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DAMAGE IN NIAS ISLAND CAUSED BY THE M8.7 OFF-SHORE SUMATRA EARTHQUAKE, MARCH 28, 2005 AND THE SUPPORT ACTIVITIES FOR THE RECOVERY AND RECONSTRUCTION

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ABSTRACT

A very large earthquake with a magnitude of 8.7 occurred nearby Nias Island of Indonesia on March 28, 2005. Strong ground motions induced heavily casualties and damages to infrastructures such as roads and bridges, and buildings. Permanent ground movements such as settlement and lateral spreading, and associated structural damage due to liquefaction were widely observed in various locations along the coastal area and reclaimed ground. Many bridges were damaged by strong ground motion and permanent movement of abutments as a result of lateral spreading of liquefied ground. The heavily damaged non-accessible large bridges within the surveyed area are Lafau bridge, Muzoi bridge and Idano Gawo bridge, which were mainly, consist of truss superstructure and RC abutments and piers. Many buildings were heavily damaged due to partial settlement, inclination and uplift of ground floor in the reclaimed area in the coastal region of Gunung Sitoli. Many months elapsed from the earthquake, the infrastructures and buildings in Nias Island had still no prospect of being re-constructed. In order to initiate recovery and reconstruction work in the region, the soil exploration data such as boring data is essential. The experts and engineers were dispatched again to Nias Island to introduce practical ground surveying methods such as Swedish Weight Sounding Test to local engineers for their applications to the recovery and reconstruction of the damaged areas. Continuation of the technical support and dissemination activity of transferred techniques should be done in the future.

Keywords: Strong Motion, Liquefaction, Lateral Flow, Swedish weight Sounding, Reconstruction

INTRODUCTION

The Sumatra Earthquake of December 26, 2004 caused the most disastrous tsunami in Indian Ocean and great disaster to the countries around the Indian Ocean, especially in Indonesia. Three months after the earthquake, another large earthquake with a magnitude 8.7 occurred on March 28, 2005 nearby Nias Island at the west coast area of Sumatra 500km away from the epicenter of the 2004 earthquake. Severe damage was caused by strong ground motion especially in Nias Island. For these disasters, Japanese organizations in cooperation with some Indonesian organizations conducted support activities for the recovery and reconstruction of the affected areas. These included making recommendations and giving instructions for geotechnical investigations and the practical utilization

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of its results for temporary repair and rehabilitation of infrastructures and buildings (e.g. Support Team of JSCE, 2005; Miwa et al., 2006a). Also educational activities on disaster prevention (e.g. Hamada et al., 2005a; Tsukazawa et al., 2005; Kitajima et al., 2006) as well as the reconnaissance surveys of earthquake affected areas. In this article, the characteristics of M8.7 offshore Sumatra earthquake, March 28, 2005 and induced damages in Nias Island obtained during these activities (e.g. Aydan et al. 2005; Miwa et al. 2006a, Miwa et al. 2006b) and additional studies are described.

THE CHARACTERISTICS OF THE EARTHQUAKE AND OUTLINE OF THE RECONNAISANCE

Table 1 gives the main characteristics of the earthquake inferred by USGS (USGS, 2005) and Harvard University (Harvard Univ., 2005). USGS estimated that magnitude (Mw) was 8.7 and hypocenter was just beneath Banyak Islands to the north of Nias Island. The hypocenter estimated by Harvard was further south and nearby Nias Island. Rupture and slip characteristics estimated by Yagi (Yagi, 2005) and Yamanaka (Yamanaka, 2005) are given in Table 2. Figure 1 shows the rupture area estimated by Yagi (Yagi, 2005). The length and width of rupture area were inferred to be about 470km and about 100km, respectively and slip was about 10m. The earthquake is a low-angle reverse fault type mega earthquake in inter-plate subduction zones. Severe damage occurred in Nias Island because of the high energy release just beneath the island.

Table 1. Main characteristics of Earthquake

Institute	Mw	Latitude (N)	Longitude (E)	Depth (km)
USGS	8.7	2.076°	97.013°	30.0
Harvard	8.6	1.64°	96.98°	24.9

Table 2. Rupture and Slip Characteristics of the earthquake fault

	Yagi (2005)	Yamanaka (2005)
Strike, Dip, rake	(329,14,115)	(320,12,104)
Moment Tensor Scale	1.6×10^{22} Nm	1.3×10^{22} Nm
Rupture Duration Time	150s	120s
Depth	28 km	27 km
Rupture Area	about 150×470 km	about 120×250 km
Slip	about 10 m	about 12 m

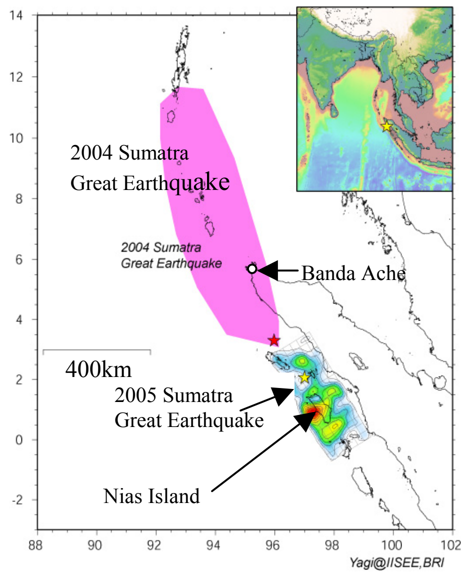

Figure 1: Epicenter and ruptured zone (revised by Yagi (2005))

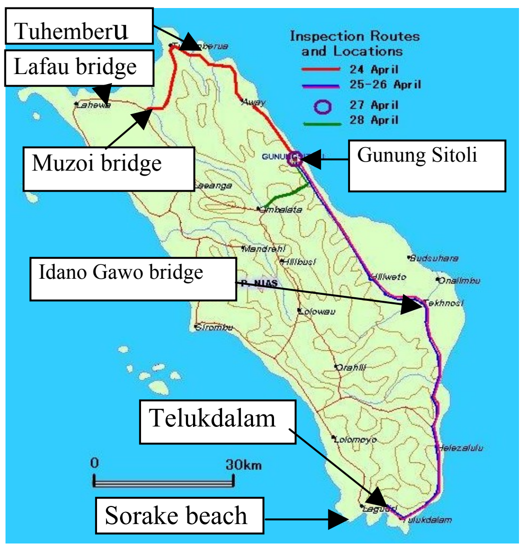

Figure 2: Investigated area in Nias Island and locations of damaged structures and area

Nias Island is about 150km long from north to south and about 50km wide from east to west, with a total population of 700,000. The economical centers are Gunung Sitoli in the north and Telukdalam in the south with concentrated population and buildings. The exact number of casualties and injured people is not well-known. They change depending upon the sources. According to information of the United Nations (UN OCHA, 2005), the number of lethal casualties is more than 850, and injured people is more than 6000. Anyhow, the town of Gunung Sitoli on Nias Island is severly hit by this earthquake. The casulaties and injuries were mainly caused by the collapse of RC buildings and brick and wooden houses. Site investigations were carried out four times, twice in April, 2005 with support activities of providing expertise knowledge and recommendations, once in January, 2006 with support activity for training of local engineers for geotechnical investigations, and once February, 2006. Figure 2 shows the inspection routes. The investigations were mainly conducted in eastern area, because of inaccessible road conditions in western area at the time of the investigations. Typical damaged structures and major cities and towns are also shown in the figure.

STRUCTURAL DAMAGE

Damage to Bridges

The roads connecting Lahewa in the northern part of island to Gunung Sitoli, Gunung Sitoli to Telukdalam in the southern part along eastern coast, and Gunung Sitoli to Telukdalam through the center of island are main roads. Bridges in Nias Island may be broadly classified as Truss bridges, RC bridges, RC Box Culvert bridges, Wooden paved steel framed bridges, and Wooden bridges. Long span bridges are either truss bridges or RC bridges with or without box culverts. Truss bridges were especially used for long span bridges along main roads. The list of bridges and dominant forms of their damage are listed in Table 3 and locations of these bridges are shown in Figure 3.

The heavily damaged non-accessible large bridges within the surveyed area are Lafau bridge and Muzoi bridge in the northern coast between Gunung Sitoli and Lahewa route and Idano Gawo bridge between Gunung Sitoli and Telukdalam nearby Tetehosi at the eastern coast. These bridges mainly consist of truss super-structures with RC foundation piers or RC box culverts. The piers of Lafau bridge and Muzoi bridge were tilted and settled due to the reduced bearing capacity and lateral spreading problems associated with liquefaction of ground. The approach embankment road was settled and laterally moved towards the river due to liquefaction. Figures 4 and 5 show the damage of these bridges respectively. A part of about 50 m to 70 m length of the approach embankment at both the sides of Muzoi bridge is settled by 4.5m at maximum and laterally moved towards the river, which can be clearly inferred from the tilted electric poles next to the bridge while the lateral movement of the ground was more than 4m on both sides. The piers were founded on piles. However, the piles were fractured at the top with exposure of the reinforcement and were not functional. The engineers of Department of Public Works pointed out that piers have piles reaching rock formation. It seems that the piles were designed against vertical loads and horizontal loads were not considered.

Figure 6 shows the damage of Idano Gawo bridge. The second pier of Idano Gawo bridge was tilted and slid towards the upstream side of the river and the box-culvert next to this pier was also tilted and slid together with the pier. The upper deck of the truss section of the bridge is horizontally shifted by about 1.3m. The river flow is directed towards the pier and box-culvert. It seems that the toe erosion of the pier and box culvert, bearing capacity of foundation and large horizontal shaking may be the major causes of the damage to Idano Gawo bridge.

The lateral spreading of liquefied ground damaged RC bridges and Truss bridge in Gunung Sitoli town. The bridge foundations have some piles and some of these piles were broken at the top. The approach embankments of bridges are generally damaged and settled due to lateral spreading of ground and failure of wing-embankment walls. The settlements were generally greater than 30cm in many locations.

Table 3. List of bridges and its damages

Point No.	Subject	remarks
	East and North Coast Road of NIAS (Gunung Sitoli- Lahewa)	
1	RC 1Span (L=20m)	Crack at the approach embankment
2	RC bridge	Crack and settlement of the approach embankment
3	(I-type steel beam girder+ wooden floor)L=15m	Crack and settlement of the approach embankment
4	RC bridge L=8m	Crack and settlement of the approach embankment (1.2m)
5	(I-type steel beam girder+ wooden floor)L=21m	Crack and settlement of the approach embankment
6	RC bridge L=14m	Crack (W=5-30cm) and settlement of the approach embankment, crack and movement of the retaining wall, lateral displacement of ground
7	(I-type steel beam girder+ wooden floor)	Crack and failure of the approach embankment
8	(I-type steel beam girder+ wooden floor)L=15m	No damage
9	Damage of the road	crack of the road, collapse of the house by slope failure
10	Truss Bridge L=40m	Crack and settlement of the approach embankment, sand boil at the village near the bridge
11	Damage of the road	crack, slope failure
12	(I-type steel beam girder+ wooden floor)L=7.5m	No damage
13	(I-type steel beam girder+ wooden floor)L=11m	Severe Crack and settlement(1.2m) of the approach embankment
14	(I-type steel beam girder+ wooden floor)L=7m	Severe Crack and settlement of the approach embankment
15	Damage of the road	crack, liquefaction, tsunami
16	Damage of the road	crack, liquefaction, tsunami
17	(I-type steel beam girder+ wooden floor)L=19m	Crack and settlement of the approach embankment, difference in level (80cm), hardly to pass
18	Damage of the road	Crack, difference in level (50-100cm), hardly to pass
19	Sawo bridge: Truss 1Span 50m	Severe Liquefaction, Lateral Flow, Large amount of sand boil, Crack and settlement of the approach embankment, abutment of the left bank moved 30cm to the river
20	Muzoi Bridge RC 2span(10m each) +Truss 1span (51m)	Severe Liquefaction, Lateral Flow, settlement of the approach embankment (3-4.5m at the right, 0.2-1.5m at the left bank), movement of the abutment and the pier (400cm) to the river, piles were broken at the piletop, Truss moved, Impassable after the earthquake
21	Lafau bridge Truss 1span 55m	Severe Liquefaction, Lateral Flow, settlement of the approach embankment, movement of the abutment and the pier to the river, piles were broken at the piletop, Truss was dropped from the abutment at the right bank, Impassable after the earthquake
22	Lahewa port	a wharf collapsed and settled due to the separation from the piles.
	East and South Coast Road of NIAS (Gunung Sitoli- Telukdaram)	
101	Idano Goho bridge RC bridge 3 Span L=47m, Truss bridge 1Span	Lateral Flow, settlement of the approach embankment, movement of the abutment to the river, piles were broken at the piletop,
102	RC bridge 1 Span L=25m	Crack and settlement of the approach embankment, lateral flow
103	RC bridge 1 Span L=26m	Crack and settlement of the approach embankment
104	slope failure	Rock fall of porous limestone.
105	Truss bridge 1 Span L=60m	Settlement of the left approach embankment (50cm), abutment moved to the river, lateral flow
106	(I-type steel beam girder+ wooden floor)L=8m	Crack at the bank
107	(I-type steel beam girder+ wooden floor)L=8m	No damage
108	RC 3box culvert bridge L=15m	Small crack at the approach embankment, Good performance
109	RC bridge 1span L=36m	Crack and settlement of the approach embankment, Fall down of the abutment, piles were broken at the pile top.
110	Idano Sebua bridge RC bridge 3 Span L=50m	Crack and settlement of the approach embankment, Fall down of the abutment, lateral flow
111	RC ridge 2Span L=34m	Crack and settlement of the approach embankment, Fall down of the abutment, lateral flow
112	Truss bridge 1Span L=62m	Crack and settlement of the approach embankment, Fall down of the abutment, lateral flow
113	Idano Gawo bridge Truss bridge 2 Span L=80m, with Box Culvert bridge 28m on both side	Tilting of box culvert and pier at right side, Impassable after the earthquake
114	Truss bridge 1 Span L=30m	Crack and settlement (1.2m) of the right approach embankment, Fall down of the abutment, lateral flow, Truss moved
115	Idano Mizawo bridge Truss bridge 1 Span L=45m	Crack and settlement of the approach embankment, Fall down of the abutment, lateral flow, Truss moved
116	Idano Mola Bridge Truss bridge 2 Span L=60m	Crack and settlement of the approach embankment, Fall down of the abutment, lateral flow, Truss moved
117	Truss bridge 1 Span L=55m	Crack and settlement of the approach embankment, Fall down of the abutment, lateral flow, Truss moved (85cm)
118	RC bridge 1 Span L=25m	almost no damage
119	RC bridge 2 Span L=35m	almost no damage
120	RC bridge 1 Span L=25m	No damage
121	Susuwa Bridge Truss bridge 1 Span L=65m	Crack and settlement of the approach embankment, Fall down of the abutment, lateral flow
122	RC bridge 1 Span L=10m	No damage
123	Truss bridge 1 Span L=54m	Truss moved
124	Truss bridge 3 Span L=90m	No damage
125	Truss bridge 1 Span L=30m	No damage
126	slope failure	Rock fall of porous limestone
127	slope failure	Rock fall of porous limestone.
128	Bailey bridge +wooden floor L=60m	almost no damage, Small crack at the approach embankment
129	Failure of the retaining wall at the seaside	Failure of the stone masonry retaining wall at the seaside
130	Telukdaram port	a part of wharf sank into the sea and some pile heads were fractured by collision of wharf segment.
131	Traditional wooden house	Good performance
132	Sorake beach	Tsunami
	West Coast Road of NIAS (Gunung Sitoli- Terukdaram)	
201	Idano Tanosaruru bridge Bailey bridge 30.5m	twisted and deformed, Crack and settlement of the approach embankment
202	Idano Oyo bridge (I-type steel beam girder+Bailey bridge+wooden floor) 55m	pier is tilted, settlement of the approach embankment
203	Idan Siwarawa bridge (Bailey bridge+wooden floor) 30.5m	collapse of abutment
204	Idano O'ou bridge (Bailey bridge+wooden floor) 185m	Bailey bridge is deformed

Many truss bridges along Gunung-Sitoli and Telukdalam route and along Gunung-Sitoli and Lahewa route were damaged by permanent movement of abutments as a result of lateral spreading of liquefied ground. The ground consists of mudstone-like layer, sand layer and clayey-silty soil and top organic soil from bottom to top. Sandy layer is generally found at the water level of river and it is expected to be fully saturated. During earthquake shaking, it seems that this sandy layer was liquefied and caused the lateral spreading of the ground. The lateral spreading of ground was particularly amplified on the convex side of the riverbank as the ground can freely move towards the river. These movements caused high lateral forces on the abutments, which caused the sliding and tilting of piers or fractured the piles of the abutments of truss bridges. Similar situations are also observed on RC bridges.

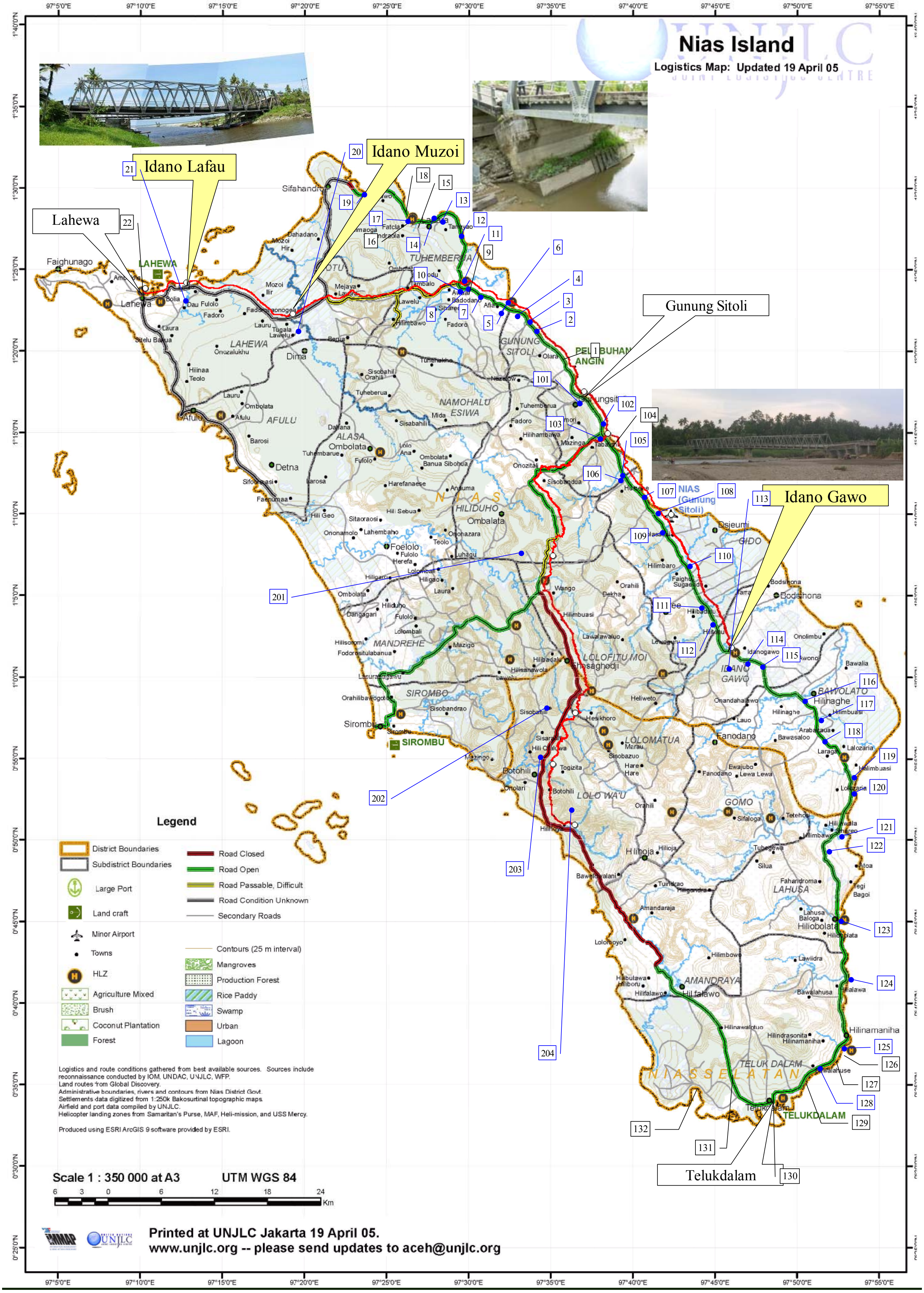

Figure 3. Investigated bridges and Major cites and towns

The approach embankments of bridges are generally damaged and settled due to lateral spreading of ground and failure of wing-embankment walls. The settlements were generally greater than 30cm in many locations. The backfill materials of approach embankments consist of gravelly soil and it is expected that the potential of settlement or liquefaction is low. The bearing supports of many bridges do not have shear-keys or stoppers against both horizontal and vertical movements. The truss section shifted horizontally towards the upstream side or downstream side at some bridges.
The damaged bridges generally need to be re-constructed and It should be moved next to existing piers where geotechnical investigation of ground and its characteristics are necessary. The present truss decks can be used in the new-constructions with some replacement of damaged elements and bolts and bearings together with appropriate stopper against horizontal and vertical relative movements.

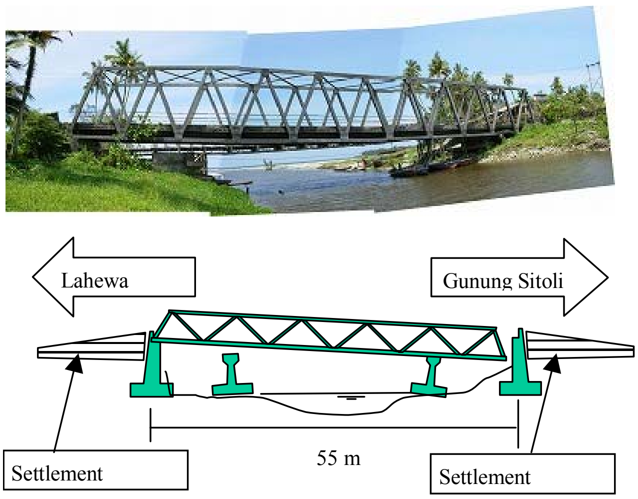

Figure 4. Damage of Lafau Bridge

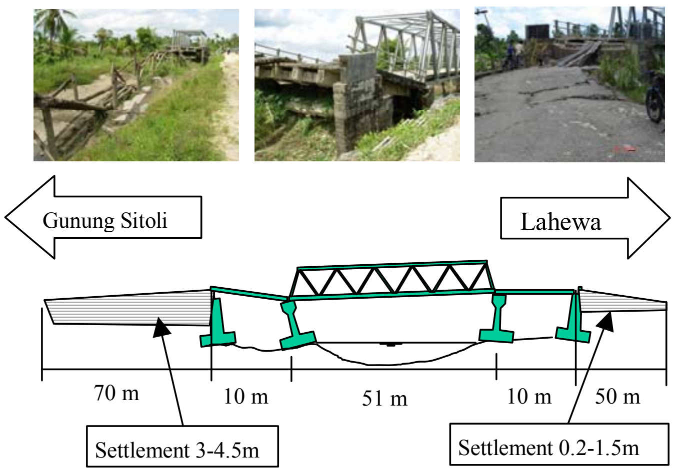

Figure 5: Damage of Muzoi Bridge

Figure 6. Damage of Idano Gawo Bridge

Damage to Roadways and Slope Failure
Roadways were damaged at many locations of the Nias Island due to embankment failure, landslides, lateral spreading, of liquefaction. Many cracks and settlements more than 1m were observed. Roadways were generally narrow (less than 5m) and the asphalt surfacing of roadways was generally in poor condition having many potholes. Many rockfalls were observed particularly along the roadways passing through porous coral limestone. These rockfalls directly hit the roadways and obstructed roadways just after the earthquake in some locations. There were many slope failures along the road in mountainous areas between Gunung Sitoli and the west coast in the center of Nias Island, where slopes consisted of weathered rock resulting in closed roads.

Damage to Port Facilities
There was some damage to port structures in Nias Island due to ground shaking. In Telukdalam new port in southern part of Nias Island, a part of wharf sank into the sea and some pile heads were fractured by collision of wharf segments. The lateral spreading caused the fracturing and settlement of piles. The wharf of old Gunung Sitoli port located in the liquefied area, where many buildings were heavily damaged by settlement and tilting, was damaged by the lateral spreading of liquefied ground. As a result, the pile heads fractured and settled . Furthermore, there was a relative movement of 15cm between the segments of the wharf.

LIQUEFACTION AND LATERAL SPREADING

As expected from the magnitude of this earthquake, the liquefaction of sandy ground is very likely. The sandy ground is observed along seashore and riverbanks in Nias Island. Permanent ground movements such as settlement and lateral spreading, and associated structural damage due to liquefaction were widely observed in various locations along the coastal area and reclaimed ground. The lateral spreading of ground nearby bridge abutments were almost entirely associated with liquefaction of sandy soil layer. The damage induced in Gunung Sitoli due to ground liquefaction is widespread along the coastal area, reclaimed ground and riverbanks. All the possible forms of ground movements and the effects of ground liquefaction were observed such as sand boils, lateral ground movements and settlement. As a result, many buildings in such areas were heavily damaged with partial settlement, inclination and uplift of ground floor. The buildings without raft foundations and continuous tie-beams could not resist to ground failures due to liquefaction unless they are built on piles extending into the non-liquefiable layer. Figure 7 shows the damages of buildings due to liquefaction. In Figure 8 grain size distribution curves for soil samples in Gunung Sitoli can be seen. It can be seen that these soils have almost the same grain size and they are very liquefiable. Swedish weight sounding tests were conducted at 2 points in Gunung Sitoli. Soil profile, converted SPT N-value from Swedish weight sounding test and Liquefaction Potential based on the result of geotechnical investigation are shown in Figure 9.

Figure 7. Effect of liquefaction and lateral spreading on RC building and truss bridge

Method of liquefaction assessment is according to the Recommendation for Design of Building Foundations, Architectural Institute of Japan (Architectural Institute of Japan, 2001). In this study, maximum acceleration of strong ground motion is taken as 350cm/s^2 for ultimate limit, which is as large as observed in liquefied area during the Hyogoken-Nambu earthquake. There is a 3m thick loose sandy layer at the subsurface of reclaimed ground (see the case of shop house in Figure 9), which is inferred to be easily liquefiable from the result of Swedish weight sounding. As mentioned above, many buildings in such areas were heavily damaged with partial settlement, inclination and uplift of ground floor. As a result, almost all buildings were demolished. At the site of Governor's house, there exists a sandy layer, but having relatively large N-value and partially liquefiable during strong ground motion obtained from the assessment based on the test result. The elevation of the site is slightly higher than that of the reclaimed area and only small damages such as cracking in floor concrete were observed after the earthquake. The results obtained from geotechnical investigation are in accordance with the observed damages caused by the earthquake. However, the geotechnical investigations of ground are scarce in Nias Island and it would be desirable to carry out such investigations in areas particularly affected by ground liquefaction in relation to recovery and reconstruction of Nias Island.

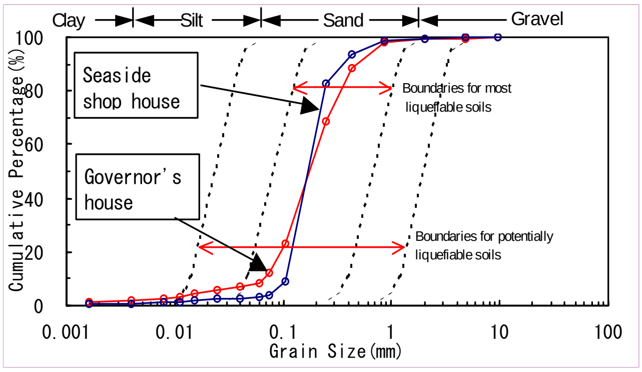

Figure 8. Grain size distribution curves for soils at 2 sites in Gunung Sitoli

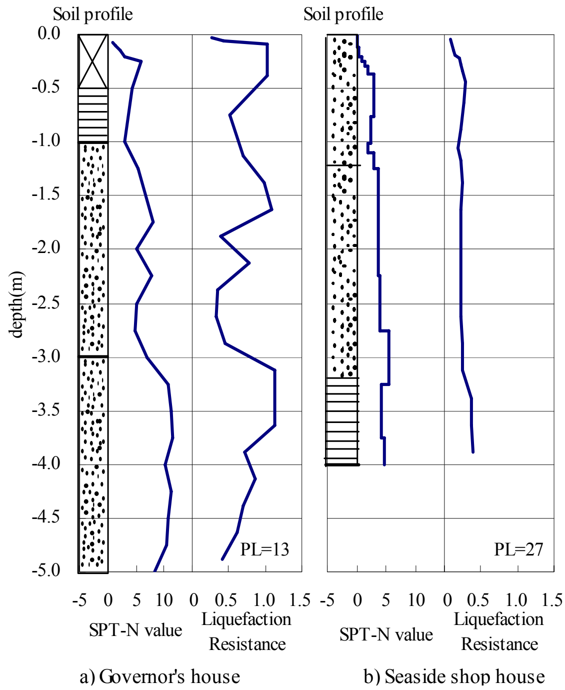

Figure 9. Soil profile, Converted SPT N-value from Swedish weight sounding test and liquefaction resistance at 2 sites in Gunung Sitoli

SUPPORT ACTIVITIES FOR RECOVERY AND RECONSTRUCTION

Background of activities

After the Sumatra Earthquake of December 26, 2004, which caused the most disastrous tsunami in Indian ocean and severe disaster to the countries around the Indian Ocean, especially in Indonesia, Japan Society of Civil Engineers (JSCE) had dispatched a reconnaissance team to Banda Ache for the investigation of the damage to Infrastructures such as road, bridges, port facilities, riverbanks and lifeline systems in February, 2005 (Goto et al., 2005). Also, JSCE dispatched an expert team for disaster prevention education to assist the educational activities for young people on tsunami and earthquake disaster in cooperation with the government agencies of the concerned countries. In order to continue and enlarge such an activity, students of Waseda and Kyoto University have conducted

disaster prevention education several times at damaged and liable to damage areas in Indonesia, in 2005 and 2006.
On the other hand, temporary repairs and rehabilitation of infrastructures, like roads, bridges and so on are of the most urgent subjects in Nias Island since many structures were damaged by strong ground motion during the large earthquake that occurred on March 28, 2005. By the request of government and legislature of province, JSCE dispatched the expert team to support the repair works and rehabilitation of public facilities in April 2005. The team visited Nias Island to investigate the damage of the infrastructure, and make recommendations for temporary repair and rehabilitation to concerned government agencies such as the Nias public work office and the government of the province of North Sumatra.
For example, the contents of the recommendations are as follows. As for the bridges, temporary supporting methods were introduced for the emergency stage. The existing truss decks of bridges can be used with some replacement of damaged parts for economical reconstruction during the reconstruction stage, but almost all bridges should be re-constructed because foundation structures were heavily damaged due to ground failure such as lateral movement or liquefaction. Pile design should be re-considered and their length should be sufficiently long to have required end bearing. The foundation pile should be designed to resist to the lateral flow force of liquefied ground. As for the foundation of buildings, box-like (mat, raft) foundations should be used in liquefiable areas in case piles could not be used. As for the structural design of foundation structures and for urban rehabilitation planning, ground investigations should be done to have fundamental data on ground characteristics.

Transferring the technique on geotechnical investigations
Although nine months elapsed from the earthquake at the end of 2005, the infrastructures and buildings in Nias Island had still no prospect of being re-constructed. In order to initiate recovery and reconstruction work in the region, the soil exploration data such as boring data is essential. However, available data is scarce and not sufficient for recovery and reconstruction works at the present time. Also, government of the province of North Sumatra requested for continuation of support. Therefore, experts and engineers were dispatched again by JSCE to Nias Island and the expertise advises and technical supports for recovery and re-construction were provided as the joint activity with the Institution of Engineers, Indonesia (Persatuan Insinyur Indonesia: PII) in January 2006.
In this project, transferring the technique on geotechnical investigations was one of the major purposes. Swedish Weight Sounding Test as an practical ground surveying methods was introduced to local engineers for the prediction methods of ground liquefaction and their applications to the recovery and reconstruction of the damaged areas. JSCE donated one Swedish cone penetration device to the Public works office of Nias Island Local Government upon the training of engineers. Also, JSCE donated the second device with an additional pull out device to Road and Bridge Office, North Sumatra Province October 2006. Activities of the support team were as follows; 1) Training on ground survey methods with Swedish Weight Sounding Test, 2) Training on the assessment methods of ground liquefaction and counter-measures against ground liquefaction based on the data obtained from the ground surveys, 3) Training for applications of the obtained soil data to actual recovery and reconstruction projects.
Swedish weight sounding tests were conducted by engineers in Indonesia under the instruction of engineers from Japan at two locations in Gunung Sitoli and at one location at Idano Gawo bridge in Nias Island, not only for obtaining the geotechnical information but also for training the local engineers at the technique on geotechnical investigations. Also, short courses for engineers in Nias Island and North Sumatra province were held on the utilization of the data obtained from the ground survey for the bearing capacity, the liquefaction assessment and so on. Meetings with the government of Nias prefecture, Agency of Recovery for Banda Aceh and Nias, North Sumatra road and bridge office were held about the activities at that time and in the next period of time. Figure 10 shows a photo of training of Swedish Weight Sounding Test. Training was continued until night. Figure 11 shows the photo of the short course in Nias Island and the meeting with the Governor of North Sumatra Province.

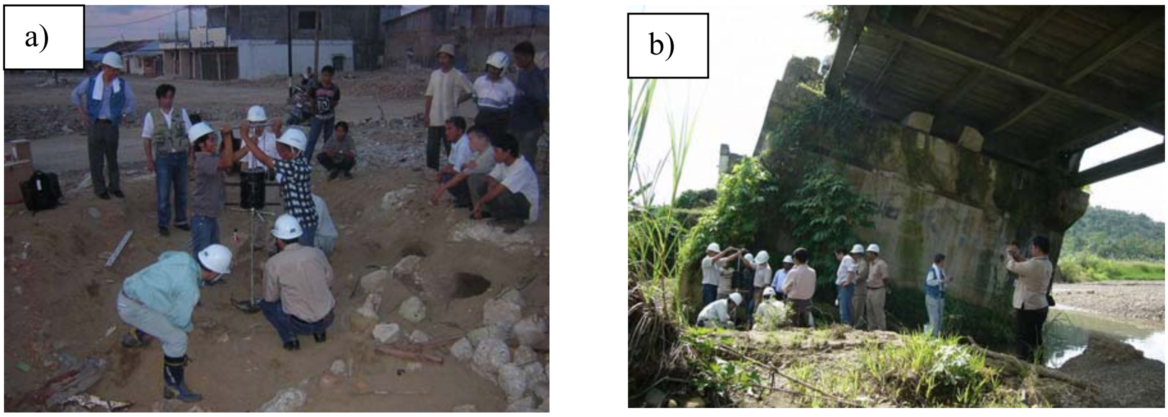

Figure 10. Training on Swedish Weight Sounding Test at (a) Gunung Sitoli b) Idano Gawo Br.)

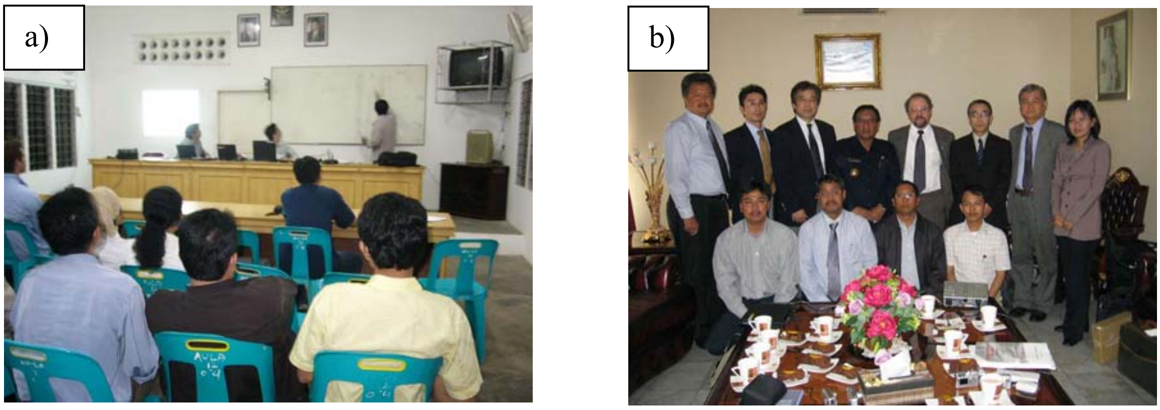

Figure 11. Short Course and Meeting (a) Short course in Nias Island, b) Meeting of the Government of North Sumatra Province)

Issues for the future

In the future, the direct contribution of civil engineers to the society will be one of the most important issues. The activity at this time, which is an example of the direct contribution to the society, made a positive influence in training of engineers on geotechnical investigation and the planning of recovery and reconstruction projects to be carried out in Nias Island and other disaster-affected regions. However, the geotechnical investigations of ground are still lacking in Nias Island and it would be desirable to carry out both such technical support activities and investigations by local engineers in Nias Island. Continuation of the technical support and dissemination of transferred techniques, which have been done so far, are necessary for firm establishment of the technique for the reconstruction and future earthquake disaster prevention activities in Sumatra island, and implement those activities to the practical use. In order to continue the support activities for recovery and reconstruction of affected region or country, raising funds and recruiting talented people are necessary. Therefore, it is important to establish collaborative relationships among the societies of engineers, universities, government, local governments, citizens, citizens' group and private enterprises in Japan. NPO is thought to be most suitable and make such activities easier as compared with existing organizations. Therefore, NPO "Engineers without Borders, Japan" has been established for such a purpose (Hamada, 2005b).

As for the actual activity in the country suffered by disaster, it is important to make collaborative relationships with the society of engineers, universities, local governments and private enterprises in the countries affected by the disaster. At present time, a member of PII and some members of soil investigation companies and construction companies participated in our activity and took part of the work like translation the English materials to Indonesian, explanation in Indonesian language to the local engineers, logistics and so on. As for transferring the technique for soil investigation, in order to be used continuously in the region, machines should be simple and the prototype of a machine should be donated so that the required quantity of machines can be manufactured in the region.

Continuous training is necessary for the soil investigation method to be taken root in this region. JSCE dispatched the third team consisting of experts and engineers to Nias Island, Medan and Padang for providing the expertise advises and technical supports for recovery and re-construction again, and for earthquake disaster mitigation in February 2007.

CONCLUSIONS

The conclusions obtained from the investigations and support activities in Nias Island following the March 28, 2005 earthquake are summarized as follows:
1) A very large earthquake with a magnitude of 8.7 occurred nearby Nias Island of Indonesia on March 28, 2005. Strong ground motions induced large number of casualties and damaged infrastructures such as roads and bridges, and buildings.
2) Many bridges were damaged by strong ground motion and permanent movement of abutments as a result of lateral spreading of liquefied ground. The heavily damaged non-accessible large bridges within the surveyed area are Lafau bridge, Muzoi bridge and Idano Gawo bridge, which mainly consisted of truss superstructure and RC abutments and piers.
3) The earthquake induced widespread liquefaction and lateral spreading. These phenomena were the primary cause of heavy damage to bridges and buildings in Nias Island. Damage of ground such as settlement, lateral spreading and associated structural damage due to liquefaction were widely observed in various locations along the coastal area and reclaimed ground.
4) The reclaimed area in the coastal region of Gunung Sitoli was strongly affected by the earthquake, while settlement and lateral spreading of ground occurred. As a result, many buildings in such an area were heavily damaged with partial settlement, inclination and uplift of ground floor. The buildings without raft foundations and continuous tie-beams could not resist to ground failures due to liquefaction unless they are built on piles extending into the non-liquefiable layer. Swedish weight sounding tests were conducted at 2 locations in Gunung Sitoli. The results obtained from geotechnical investigation are in accordance with the observed damages caused by the earthquake.
5) The team of experts was dispatched and made recommendations for temporary repair and rehabilitation of infrastructures and buildings. Because available soil investigation data is scarce and not sufficient at the present time, the Swedish Weight Sounding Test as a practical ground surveying method was introduced to local engineers for the prediction methods of ground liquefaction and their applications to the recovery and reconstruction of the damaged areas.
6) Support activities for recovery and reconstruction as well as disaster prevention education or technical support to the area suffered by natural disaster should be conducted and continued as the direct contribution of the society of civil engineers. In order to continue the support activities for recovery and reconstruction, the building of good collaborative relationships between the government, local governments, societies of engineers and NPO both in Japan and the country affected by the disaster are necessary.

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