Sumatra Earthquake 26 Dec 2004

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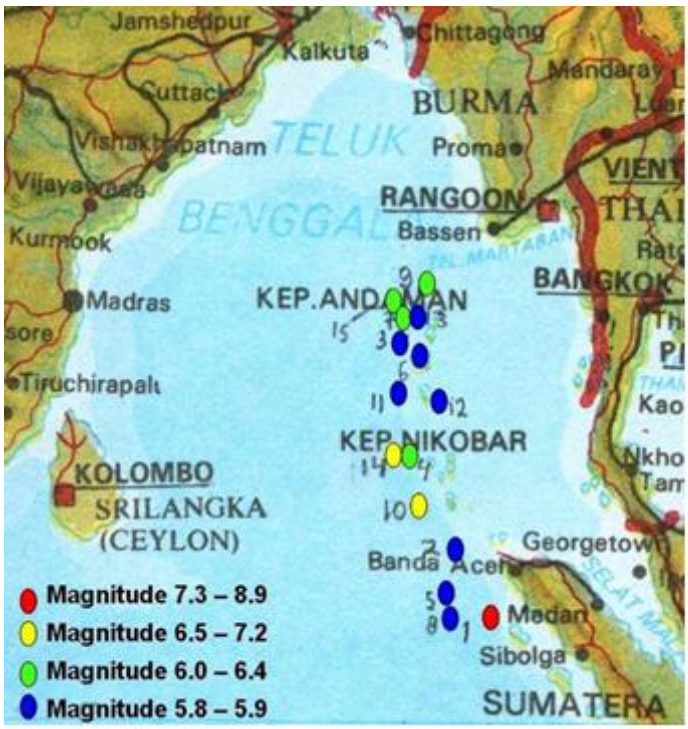
1. Aceh Tsunami Dec 26, 2004



EQ 26 December 2004			
No	Time	Depth (km)	Magnitude
1	00:58:50	10.0	8.9
2	01:48:46	10.0	5.9
3	02:15:57	10.0	5.8
4	02:22:01	10.0	6.0
5	02:34:50	10.0	5.8
6	02:36:06	10.0	5.8
7	02:51:59	10.0	6.0
8	02:59:12	10.0	5.9
9	03:08:42	10.0	6.1
10	04:21:26	10.0	7.3
11	06:21:58	10.0	5.7
12	07:07:09	10.0	5.7
13	07:38:24	10.0	5.8
14	09:20:01	10.0	6.5
15	10:19:29	10.0	6.2

Main Shock and After Shocks within one day of the Sumatra Earthquake, December 26, 2004, USGS

On Sunday morning Dec 26, 2004 Banda Aceh was holding a 10 K marathon and approximately 1000 residents were doing their daily exercise at Blang Padang square, where the Suelawah plane monument is located. The city was crowded by the 10 K participants in their sports gears and some participants had reached the finish line, when at that time 07.58.50 WIT (Western Indonesia Time) the earth was shaken by a strong earthquake. Almost everybody was panic and lay down on the ground. Some could watch the most popular hotel in Banda Aceh, the Kuala Tripa hotel shook and settled and subsequently the lobby story collapsed. People at Blang Padang did not run because it was an open field. After the earthquake shaking stopped, people start wandering in the city watching some collapsed buildings. A TV reporter even toured the city to check damaged and collapsed buildings. At around 08.42 WIT, the first tsunami wave reached the coastlines of Banda Aceh and according to eye witnesses, the first wave was not so powerful and caused flood from the coastal area to the “center” part of Banda Aceh and some people start shouting: “water, water from the sea” and many people start running towards the center of the city. However, at around 08.53 WIT, a second more powerful wave swept the coastal area and caused significant destruction and many people still running on their way to higher ground were swept and cascaded by debris of collapsed buildings and died instantly. Some made it to higher ground; many were dragged by the flood several km.

At around 09.15 WIT, the third and most powerful wave swept through the coastal area up to a distance of approximately 4 km inland and brought destruction along their path. Most of the buildings that collapsed were non-engineered buildings and were subjected to the tsunami forces such as battering, scouring, impact and buoyancy. Many fishermen boats and cars were dragged from coastal areas to the city by buoyancy of the tsunami flooding and ramped buildings in its way. Almost all buildings along the coastal areas were literally disintegrated by this tsunami and the debris was dumped into the city up to approximately 4 km from the coastal area. The total destruction by the tsunami was within an area of approximately 15 km sq from the East to the West of Banda Aceh and along a distance of 2 km inland. After the third wave, Banda Aceh was inundated up to a height of approximately 2 m for approximately 30-40 minutes within an area up to 4 km inland and subsequently water start flowing back to the sea and at around 11.00 WIT the water level was approx 30-40 cm. (note: the timing of the arrival of the tsunami waves was obtained from an amateur video, but the video camera was not available for verification).

2. "Early Warning"

As mentioned earlier, the first tsunami wave came approximately 40 minutes after the M 8.9 earthquake and people on the coastal areas saw that the sea level subsided from the beach and also saw a huge wave was approaching the coast. Subsequently some people started shouting and issued warning that a flood was coming and started running towards the center of the city. However, most of the coastal areas occupants were not "trained" to immediately evacuate upon hearing the "early warning". Most of them do not have the idea what a tsunami wave could do to them until it was too late. Due to this "early warning", approximately 30 % of the coastal area population survived the tsunami and some 70 % of them were literally wiped out together with their houses. It just so happen that the coastal area is a highly populated area and approximately 100 thousand were living in that area. Therefore, the estimated casualties from that area only are approximately 70 thousand. The rest are from the "inland" areas that were inundated by the tsunami "flood". Similar "early warning" procedure was also practiced in Meulaboh.

Source: Kompas, 15 January 2005

Banda Aceh: People were running to higher grounds after the first wave.

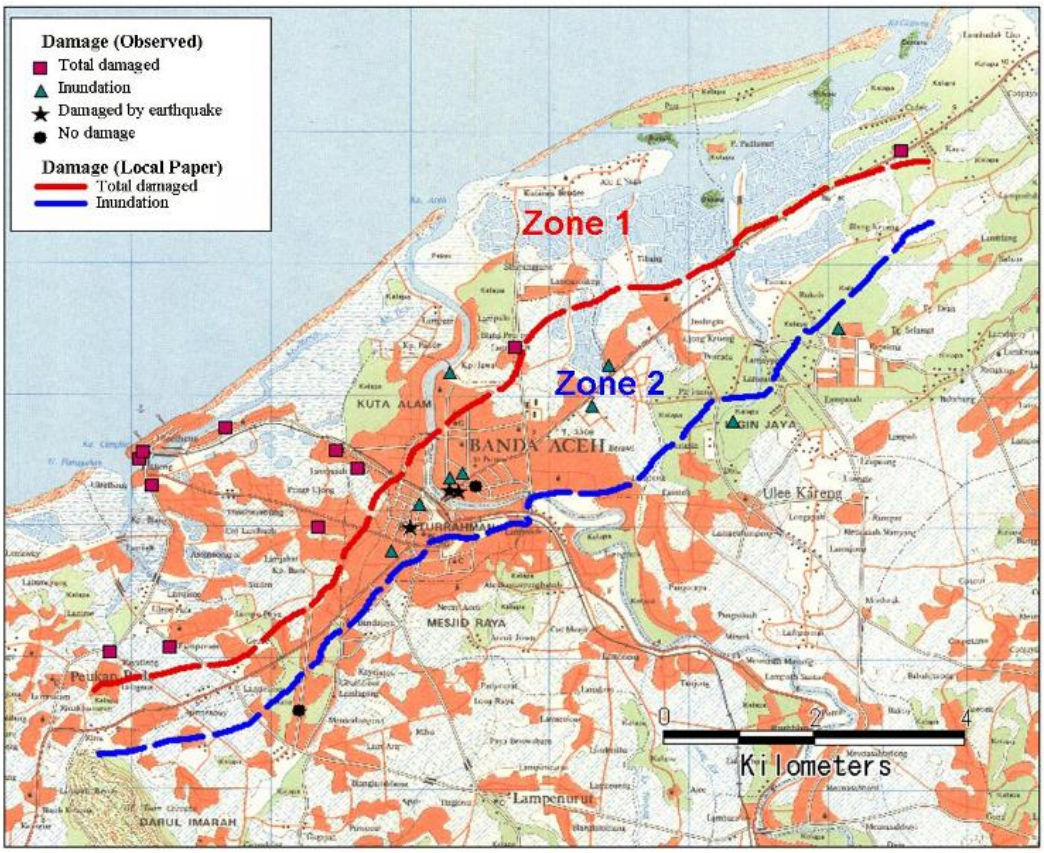
Source: Korem 012

Meulaboh: People were running to higher grounds after the first wave.

Sites Surveyed

3. Tsunami affected "zones"

In general there are two zones affected by the tsunami, zone 1 is the coastal areas were destructed by the tsunami forces such as battering, scouring, impact and buoyancy. In Banda Aceh this zone goes up to 3 km inland. Zone 2 was only inundated, where the tsunami force is already reduced and only caused flooding, dumping mud and debris. This area is approximately 0.5 to 1.5 km further inland.



Damaged & Inundation Zones in Banda Aceh

4. Propagation of Tsunami Waves

In areas where the beach is gently sloped, the tsunami waves were very powerful and this is evident in places like Lhok Nga, Ulhue Lhe, Krueng Raya and Meulaboh. The destruction by the tsunami in those areas was very severe. The damage was mostly by the battering and scouring forces of the tsunami. This is evident from the timber debris originating from frames of timber houses which were practically disintegrated into building components. For masonry construction, walls were shattered into pieces of almost equal size and RC columns ripped off from the foundations and beam column connections severely damaged.

In places where there is a harbor with deep water, the tsunami wave strength was reduced and the dominant force is buoyancy. This could be observed at Lhok Nga cement factory jetty, Malahayati harbor and Ulhue Lhe harbor. In the case of Ulhue Lhe harbor, the tsunami waves came from the North and its buoyancy effect cause damage to the Harbor buildings. The jetty was protected by breakwater walls.

In areas close to the center of the city of Banda Aceh, damage by impact force could be observed. The impact force is caused by floating of fishermen's boats and also by cascading debris in mud. The impact force is exaggerated by the density of mud which is larger than water. It was observed that the tsunami flowed into rivers and lagoons and subsequently spilled over into landward areas. It is also observed that, in hilly areas, tsunami waves were able to run up much higher elevation along hill slopes and valleys than those in plain areas.

Various reports define the tsunami heights and are not exactly the same. The tsunami heights observed were from measurements of water level traces on walls from the ground level are approximately as follows:

- Meulaboh (Western Coast) about 4 m
- Lhok Nga (West of Banda Aceh) about 15 m (run-up height against hillside)
- Banda Aceh about 8 m in coastal areas (zone 1) and 2-3 m in zone 2
- Krueng Raya (North coast) about 6 m (watermark on coastal side wall of the Mosque)

The different tsunami heights in different locations have almost the same destructive powers as can be seen in the pictures.

Inundation Height in Banda Aceh






Inundation Height in Meulaboh

Tsunami Run-Up Height in Lhok Nga

5. Damage of Buildings

Two types of buildings affected:

a. Engineered Buildings

b. Non Engineered Buildings.

a. Engineered Buildings consist mostly of Reinforced Concrete Structures

Almost all "engineered" buildings in Banda Aceh were unaffected by tsunami but some collapsed by the shaking of the Dec 26, 2004 earthquake

The causes of typical damage of reinforced concrete engineered buildings during the Sumatra earthquake in Banda Aceh were mostly due to vertical irregularities in certain RC buildings creating abrupt changes in stiffness and strength that may concentrate forces in an undesirable way. Also poor quality of concrete and detailing contributed to the collapse of those engineered buildings.

Right after the M 8.9 occurred, some high-rise buildings were damaged and a couple collapsed. The most obvious damage occurred to Kuala Tripa hotel, a 5 story RC building. It suffered a "first soft story" collapse. The second and third floor was severely damaged because of the impact but the building as a whole did not collapse. The collapse was caused by poor detailing and most probably it was analyzed as 2-D structures, therefore overlooking the first soft story effect. Another visible collapse was a three story supermarket, the Pante Pirak. The collapse was due to poor quality of construction. Another building that partially collapsed was the office of the department of finance. One of the wings suffered a pancake type of collapse. From the damaged columns it can be seen that the detailing was poor. This building suffered partial damage when shaken by a moderate earthquake in 1983. There were few other buildings such as two stories shop house buildings that were damaged by the earthquake shaking, however, most of those buildings were poorly designed as well as poorly constructed. In general, it can be said that very few buildings collapsed or were damaged by the Dec 26 2004 earthquake shaking because the epicenter was some 240 km away from Banda Aceh. Even the subsequent aftershocks with an epicentral distance of approximately 100 km, did not cause any further damage to those buildings as well as other buildings.

Kuala Tripa Hotel


Pante Pirak Supermarket


Department of Finance's Office

b. Non Engineered Buildings consist of:

i. Burnt Brick Masonry with sand and cement mortar.

ii. Timber buildings

The majority of the buildings that collapsed in Banda Aceh city, and villages in Lhok Nga, Krueng Raya, and Meulaboh city, are non engineered buildings consisting of two types. The first type is a one or two stories buildings made of burnt brick confined masonry using sand and Portland cement mortar. The roof mostly consists of galvanized iron sheets. All those buildings used RC "practical" columns and beams as confinement. The second type is timber construction consisting of a timber frame and also timber planks walls and usually use galvanized iron sheets as roof.

Almost none of the people's housing, one to two story masonry buildings collapsed by the shaking, even though some had cracks in the walls. **The destruction was caused by the tsunami forces.**

Most of the buildings in the coastal areas consist of non-engineered timber structures and confined masonry structures. The ratio of those two types of structures is estimated to be 30 % to 70 %. The epicenter of the M8.9 earthquake is approximately 240 km SW of Banda Aceh, therefore the shaking was not too significant and timber structures are reasonably built

and could withstand the M8.9 earthquake shaking. Masonry structures are also reasonably built. In Indonesia in almost all rural as well as urban areas , a good earthquake resistant design feature can be identified, namely almost all masonry buildings are built with reinforced concrete framing, consisting of the so called “practical columns and beams”. They did not collapse by the M8.9 earthquake shaking. Such type of masonry construction has become a new culture in Indonesia and from past earthquakes it is evident that provided they were built with good quality materials and good workmanship, they survived the most probable strongest earthquake in accordance with the Indonesian seismic hazard map. In Indonesia, the damage and collapse of the new culture “non-engineered” masonry buildings are mostly caused by the poor quality of materials and poor workmanship, resulting in, among others poor detailing, poor concrete quality, and poor brick lying.

The reconstruction period is a good momentum to start making quality control a culture to improve the performance of such buildings when shaken by earthquakes.

Banda Aceh (Zone 1)

Banda Aceh (Zone 2)








Ulhue Lhe (Zone 1)

Source: Digital Globe








Lhok Nga (Zone 1)













Krueng Raya (Zone 1)





Meulaboh (Zone 1)




Meulaboh (Zone 2)








6. Damage of Infrastructure

As was the case with buildings, most of the damage of infrastructures was caused by the strong force of tsunami and not by shaking.

- **Roads**

  Some roads in Banda Aceh were scoured by tsunami but the majority was still in tact. Most of the main roads in zone 1 were covered by huge amount of tsunami debris. Several parts of the road from Banda Aceh to Meulaboh were washed away by tsunami.

Some of the Damage of Roads and Bridges from Banda Aceh to Meulaboh

Ulhue Lhe Lhok Nga

- **Bridges**

  In Banda Aceh, several bridges were destroyed, the one at Jl Iskandar Muda and the one leading to Lhok Nga. The Lhok Nga Bridge has a main span of 20 m and secondary span of 10 m made of galvanized steel frames. Both were dumped into the river. Along the road from Banda Aceh to Meulaboh (distance approx 270 km), several bridges were washed away by tsunami.

- **Ports**

  Generally, jetties and wharf of ports in Banda Aceh and in Kreung Raya as well as the jetty of the cement factory Lhok Nga were slightly damaged but could still function. Part of the platform of the jetty in Meulaboh was washed away by tsunami, but the supports were still in tact. The main building of the Ulhue Lhe harbor in Banda Aceh was damaged and only the frame remained.

Fishermen Jetty in Ulhue Lhe


Lhok Nga Cement Factory Jetty


Part of Jetty Meulaboh Harbor

Jetty Malahayati Harbor

- **Power supply**

  Main Power generating plant in Banda Aceh was not affected by the shaking or tsunami. However, many distribution poles and wires in devastated areas collapsed.


- **Telecommunication**

  Some mobile phone antennas towers were dismantled by the tsunami and dragged up to 2 km from its foundations. Many telephone junction boxes were practically destroyed.

- **Water supply**

  Water Treatment plant in Banda Aceh was not affected by neither the shaking nor the tsunami, however, the piping systems were destroyed by scouring of the tsunami.

- **Industrial**
  - A cement factory located at beach side in Lhok Nga district was severely damaged.
  - Oil depot in Kreung Raya (East of Banda Aceh) was damaged and several storage tanks were dragged up to 1 km. The tanks were submerged by about one-third of its height.

Cement Factory, Lhok Nga

Pertamina Oil Depot, Krueng Raya

7. Emergency Response System

The mega tsunami that devastated Aceh was extraordinary and almost half of the 4 million population of Aceh were directly as well as indirectly affected. One or several of their family members are missing or died during the tsunami, therefore, since day 2, almost no local people were participating in the search and rescue because they must take care of their own family first. This resulted in the management of the deceased is very slow and until 7 days after the M 8.9 earthquake, many dead bodies were still scattered in streets and under debris. Only the Red Cross and the army were taking care of the deceased. Also, telecommunication broke down totally, making communication and coordination between the local and the central government

very slow and difficult, resulting in the late management of logistics, such as food, medical supplies, gas etc. Electric power was also switched off inspite of the fact that the power generating plant was not affected by the earthquake or tsunami. Electric poles and wires in certain areas were damaged by the tsunami. The telecommunication was only partially restored after almost two weeks and this created panic for survivors in trying to contact their relatives and also in updating the central government about the facts on the ground. Electric power was also partially restored after two weeks.

The management of debris and rubble created by the tsunami was also late and resulted in the late start of the "recovery" process. Subsequently, after assessing the situation, the central government brought in additional army battalions from outside Aceh and also volunteers from various provinces started pouring in to take care of the complex problems arising from the tsunami. The "outside" people were not affected by the tsunami and could therefore concentrate on the assignments given to them. The Emergency Response Medical volunteers that came from a various provinces did a very good job in managing the tsunami victims and subsequently with the foreign armies' medical teams managed to control the outbreak of various communicable deceases.

Right after any disaster, it is essential to refunction TELECOMUNICATION immediately. This will make emergency response easier and faster.

In general, multinational armies and volunteers arrived in Aceh one week after the earthquake and tsunami and they were immediately involved in the emergency response, however, many foreign armies started to build field hospitals which in a tsunami case might be needed but NOT that many since the urgency was not there. As is known, a tsunami caused more dead victims than injured ones. Also, as a common case, many foreign countries sent medical supplies labeled in their own language and these are useful when used by their medical staff who really understand s what is written in the labels, but not so for the local staff except those written in English.

The challenges in the recovery is not to repeat mistakes from past disasters , among others on how to prevent NGOs, local as well as foreign from bringing in all sorts of "alien" materials and products such as knockdown houses which are not compatible with the local culture. All Government officers and community leaders and donors are discussing about the recommendation to relocate the destructed villages and almost all of them are relying on NGOs/donors who have shown willingness to "adopt" certain villages. **Appropriate planning and analysis shall be made prior to recommending implementing post earthquake disaster relocation.**

Efforts must be emphasized on how to make such masonry houses earthquake resistant and information dissemination on how to appropriately build masonry houses, meaning the enhancement of the current practice to produce good quality buildings as a culture. Earthquake resistant should be interpreted as resistant if shaken by an earthquake and not if subjected to tsunami, particularly to cater mega tsunamis such as the Dec 26, 2004 one. It is considered impractical to design buildings having adequate strength for resisting extreme tsunami loads, such as: hydrostatic pressure, buoyancy, battering, impact, and pulsating water, translation, scouring, and overturning. Extreme pressures were exerted on all surfaces of structures during the Aceh tsunami. Such pressures resulted in cracking, displacement, and collapse of walls, floors and framing of structures. In some areas, timber as well as masonry houses were totally disintegrated by the tsunami.

Coordination by the Indonesian government during the first weeks of the disaster was not well managed resulting in the uncoordinated locations of foreign armies' activities and facilities. Also the flow and storage of so many food as well as medical supplies was not well organized.

During the multi national presence, everything seemed to be relatively easy to get, free of charge, particularly healthcare and some medical supply as well as food. If the free medical care and particularly free food supply is provided for too long, it can create an over expectation on the displaced people and cause envy among the people unaffected by the tsunami.

8. Economic Effects of the Tsunami

It is predicted that the Aceh tsunami of Dec 26, 2004 will not have a significant effect towards the Indonesia economy and the 2005 national growth is still predicted as 5-6%. It is also predicted that the tsunami will not negative effects towards the expectation and risk perception on the Indonesian economy and will not disrupt investment plans as well as the performance of the exchange rate.

That statement was issued by the Band of Indonesia, Directorate of Economic Research and Monetary policy. In addition the report also stated that if the flow of emergency supplies can be handled smoothly, the possibility of inflation could be minimized.

The effect of tsunami towards the Banking sector will also not be too significant because the role of banks in Aceh is small, below 1% of the national banking.

The role of Aceh economy towards the GNP is relative small, approximately 2%. It is predicted that the main Aceh economy activity in 2005 will be in the construction sector due to the reconstruction of the devastated areas. The effect of the tsunami towards export/import is also relatively small. The main export of Aceh is dominated by oil and gas products and the facilities for that purpose is not affected by the tsunami. The main import is chemical products and raw materials for both industry and this also will not be disrupted because the tsunami did not affect industries. However, the overall annual growth will be lower than the previously predicted 3.5%.

(Source: Report BI)

9. Devastating Local Impact

Inspite of the fact that the tsunami most probably will not disrupt the Indonesian economy, the loss of jobs could be crippling at the local level. Even though the damage of agricultural land is only 10%, it will take many years to recover. Farmers lost their livestock and equipments. The aquaculture losses were quite substantial.

Apart from all those, as mentioned earlier, the tsunami also swept and destroys many roads, bridges, drainage systems, water piping, electrical lines, and telecommunication towers.

The repair and rebuilding of those all and the resettlement of displaced people will take many many years and will need a substantial amount of fund, maybe a substantial percentage of the gross domestic product of the country.