Learning from Earthquakes

The Northern Sumatra Earthquake of March 28, 2005

Editor's Note: *Beginning with the March issue and in each one subsequently, we presented six reports by the many teams that observed the effects of the December 26, 2004, earthquake and tsunami in countries around the Indian Ocean. This report adds information on structural damage, largely from shaking, on two islands west of Sumatra in a subsequent large earthquake in roughly the same epicentral area as the December quake. Publication of this report is supported by funds from the National Science Foundation through EERI's Learning from Earthquakes Program under grant # CMS-0131895.*

Within a few days of this earthquake, a team set out from Jakarta to study the earthquake damage on the islands of Nias and Simeulue. The team leader and author of this report was Teddy Boen, consulting engineer in Jakarta and senior advisor, WSSI. Survey team members on Nias were Teddy Boen, G. Hendra, P. Idrus, K. John, James Wong, M. Agus, and B. Bernard. Survey team members on Simeulue were Teddy Boen, G. Hendra, and Akil R. Karsono.

Introduction

On Monday night March 28, 2005 at 11:09 pm local time, the Nias and Simeulue islands were shaken by a M8.7 earthquake with a depth of 30 km. The epicenter of the earthquake was on the Great Sumatran fault, between the two islands at 2.074°N, 97.013°E (see Figure 1). This is 115 km from Gunung Sitoli, the district capital of Nias, and 84 km from Sinabang on Simeulue. In Gunung Sitoli and Teluk Dalam, many house shops collapsed and killed around 1,000 people while they were either sleeping or trying to run from the second and third floors. In Simeulue, some house shops collapsed, and about 100 people were killed. There was a rush to exit houses and run to higher places because the people feared a tsunami similar to that of December 26, 2004. There was a local tsunami, but not of the size or ferocity of the previous one.

Nias Island is part of North Sumatra Province and Simeulue Island is part of Aceh Province. The population of Nias is 730,000 and that of Simeulue is 80,000. Most of the people on Nias and Simeulue were already asleep, or about to be, when the earthquake occurred. Right after the earthquake, electric power was cut off and telecommunication disrupted. In Gunung Sitoli and Teluk Dalam, Nias, the damage was concentrated in certain areas close to the beach. In Simeulue the damage was also concentrated in areas close to the beach. Strong aftershocks (32 km from Gunung Sitoli [M 6.0] and 41 km from Sinabang (M 5.5]) did not cause any further damage to either damaged or undamaged buildings.

Tectonic Effects

During the survey in Simeulue as well as in Nias Island, we observed some subsidence in certain very limited areas. There were also "pop-

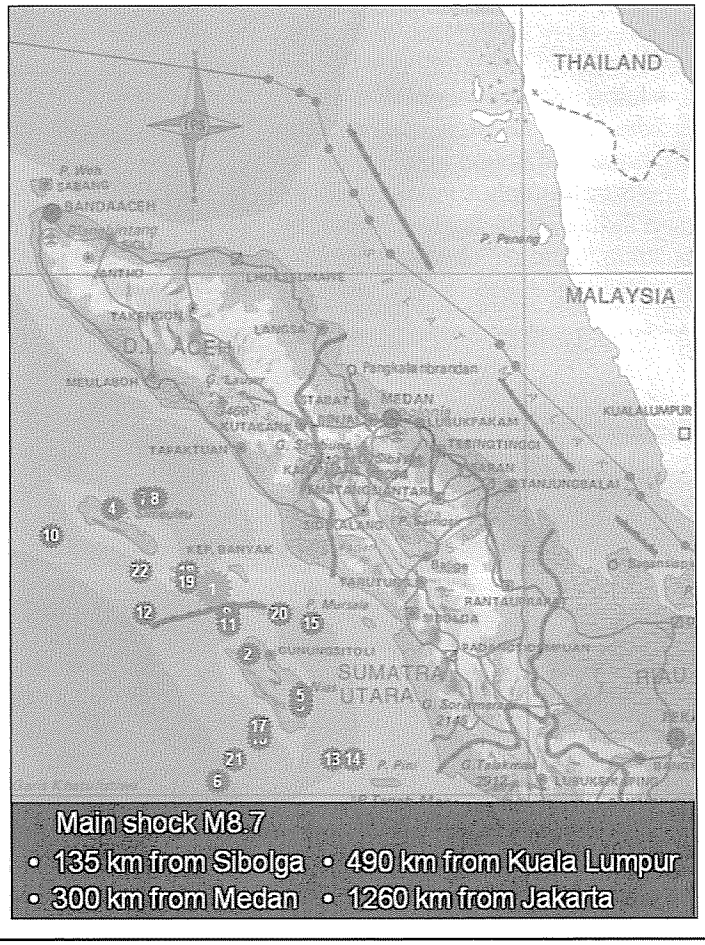


Figure 1. *Main shock and aftershocks of the Nias/ Simeulue earthquake, March 28, 2005 (USGS).*

Figure 2. *"Pop up" beach at Matanurung, East Simeulue.*

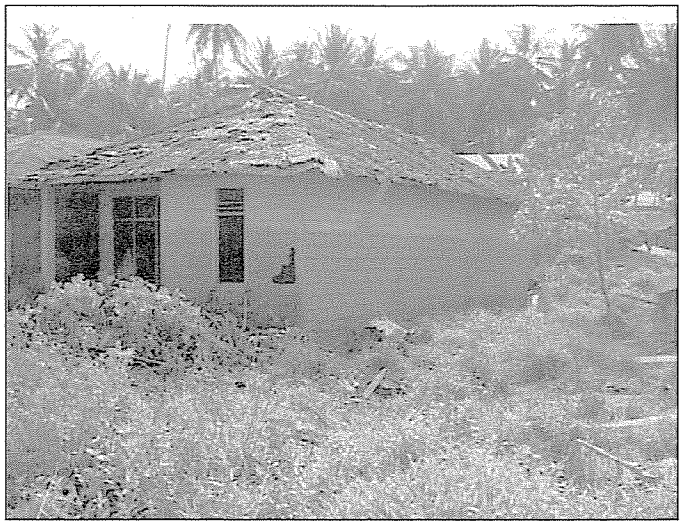


Figure 3. *Local tsunami height approximately 1.80 m.*

up" beaches in Nias and Simeulue, caused by uplift (see Figure 2). Staff members of NGOs who worked in several places across Simeulue reported that they also observed similar pop-up beaches all over the island.

After the earthquake, a local tsunami hit limited areas. In Nias, along the road entering Sorake and in Sorake itself, the tsunami height was approximately 1.80 m, as can be seen on the wall of house in Hiliamaetaniha, approximately 1 km from Sorake (see Figure 3). In Sorake, several building foundations were scoured by the tsunami, and some buildings collapsed. The local tsunami went inland up to 400 m in Hiliamaetaniha. From the damage, it appeared that the flow force was not too strong. In Simuelue, traces of local tsunami could be seen in Labuan Bajau primary school # 2 (see Figure 4). The tsunami height was approximately 0.5 m and no evidence of flow force could be seen.

Damage to Buildings

Two types of buildings were affected: engineered and nonengineered. In Nias and Simeulue, there are few engineered buildings except for district head offices, hospitals, and some other government buildings. Engineered buildings consist mostly of reinforced concrete combined with masonry walls. Almost 95% of the buildings are nonengineered, made of confined masonry half-burnt brick, concrete block, and timber.

Engineered Buildings: Some engineered buildings in Nias and Simeulue were damaged during the earthquake, and some collapsed. There are two main reasons for this. The reinforced concrete buildings

Figure 4. *Damage by local tsunami in Labuan Bajau school, Simeulue.*

Figure 5. *District head office in Simeulue.*

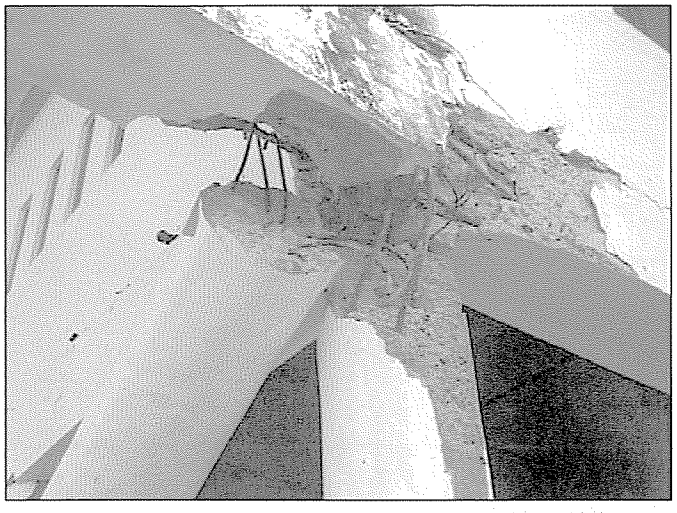


Figure 6. *Damage to district head office in Nias.*

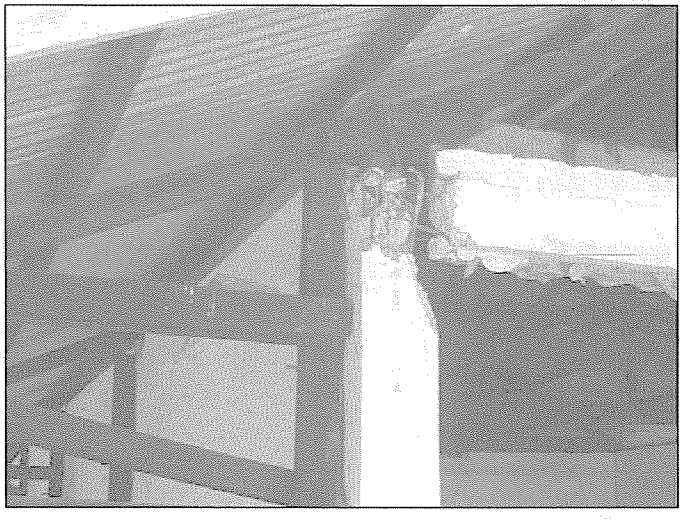
Figure 7. *Damage to district head office in Simeulue.*

were not designed for the seismicity of the islands. We also found that poor quality of concrete and detailing contributed to the collapses. Even though Indonesia has a seismic code, it was not enforced in either island. Additionally, the building permit system was not yet in place.

For example, both district head's offices were damaged (see Figure 5). We surmise that in each case, the structure was analyzed as 2-D, with the torsional effect overlooked. From the damage, it was evident that the concrete quality was low and the detailing was not in accordance with requirements for earthquake-resistant construction (see Figures 6 and 7).

Nonengineered Buildings: Most of the buildings were nonengineered that collapsed in Gunung Sitoli in Nias, Sinabang City in Simeulue, and villages along the road from Sinabang to Labuan Bajau and from Gunung Sitoli to Teluk Dalam in Nias. There are three main categories of nonengineered buildings: 1) one or two-story houses of burnt brick or concrete block masonry with sand/cement mortar; 2) two to four-story shop houses of burnt brick or concrete block masonry with sand/cement mortar; and 3) timber buildings. In some areas, sea sand is used for concrete mix and, of course, results in poor quality concrete.

The one or two-story buildings were mostly houses, schools, and community health centers. The roofs of the houses mostly consist of galvanized iron sheets or thatch made of coconut tree leaves; other buildings use galvanized iron sheets. These masonry buildings survived the shaking without collapse, though some had cracks in the walls (see Figure 8).



Figures 8a and b. *Nonengineered masonry houses damaged and collapsed in Nias.*

Figure 9. *Timber houses collapsed in Nias due to lack of maintenance.*

Figure 10. *Traditional indigenous house in Nias, not damaged.*

Figures 11a and b. *Traditional indigenous houses damaged due to lack of maintenance in Bawogosali Village, Teluk Dalam, Nias.*

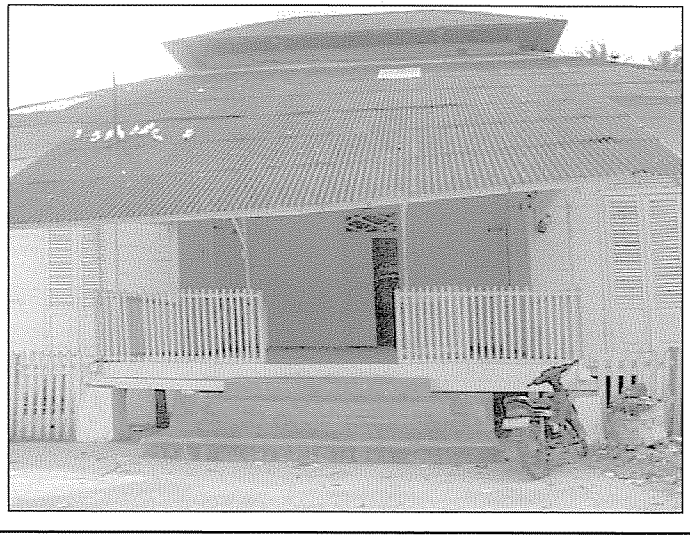


Figure 12. *Indigenous house built during Dutch occupation, slightly damaged due to lack of maintenance in Nias.*

The two to four-story shop house buildings also use burnt bricks or concrete block masonry with sand and Portland cement mortar. The roofs of these shop houses are usually RC slabs. All the buildings use RC "practical" columns and beams as confinement. The term "practical" is used because the specs are not based on any calculations and are adopted as a standard practice. The shop houses are built according to prevailing practice by contractors and foremen, without structural analysis or drawings. In neither Nias or Simeulue was the building permit system enforced;

Figure 13. *"Pancake" type of collapse of shop houses that killed many people in Teluk Dalam, Nias.*

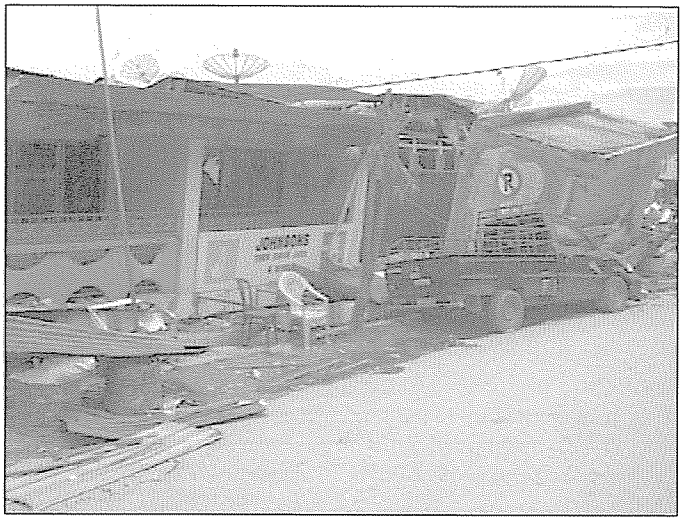


Figure 14. *Another pancake collapse in Gunung Sitoli, Nias.*

therefore no structural check was performed to catch poor-quality materials or poor workmanship.

Timber houses consist of a timber frame and timber plank walls, and galvanized iron sheet or thatch roofs. In spite of the closeness to the epicenter of the earthquake, the damage was not significant in reasonably built timber structures. Very few one-story timber houses collapsed during the earthquakes. The damage that occurred resulted from deterioration of the poorly maintained columns (see Figure 9). In addition, some timber columns were not anchored to the foundation. There were no tie beams to tie the columns together, so the columns moved in different directions during the earthquake. Some timber houses were leaning after the earthquake because the connections were not appropriately done.

Two types of indigenous nonengineered buildings still exist on Nias. First, the traditional houses built some 200 years ago are earthquake-resistant and withstood the shaking (see Figure 10). When these traditional buildings were damaged, the main cause was deterioration due to lack of maintenance (Figure 11). These types of buildings are not built anymore because of the lack of expertise in this generation, and because they are too costly to build. The other buildings, built by the Dutch some 150 years ago (Figure 12), are also earthquake-resistant when properly maintained.

Causes of collapse: The main causes of collapse in the two to four-story shop houses were poor materials and poor workmanship, exacerbated by the prevailing procedures of building in stages, depending on the availability of funds. The long intervals between the construction of various elements result in weak joints.

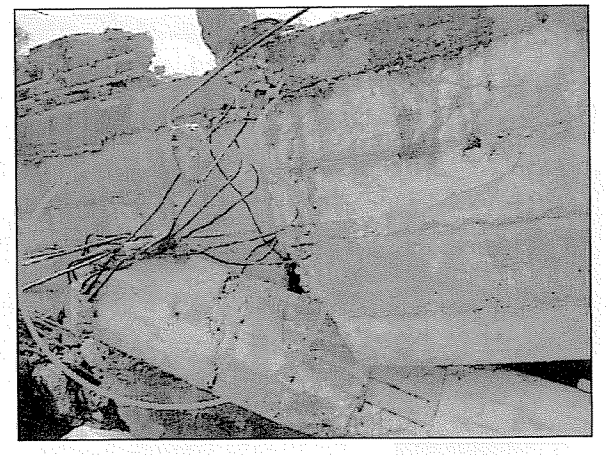
First the foundation is built with the column-reinforcing bars already in place. If additional funds are available, the columns are poured. The size of the columns average 30 x 30 (40) cm with eight reinforcing bars of diameter 12 mm and stirrups (usually not properly bent) of 6 mm at an average distance of 20 cm. Subsequently, the walls are built. Construction of some buildings stops after the walls are completed. The next stage is constructing the beams and floor slabs for the next story with splices for the upper-story columns. Most buildings are in use as soon as the first story is completed. Only after several months or years, when more funds are available, do the second-story columns and walls get built; the process of constructing the first story is essentially repeated. Some people continue the process for the third and fourth stories. Column reinforcements and stirrups are not sufficient if the structure works as an open frame, particularly in the longitudinal direction.

In the damaged structures we looked at, the length of the column splices for the upper floors construction was generally insufficient, and the concreting at the splices was very poor. This resulted in the shear failure of the columns, particularly at the joints; this was the main reason for the "pancake" or soft-story collapse of shop houses, particularly in Nias (Gunung Sitoli and Teluk Dalam), that resulted in most of the deaths (see Figures 13, 14 and 15).

For one-story confined masonry houses, the construction is also done in stages. First the foundation is built with column reinforcement embedded. The column size is 12 x 12 cm with four reinforcing bars of diameter 8 mm and stirrups of diameter 6 mm at an average distance

of 20 cm. If enough funds are available, the columns are poured. At a later date, the walls and the ring beams are built and, finally, the roof is constructed.

We observed several shop house buildings that were built and supervised by the owners, and did not suffer damage. We learned that they had been built continuously, not in stages with long intervals caused by shortages of funds. The workmanship and materials used were also of better quality.



Figures 15a and b. *Nonengineered masonry shop houses damaged and collapsed due to weak columns in Lagundri, Gunung Sitoli, Nias.*

Prospects for Change

In all areas in Indonesia, a good earthquake-resistant design feature is available, namely reinforced concrete framing consisting of practical columns and beams. However, in many places in both Nias and Simeulue, the columns and beams were not constructed in accordance with prevailing practice on Java. In spite of that, most did not collapse in the M8.7 earthquake shaking. Such masonry structures have become a new culture in Indonesia, and from past earthquakes it has become evident that they are appropriately resistant to the earthquake forces identified in the Indonesian seismic hazard map. This new culture is associated with social status: as their economic condition improves, people tend to build masonry houses at least partly because they are a sign of status.

The reconstruction period is a good opportunity to introduce the building permit system and to start enforcing the seismic code. Officials must start making quality control part of the culture in order to improve the performance of buildings in earthquakes.

Figure 16. *Cracks on road in Lasara, Gunung Sitoli, Nias, caused by lateral spreading.*

Infrastructure Damage

Most of the damage to infrastructure occurred to bridges, and there were fissures along the roads produced by subsidence and lateral spreading. Many bridges in both Simeulue and Nias were displaced from their supports from 30 cm to 100 cm. Many bridge abutments settled during the earthquake, thereby damaging bridge approaches. The differential settlement was jointly caused by lurching, liquefaction, and uneven compaction, particularly close to the abutments (see Figures 16 and 17).

The main electric power generating plant in Gunung Sitoli in Nias was damaged by the shaking (Figure 18). Transformers were slightly overturned (Figure 19) and some generator foundations settled. But the cable network in the city as well as along the road from Gunung Sitoli to Teluk Dalam was not affected, and after the power plant was repaired, electric power resumed. In Teluk Dalam, the cable network was practically intact. The power-generating plant in Simeulue was not damaged, but some cable network to Lasikin was damaged and took a few days to restore.

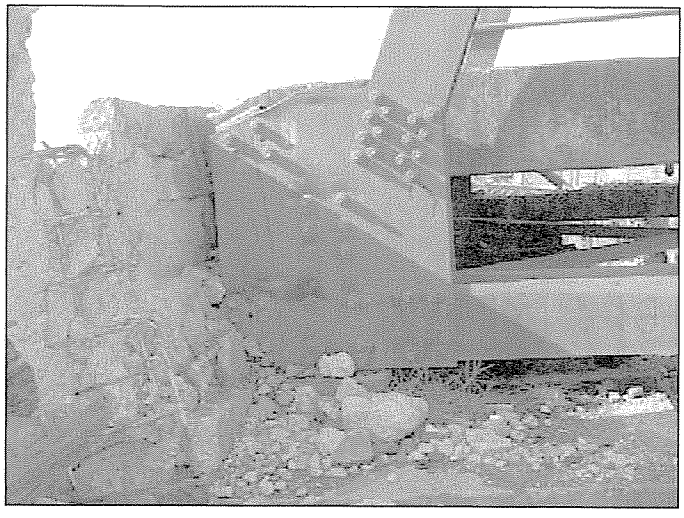
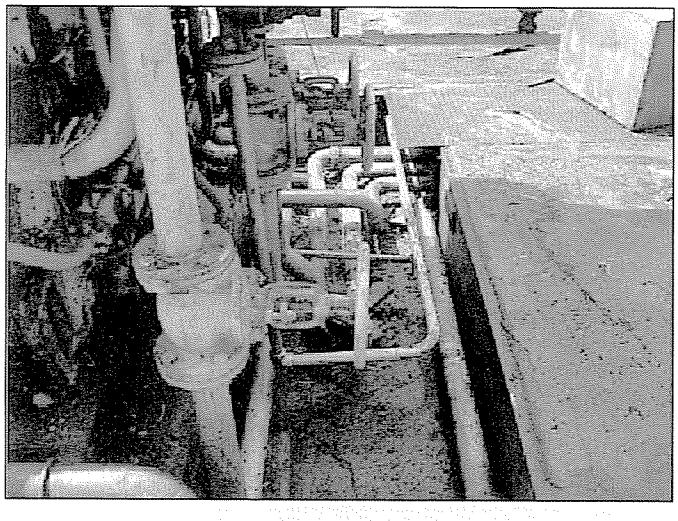
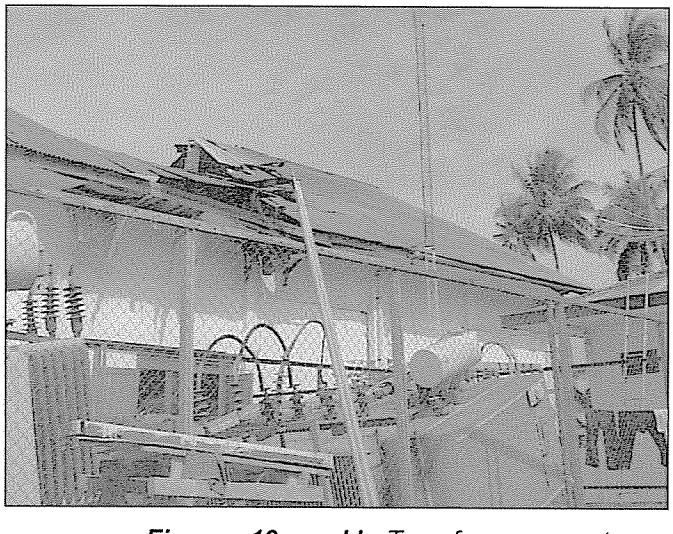


Figure 17a. *Movement of end support, bridge in Kelapa Street, Gunung Sitoli, Nias.*

Figure 17b. *Settlement of bridge approach in Teupah Barat, Simeulue.*



Figures 18a and b. *Power generating plant in Gunung Sitoli, Nias.*



Figures 19a and b. *Transformers overturned at power generating plant in Gunung Sitoli, Nias.*

Figure 20. *Damage to drinking water pipes by local tsunami in Lagundri, Hiliamaetaniha, Nias.*

Figure 21a. *Deformed jetty due to shear failure of column joints, Simeulue.*

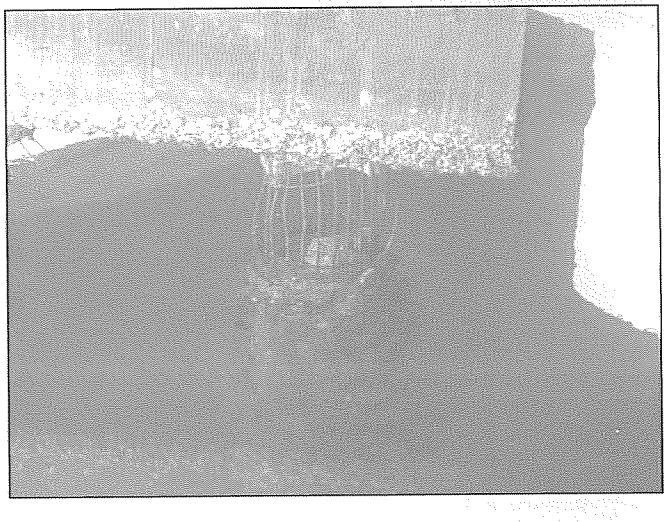


Figure 21b. *Shear failure of the column joint, Simeulue.*

The water purification plant in Gunung Sitoli, Nias, was not damaged, but the piping network was disrupted by the tsunami (see Figure 20). Distribution was done by water tank trucks. In Sinabang, Simeulue, the water purification plant was not activated prior to the earthquake because of a change in the piping system due to the widening of the main road. After the earthquake, water purification was provided by a German NGO, and water was delivered by tank trucks.

One part of the newly constructed jetty at Gunung Sitoli, Nias, sank into the sea, most probably because the piles were not driven down to the hard layer. Apart from that portion, the remaining jetty was still intact, which was fortunate in itself because hollow piles had been used. These should not, in fact, be used for undersea structures because the thickness of the concrete cover is not sufficient to protect the reinforcing bars from corrosion. In Simeulue, many of the same type of piles supporting the jetty were sheared at the connection between the pile head and the piles, because the upper parts of the columns were already deteriorated and weakened (see Figure 21).

Airport runways at Gunung Sitoli in Nias and Lasikin in Sinabang were not damaged; airplanes were able to land and take off right after the earthquake. At Lasikin Airport, some buildings collapsed, namely the terminal building (Figure 22), a storage building, and some airport staff residential houses.

Figure 22. *Collapsed Lasikin Airport Terminal Building, Simeulue.*