Chapter 10

Damage to Ports and Coastal Facilities

10.1 Area Investigated

Tsunami induced heavy damage to ports and coastal facilities along the west and north coast of Sumatra Island. Figure 10.1 shows the investigated facilities around Banda Aceh area. The coastal area of Banda Aceh is consists of alluvial flat area around -0.45m to +4.5m from mean sea water level. Most of area below the mean sea water level is used as aquaculture ponds.

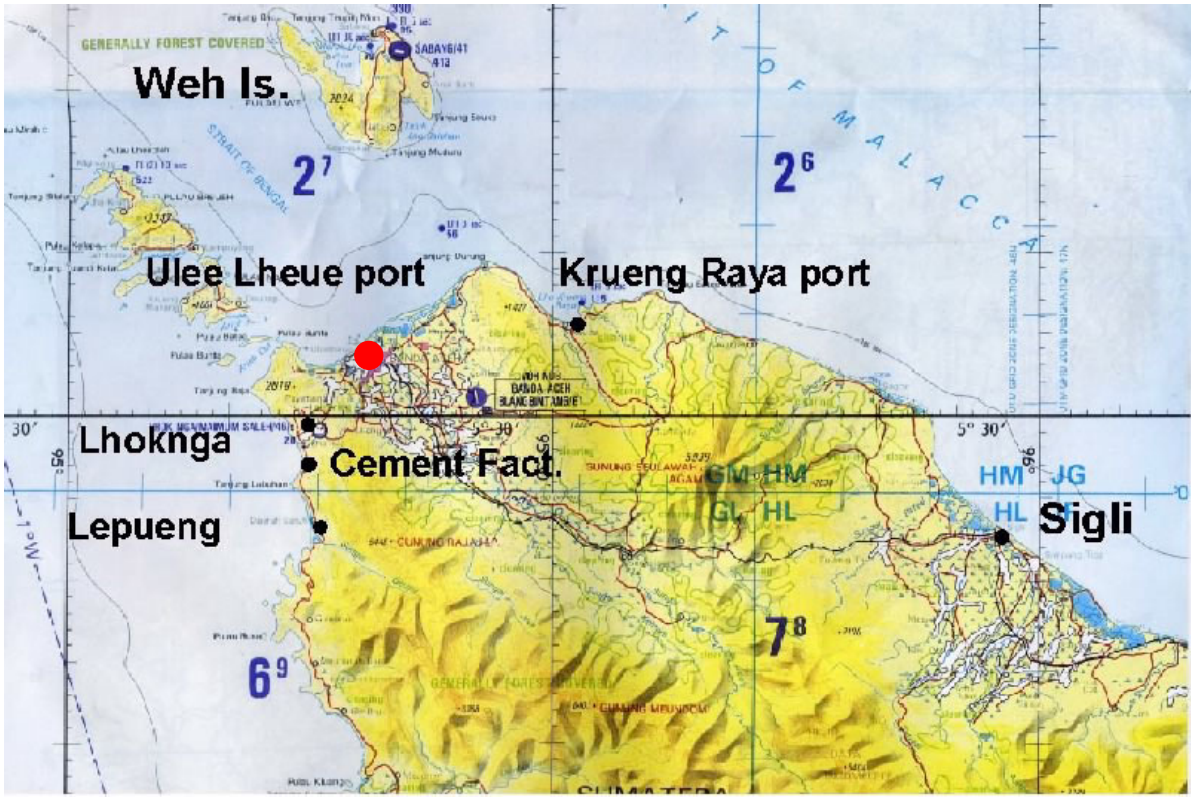

Figure 10.1 Investigated area (Northern part of Sumatra Island,
Modified from TPC L-9B published by DMA-USA)

10.2 Ulee Lheue Port

Figure 10.2 show satellite views of Banda Aceh port before and after the earthquake. As noticed from the comparison of two satellite views, a huge area was damaged by the tsunami and was settled, eroded and scoured due to probably ground liquefaction induced by ground shaking as well as due to the tsunami waves. The ground consists of sandy soil in this area. It is also of great interest that some parts of the dykes of the harbor disappeared. Besides the effects of liquefaction, the flow direction of tsunami waves might have some damaging effects on the missing section of the dykes.

Before the earthquake

After the earthquake

Figure 10.2 Satellite views of Ulee Lheue port before and after the earthquake

The plan view of Ulee Lheue port is shown in Figure 10.3 and 10.4. The residential area is protected by rubble stone (2000kg-3500kg) revetment with gentle slope as shown in Figure 10.5. The severely damaged missing area between residential area and the ferry terminal is used as small boat/fishery boat access port with submerged breakwater as shown in Figures 10.4 and 10.5.

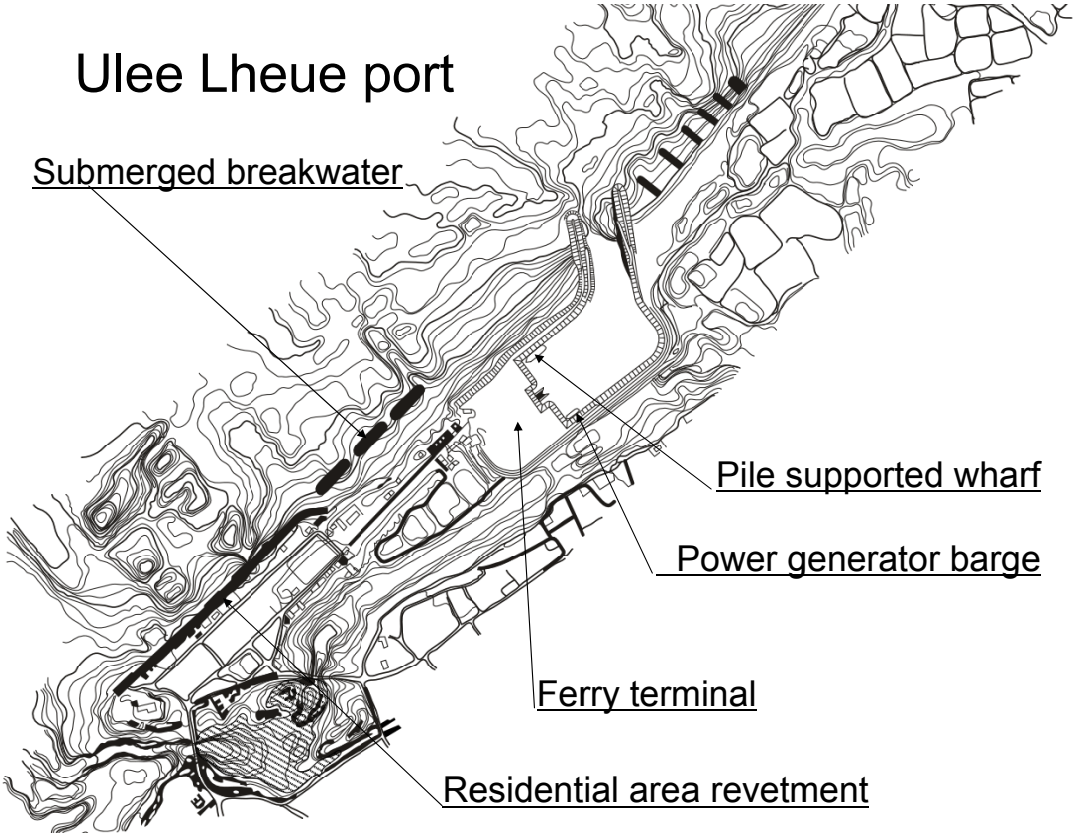

Figure 10.3 Plan View of Ulee Lheue Port

(Traced drawing of the picture provided by Departemen Permukiman dan Prasarana Wilayaha, Direktorat Jenderal Sumber Daya Air, Detail Design Panttai Syiah Kuala Kota Banda Ache, 2003)

Large stone blocks were thrown by the tsunami waves over the wharf of the port as seen in Figure 10.3 However, as shown in Figure 10.2, just behind the stone rubble revetment a residential area was disappeared. During construction of the revetment, naturally deposited sandy dyke was excavated and stone rubbles were placed and then remolded as shown in Figure 10.5 top. The remolded water pluvial sand layer should had been liquefied during the earthquake motion.

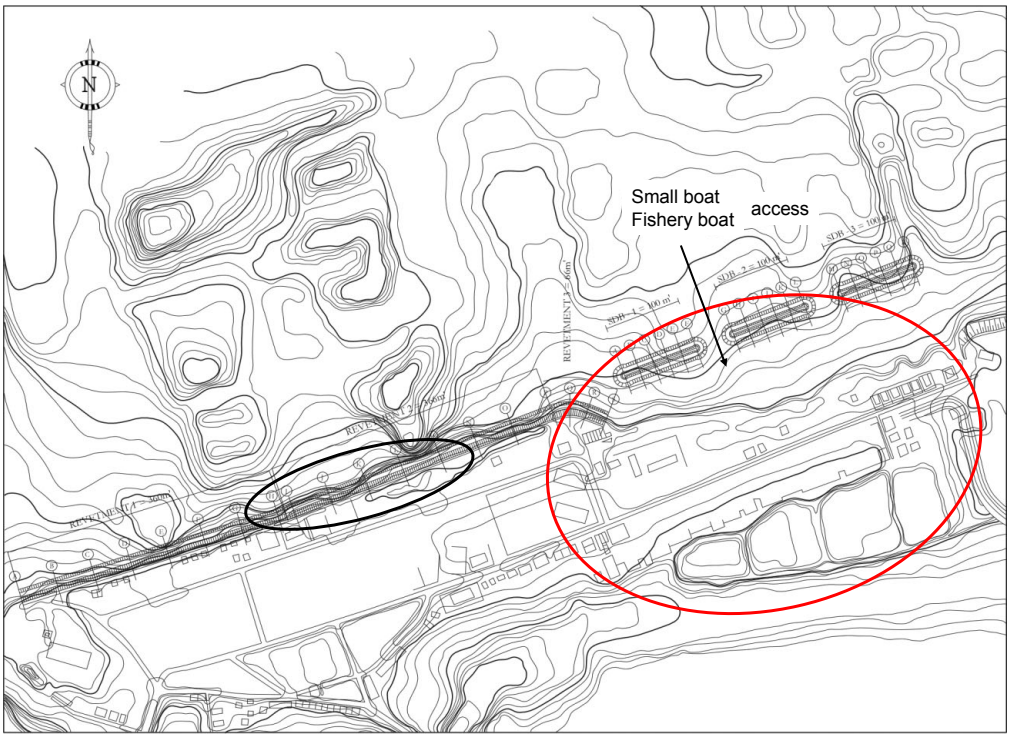

Figure 10.4 Plan view of the revetment and the submerged breakwater

(Traced drawing of the picture provided by Departemen Permukiman dan Prasarana Wilayaha, Direktorat Jenderal Sumber Daya Air, Detail Design Panttai Syiah Kuala Kota Banda Ache, 2003)

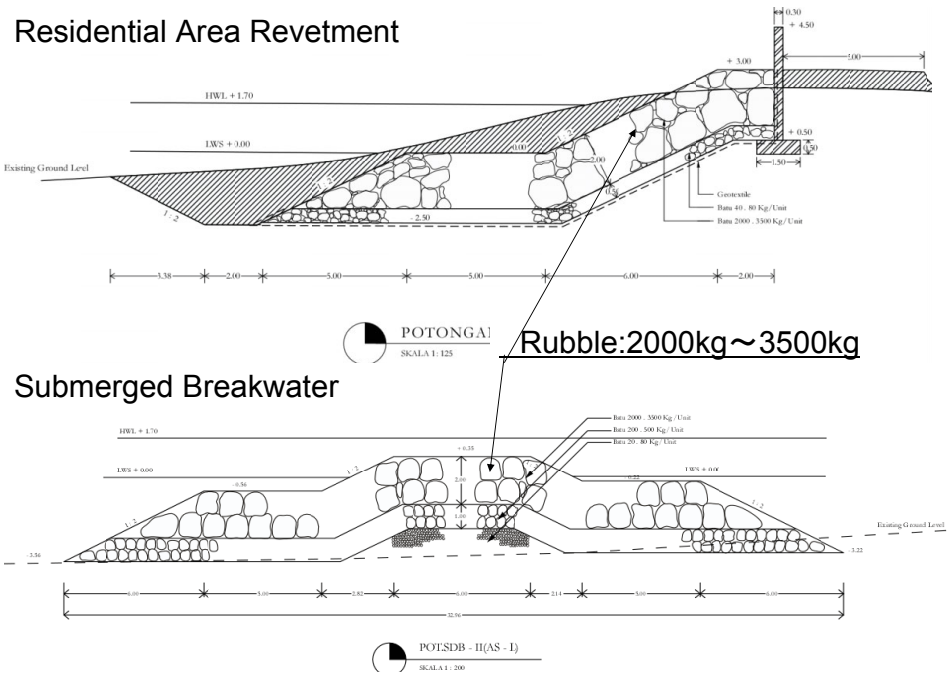

Figure 10.5 Cross section of revetment and submerged breakwater

(Traced drawing of the picture provided by Departemen Permukiman dan Prasarana Wilayaha, Direktorat Jenderal Sumber Daya Air, Detail Design Panttai Syiah Kuala Kota Banda Ache, 2003)

The pile supported wharf for ferry boat (Figure 10.6) has no damage during the earthquake motion and the tsunami. However, two pieces of rubble stones (2,000kgf-3,500kgf) observed on the deck as shown in Photo 10.1 due to the tsunami wave.

Photo 10.1 Pile supported wharf for ferry boat

Although the dolphin for a barge with a power generator was not damaged by the tsunami as seen in Photo 10.2, the barge (Photo 10.3) was displaced from the dolphin to a distance of 3km inland.

Photo 10.2 Dolphin for a power generator barge

Photo.10.3 Power generator barge

The RC building of the port facility collapsed at the ground floor as seen in Photo 10.4. However, the main cause of collapse was ground shaking rather than the tsunami waves because of the second floor with slightly damaged columns was survived during the tsunami waves (Photo 10.5). The ferry terminal building, which is a RC pile-deck structure without shear walls, collapsed at ground floor and the ground floor columns acted as a base isolation system. The second and top floors survived the earthquake and the tsunami.

Photo 10.4 Ferry terminal (collapsed ground floor)

Photo 10.5 Ferry terminal (2nd Floor)

The port facility for the cement factory was also damaged by the tsunami. The 5m high gravity type parapet with a trapezoidal cross section was overturned as shown in Photo 10.6. Totally, three blocks were overturned, two blocks of the parapet were overturned outside direction of the port and other one was overturned opposite direction. To investigate the overturned scenario, detail consideration of the layout of the parapet and tsunami wave action should be needed.

Photo 10.6 Damaged seawall at cement factory

Photo 10.7 shows the damage of pile-supported wharf due to the capsized ship impact force during the tsunami. A pile supported wharf showed good performance during tsunami waves as mentioned in section 10.2, however, it must be considered drifting object's impact force against the structures.

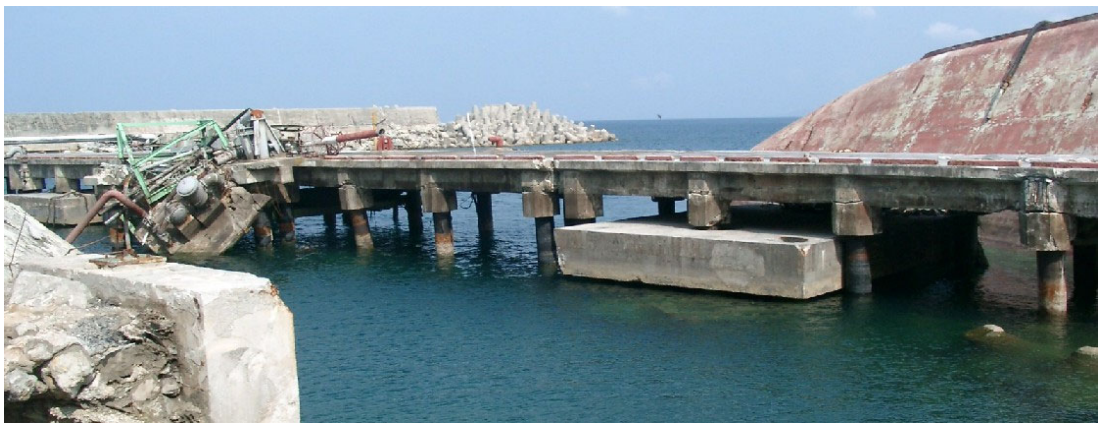

Photo.10.7 Damaged pile-supported wharf at cement factory

10.4 Remarks

From the site observation/investigation of Banda Aceh coastal area facilities, following findings are summarized.

(1) It was quite difficult to distinguish between damages of port/coastal area facilities caused by the earthquake motion and by the tsunami wave action. Significant damages were caused by scouring phenomenon and impact force of drifting objects during the tsunami. However, the possibility of double action effect by the earthquake motion and tsunami wave should be considered.

(2) The pile-deck structures such as pile-supported wharf, pile-supported dolphin and the ferry terminal pile-deck structures (pilotis style) showed good performance during tsunami wave. A pile-deck structure with a high seismic performance should be effective as a tsunami refuge structure as shown in Photo 10.8 (an actual tsunami refuge terrace in Japan). It must be noted that the impact action of drifting objects should be considered in the design of structures against tsunami.

Photo 10.8 Tsunami Refuge Terrace at Aonae fishery port, Hokkaido, JAPAN
(Refugees run up the terrace and then evacuate to mountain area through the overpass deck when tsunami warning alert is announced.)

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