in weakening of structures. The concrete was already cracked due to corrosion and sapling resulted during shaking.

During the visit, the buildings were surveyed in Port-Blair and Car Nicobar. In Port-Blair, the buildings have been damaged mostly due to ground shaking and not many buildings have been subjected to pressure of tsunami waves. In Car Nicobar, Air Force Colony was the worst hit and most of the buildings have suffered total collapse due to the combined effect of ground shaking, liquefaction and tsunami. Case studies of some of the important buildings in the islands are presented in the following sections.

Air force station at car Nicobar had a beautiful residential colony near the sea shore. Due to their proximity to sea and low ground level, the colony buildings were subjected to the Tsunami waves. The buildings suffered damage due to ground shaking and liquefaction, and the final blow from Tsunami waves. Most of the buildings have suffered total collapse (Fig. 4) and many have been washed away by the waves. The height of the waves can be visualized by the objects put at the tree tops.



**Fig. 4 Collapse of buildings due to tsunami waves**





*Fig. 5 Collapsed and submerged Jungali Ghat Jetty, Port Blair, Andaman Island*



*Fig. 6 - An ariel view of tsunami inundation in Car Nicobar*

## PORT AND HARBOUR STRUCTURES

The port and harbour structures have been severely damaged. Some portion of Fisheries jetty at Phoenix Bay complex and Jungali Ghat jetty in Andaman island; jetties at Katchal and in Campbell Bay islands of Nicobar have collapsed and submerged in water. The harbour structures at Port-Blair namely, Haddo Wharf, Phoenix Bay Harbour complex, Chatham (Old and New), Hope Town and Jungali Ghat have been damaged by pounding between the berth blocks. Part of the Jungli ghat jetty was submerged as shown in Fig.5. The relative displacement between the different berth blocks has resulted in misalignment of crane rails hampering the cargo handling. The tsunami waves affected about 0.5m to 1.5 km inside the coast line. Figure 6 shows the inundation along the coast.

## CONCLUSIONS

The earthquake intensity estimated in Port Blair, Andaman Nicobar Island is VI and in coastal region is about VII.

- The water level in the sea at Port-Blair has been raised by about 1.0 m and many land areas came under water suggesting the land mass has gone down due to the major earthquake upheaval.
- The main earthquake shock also generated tsunamis which hit the islands and east coast of mainland India at different intervals of time and with different wave heights. The height of tsunami waves at Port Blair was about 1-2 m where as in Car-Nicobar the height was about 10m. The tsunami waves affected about 0.5m to 1.5 km inside the coast line. At Car-Nicobar Island tsunamis swept the shore and caused severe damage to the buildings located near the coast. Andaman Island was also affected by earthquake and tsunami.

Important coastal structures and human habitat should therefore be away from the coast and the foundation should be above the maximum tide level as far as possible.

- There was large scale ground failure such as ground cracking, large scale subsidence and liquefaction was observed which resulted damage/ failure to many buildings and port structures. At Car Nicobar Air Force station damage to the concrete runway at the joints were observed due to concrete blocks hitting each other.
- Significant damage was observed in port and harbour structures, and bridges (their lifeline structures) due to earthquake vibration mainly since its foundations rested on loose marine saturated deposits or filled upland. Many damages occurred due to earthquake vibrations leading to settlement/ liquefaction in many cases and later subjected to tsunami waves.
- Wharf and jetties have damaged mostly due to collapse and submergence of part of Jetty, pounding of deck blocks and the blocks have undergone relative horizontal displacement which has misaligned the crane rails.
- In Port Blair RCC frame buildings have performed well and undergone minor damage. The construction of structures on piles has shown better performance.