



GEOTECHNICAL SURVEY REPORT ON 2006 YOGYAKARTA (MID-JAVA) EARTHQUAKE

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ABSTRACT: On May 27, 2006, an earthquake having the moment magnitude M_w of 6.3 struck Yogyakarta and partly Central Java provinces of Indonesia. This report summarizes results from field investigations on geotechnical issues. Portable dynamic cone penetration tests were conducted in order to investigate subsurface soil condition at several sites. Liquefaction, landslide, and rock fall were observed at several locations, spreading over Bantul district, the Yogyakarta city, the southeast part of Sleman district, and the southwest part of the Klaten district. In addition, a large number of residential and public buildings and a historical monument that suffered from damage were reported.

Key Words: Earthquake, Yogyakarta, Klaten, Portable Cone Penetration Test, Liquefaction, Well Plugging, Sand Boiling, Landslide, Slope Failure, Rock Fall

INTRODUCTION

An earthquake, having the moment magnitude M_w of 6.3 (USGS, 2006 and NIED, 2006)/ M_w of 5.9 (BMG, 2006), struck Yogyakarta and partly Central Java provinces of Indonesia, on Saturday May 27, 2006 at 5.53 am local time. It caused 5,778 casualties, 37,883 injuries, and 139,859 collapsed houses as of June 27, 2006 (Media Center of Satkorlak 2006). Mostly, these severe effects occurred in Yogyakarta province and Klaten district of Central Java province.

As shown in Figure 1, Yogyakarta is located in south-central of Java island. It is surrounded with the province of Central Java at the West, the North, and the East, while the Indian Ocean borders on the south. Merapi volcano, the most active volcano in Indonesia recently, is located several tens kilometers from the downtown of Yogyakarta to the north. The population of Yogyakarta province including the Yogyakarta city, Bantul, and Sleman districts in 2000 was 3,120,500. The province of Yogyakarta has a total area of 3,185.80 km² (Yogyakarta, 2007) which has the second-smallest area of the provinces in Indonesia, after the Jakarta Capital Region. Meanwhile, Klaten district located in Central Java province (to the northwest of Yogyakarta province) has a total area of 66,595 km² and population of 882,494 in 2006 (Klaten, 2007).

As members of the survey team dispatched by the Japanese Geotechnical Society, the authors conducted site visits to examine the evidences and interviews with the local inhabitants from June 24 to July 2, 2006. In order to investigate the subsurface soil properties, portable dynamic cone penetration tests (JGS 2003) were carried out at six sites. Results from that field survey especially on geotechnical issues were briefly summarized in this report. The details will be reported elsewhere (Koseki et al., 2007).

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OVERALL DAMAGE

According to a report published by Bakornas Indonesia as shown in Figure 2, four levels of earthquake intensity based on the Modified Mercalli Intensity (MMI) scale were measured in Yogyakarta region and its vicinity (Kedaulatan Rakyat, 2006). The highest degree of MMI scale at level VII affected to the region spreading over from the south part of Bantul district to the southwest part of Klaten district. Meanwhile, level V of MMI scale was observed in the outer region of Yogyakarta city, including Wates, Sleman, Boyolali, Surakarta, and Wonosari.

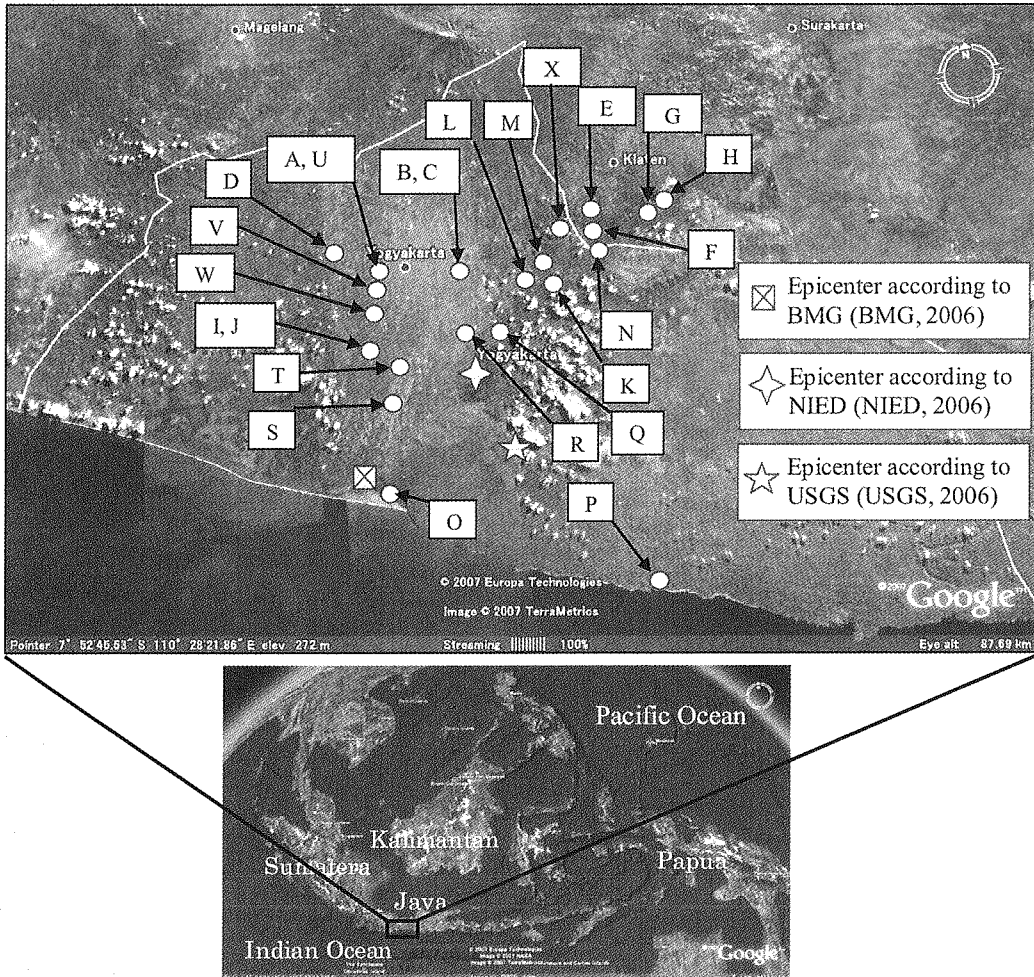


Figure 1. Map of Yogyakarta and its vicinity (modified from Google Earth, www.earth.google.com)

From a geotechnical point of view, some hazards were observed throughout the earthquake affected zone including liquefaction, landslide, and slope failure. In addition, damage to residential and public buildings, and a historical monument were observed as well.

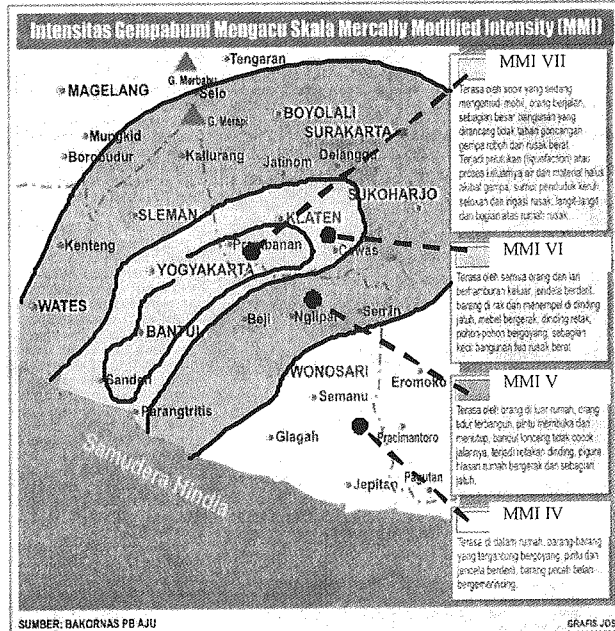


Figure 2. Distribution of affected area based on MMI scale (modified from Kedaulatan Rakyat, 2006)

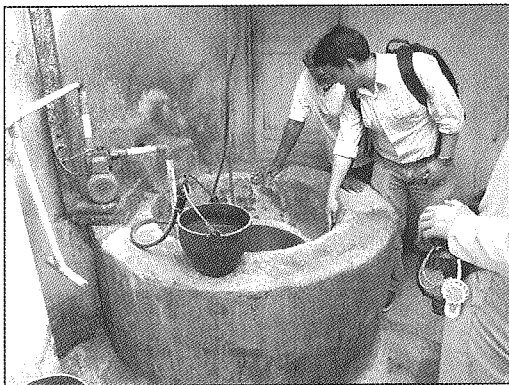


Photo 1. Plugged well at Site A



Photo 2. Evidence of sand boiling in banana field at Site B

LIQUEFACTION

At site A at Bintaran Kidul in Yogyakarta city, several wells were plugged by sandy soil due possibly to liquefaction. According to the owner of a well (Photo 1), muddy water followed by sudden rise of water level in the well was observed immediately before the earthquake. Then during the earthquake, water

spouted out to a height about 2.5 m. The thickness of sandy soil which plugged the well was about 3 m. The plugged sandy soil was re-excavated and was used to re-fill around the well casing which suffered from the relative settlement of about 5 cm.

At site B at Jagalan village, Tegal Tirto, Berbah in Sleman District, sand boiling occurred in banana and paddy fields as shown in Photos 2 and 3, respectively. As shown in Photo 4, one of the residents showed his water pump system that had been replaced with new pipe line, since the previous pipe line was plugged by sandy soil after the earthquake. At this site, a dynamic cone penetration test was conducted measuring number of blow count, N_d that is converted into equivalent N_{SPT} value (Atarashi, 1986). As shown in Figure 3a, soft soil deposit with N_{SPT} values less than 10 could be found at maximum 3 m in depth, where the ground water level was about 2 m from the ground surface.



Photo 3. Evidence of sand boiling in paddy field at Site B

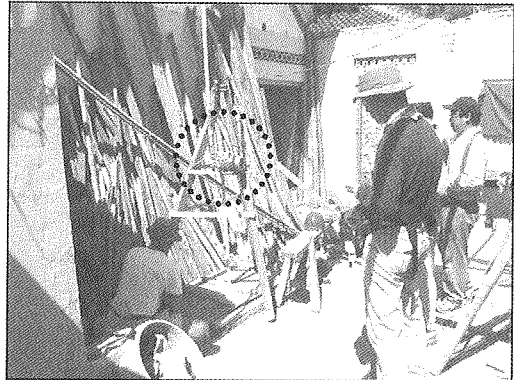


Photo 4. Water pump at Site B

At site C at Candirejo village, Tegal Tirto, Berbah in Sleman District, spouting out of groundwater at maximum about 1 m in height for about 24 hours after the earthquake was observed. Even at the time of the survey that was conducted in one month, water was still springing out (Photo 5). At this site as shown in Figure 3b, soft soil deposits with N_{SPT} values less than 10 having thickness of about 3 m were identified.

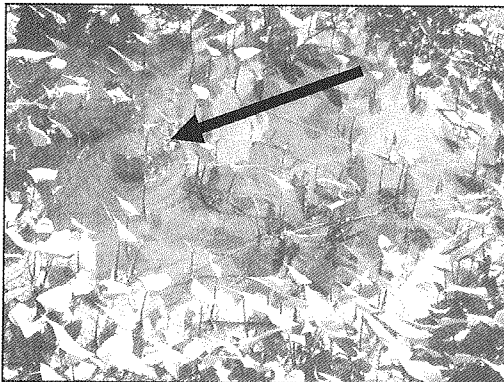


Photo 5. Springing water at Site C

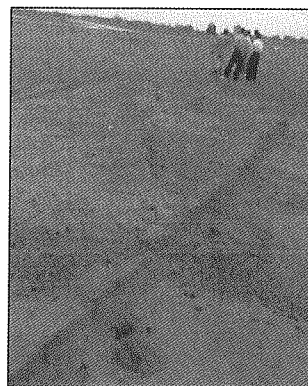


Photo 6. Evidence of sand boiling at Adi Sucipto Airport (by courtesy of Dr. Fitri Mardjono, Gajah Mada University)

As shown in Photo 6, sand boiling occurred at Adi Sucipto Airport (Mardjono, 2006). This location is close to the Site C as mentioned above.

At Site D at Muhammadiyah University in the suburb of the Yogyakarta city, as shown in Photo 7, a revetment surrounding a pond failed. A dynamic cone penetration test was conducted on the embankment. As shown in Figure 3c, rather stiff soil deposit with N_{SPT} values more than 10 could be found at about 0.5 m depth.

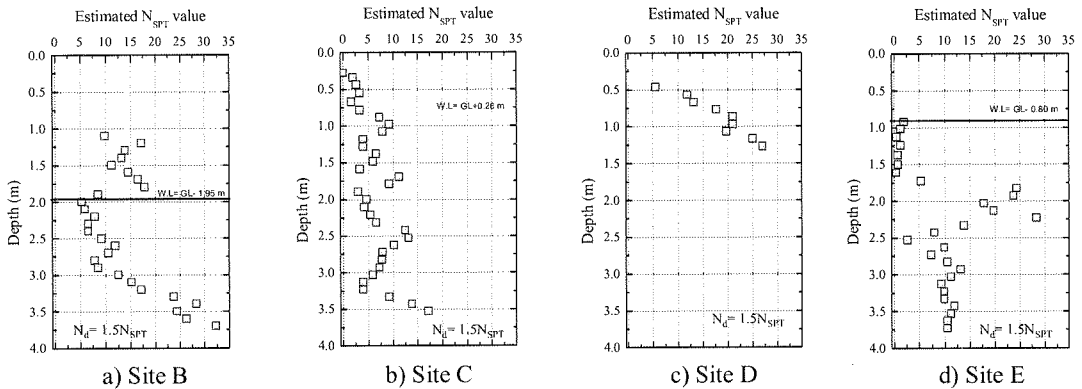


Figure 3. N_{SPT} values at Sites B, C, D, and E

At Site E at Mutihan in Klaten district, spouting of groundwater to a maximum height of about 1 m was observed after the earthquake (Photo 8). In this region, high collapse ratio of houses was observed. As shown in Figure 3d, soft soil deposit with N_{SPT} values less than 5 was observed until about 1.75 m depth, where the groundwater level was about 1 m from the surface. In addition, another soft soil deposit with N_{SPT} values of about 10 was observed at deeper than about 2.5 m from the ground surface.

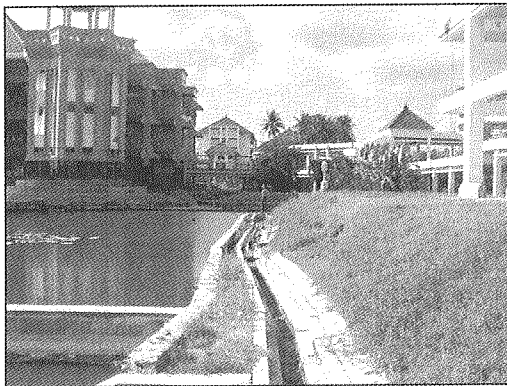


Photo 7. Damaged revetment at Site D



Photo 8. Location of the spouting of groundwater at Site E

At Site F at Katekan village in Klaten district, several wells were plugged by sandy soil (Photo 9). Several days after the earthquake, the inhabitants repaired the wells by re-excavating the sandy soil. As shown in Photo 10, the re-excavated sandy soil was collected to be used as material for re-constructing their houses.

At Site G at Bayat and site H nearby Jombor Lake in Klaten district as shown in Photos 11 and 12 respectively, no extensive damage was observed. In addition, at Site H, plugging of well and spouting of groundwater were not reported throughout the village.

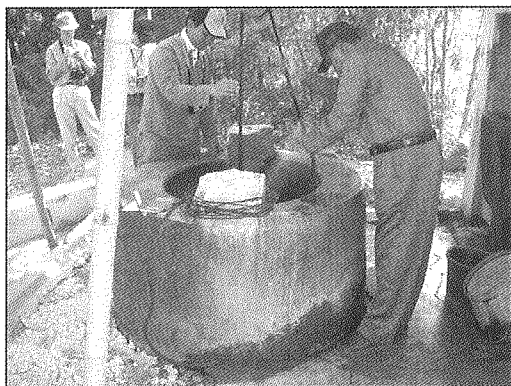


Photo 9. A plugged well at Site F

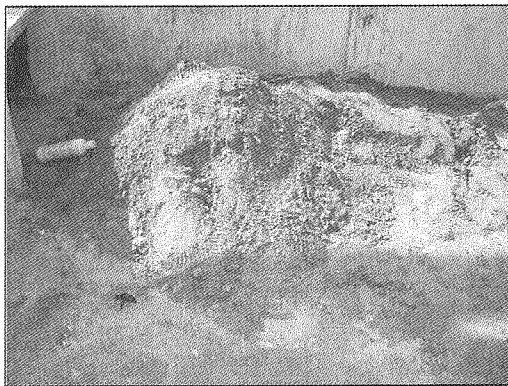


Photo 10. Re-excavated sand from a well at Site F

At Site I in Patalan, Bantul district, a primary school building and its surroundings were damaged as shown in Photo 13. At Site J that was about 1 km from Site I towards the north, a housing lot was under construction on a paddy field as shown in Photo 14. Results of dynamic penetration tests at Sites I and J are shown in Figures 4a and 4b, respectively. At both sites, the groundwater level was shallower than 1 m from the ground surface, below which soft soil deposits with N_{SPT} values less than 10 could be found for a thickness of about 2 to 3 m.

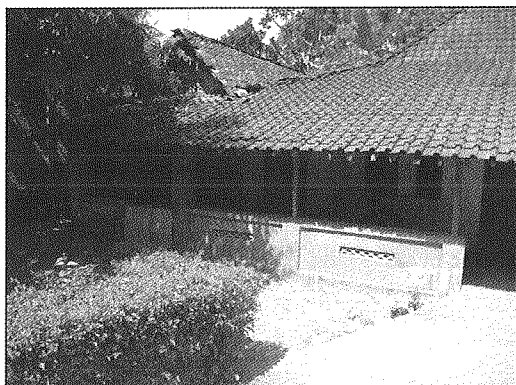


Photo 11. Houses condition at Site G



Photo 12. Houses condition at Site H



Photo 13. Damaged primary school at Site I

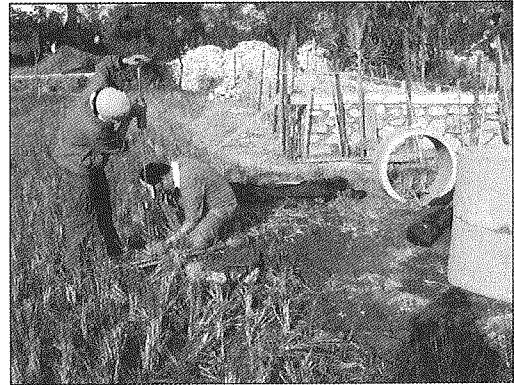


Photo 14. Housing lot on paddy field at Site J

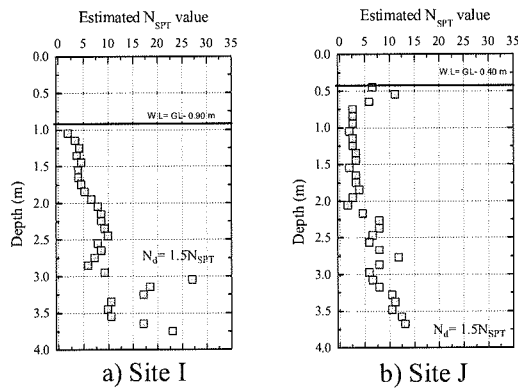


Figure 4. N_{SPT} values at Sites I and J

LANDSLIDE

At Site K at Lepen – Sengir village (Sumberharjo) in Sleman district, a large scale landslide occurred as shown in Photo 15 and 16. The landslide body that having an area of about 100 x 200 m slid downward by 20 m at maximum. At the time of the earthquake, at least 14 households lived on the landslide mass. Although the large landslide caused complete collapse of 6 houses, no one was killed. Reportedly, after feeling the earthquake motion, they could run out from their houses before their collapse.

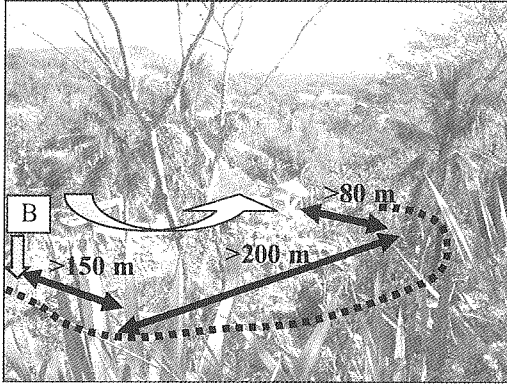


Photo 15. Landslide area that was viewed from Position A (Photo 16) at Site K

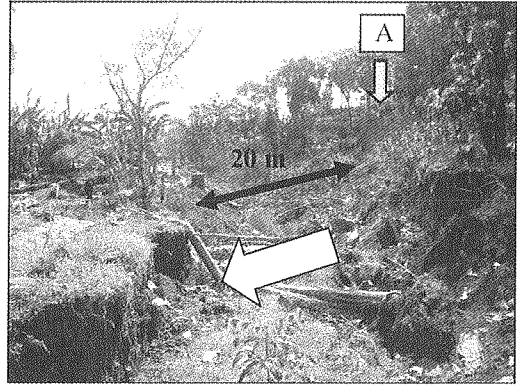


Photo 16. Landslide area that was viewed from Position B (Photo 15) at Site K

SLOPE FAILURE/ROCK FALL

A large number of slopes in the mountainous area were failed. The failures occurred both in populated and less populated area. In this survey, some of them were observed from a long distance due to difficulties of transportation to reach the remote area.

At Site L at Bangkel village, Srimulyo in Bantul district, several rock masses fell down as shown in Photo 17. In addition, a scar due to slope failure/rock failure on hilly area of Mountain Blencong at Site M was viewed from top of Bangkel hill at Bangkel village as shown in Photo 18.

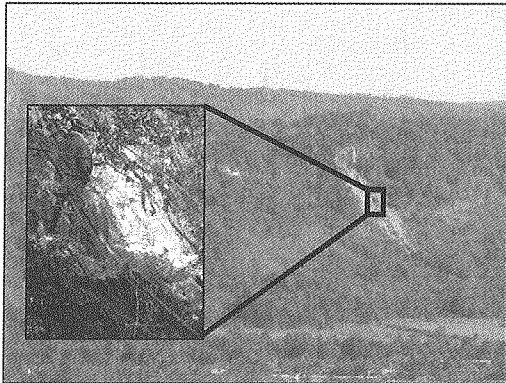


Photo 17. Rock fall at Site L

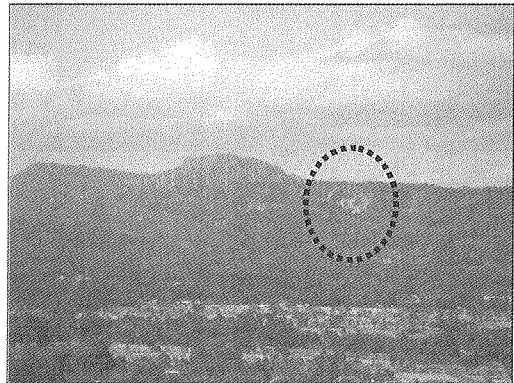


Photo 18. A scar on hilly area at Site M

Two scars on a part of Southern Mountains were observed at Site N as shown in Photo 19. These scars were viewed from Katekan village in Klaten district.

At Site O at Parangtritis beach in Bantul district, several rock-falls occurred in the hilly side as shown in Photo 20. In this area, most of the hills consist of limestone as shown in Photo 21.

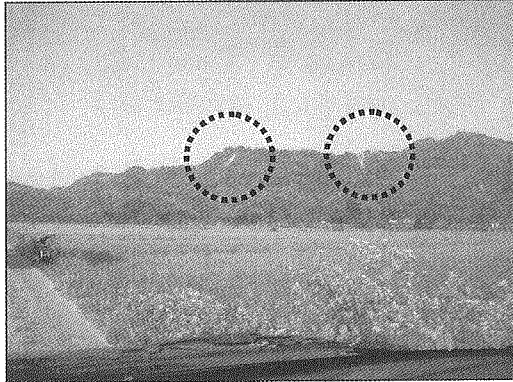


Photo 19. Two scars on Southern Mountain at Site N

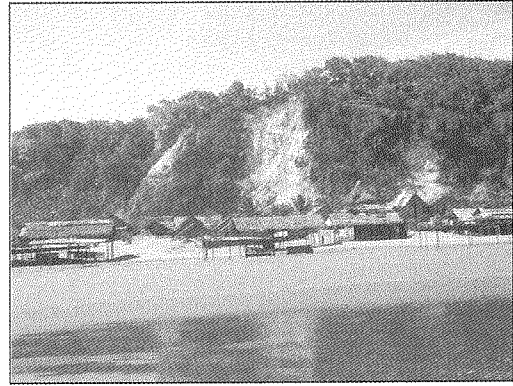


Photo 20. Slope failure at Site O

At Site P at Baron beach in Gunung Kidul district, large rock falls occurred along the coastline as shown in Photo 22. Before the earthquake, position of the rocks was overhung due possibly to that the foot part of the rock slope was eroded by wave action as typically shown in Photo 23. Reportedly, plugging of well and spouting of groundwater were not observed in this area at the time of the earthquake.

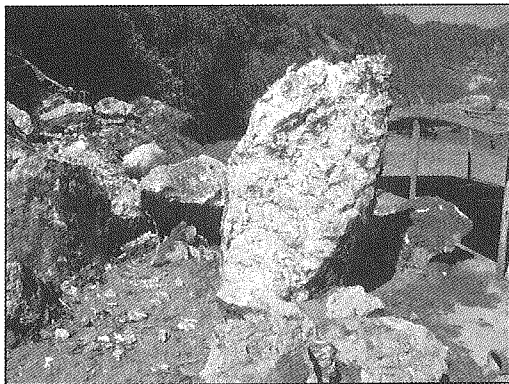


Photo 21. Chunks of rock fall at Site O

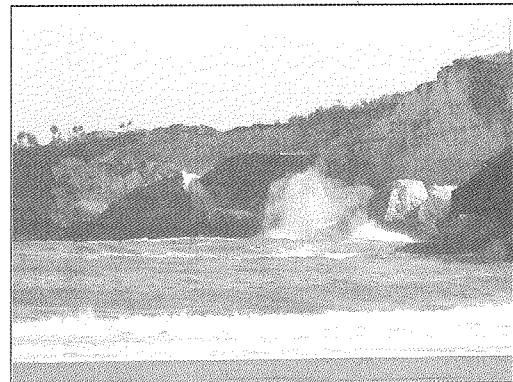


Photo 22. Rock fall at Site P

At Site Q at Wonolelo village in Bantul district, a scar on hill was observed as shown in Photo 24. Several households lived at the middle and top parts of the hill. Reportedly, the water level of wells that were owned by the households decreased after the earthquake.

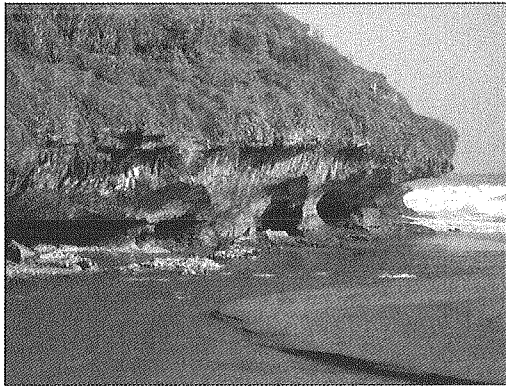


Photo 23. The overhung rock at Site P

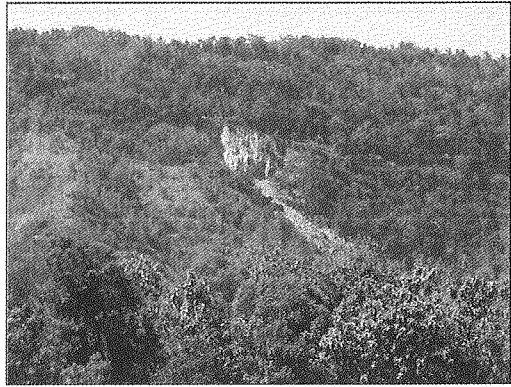


Photo 24. A scar on hill at Site Q

At Site R at Trimulyo village in Bantul district, a rock slope adjacent to a village failed and the debris blocked the road (Photo 25). At the time of the survey, the road had been cleared of the fallen rock as shown in Photo 26. Reportedly, the failure was caused by the aftershock, not by the main shock, and thus the local inhabitants could evacuate safely before the failure occurred.



Photo 25. Rock fall at Site R

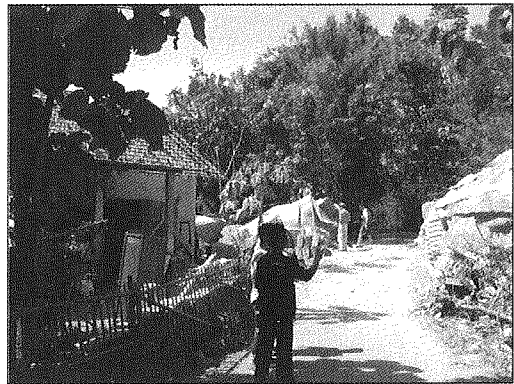


Photo 26. Road that was cleared of the fallen rock at Site R

DAMAGE TO RESIDENTIAL AND PUBLIC BUILDINGS

As mentioned above, more than 130,000 houses were collapsed. In urban area, typically the houses were built with clay brick and lime/cement mortar using reinforced concrete framing system. On the other hand in rural area, traditional wooden houses still existed among the brick houses. In addition, several public buildings were damaged, including university, commercial, and government office buildings.

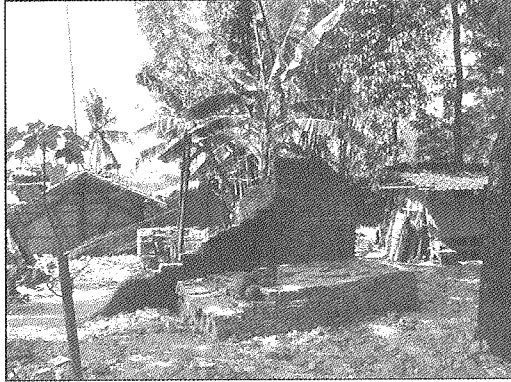


Photo 27. A collapsed house at Site S



Photo 28. A damaged traditional house at Site T

At Site S at Pundong in Bantul district, severe damage to houses was observed as shown in Photo 27. Meanwhile, in the adjacent area at Camden village at site T, a traditional wooden house suffered from damage as well.

At Site U in the Yogyakarta city, a shopping mall was damaged as shown in Photo 29. Failure at the connection between wall and slab of floor occurred. At the time of the survey, the building was under repair. Meanwhile, business activities inside the building had already resumed.

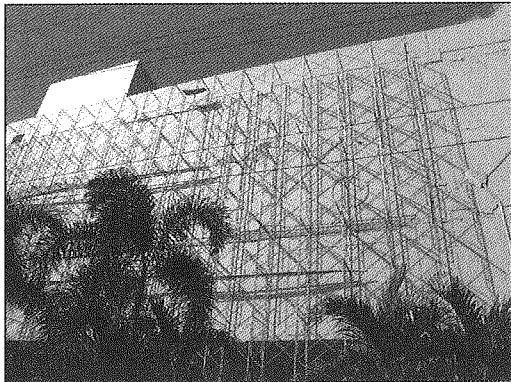


Photo 29. A damaged shopping mall at Site U

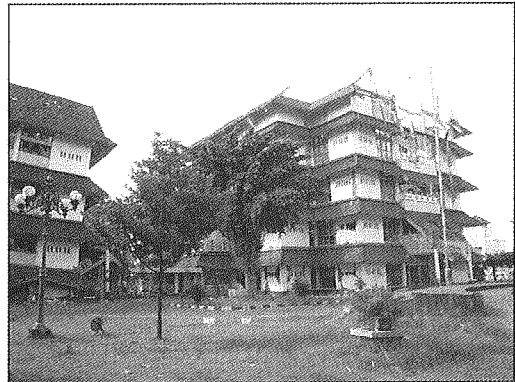


Photo 30. Severe damage to university building at Site V

At Site V in the suburb of the Yogyakarta city, multi-story university buildings of STIE (university of economic) Kerja Sama were severely damaged (Photo 30). The building on the left hand side suffered from collapse of the first floor, while the other on the right hand side suffered from damage to roof and other upper structure.

At Site W in the suburb of the Yogyakarta city, a building that belongs to BPKP (Controller of Financial and Development Agency) suffered from extensive damage. The first and second floors of this three-story building were collapsed.



Photo 31. A damaged government building at Site W

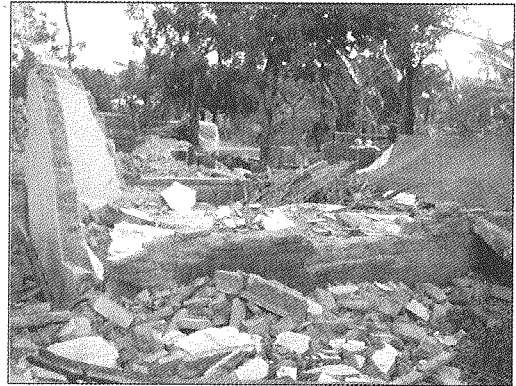


Photo 32. Severe damaged to houses at Site E

At Site E at Mutihan in Klaten district, houses were severely damaged as shown in Photo 32. As the result of cone penetration tests as shown in Figure 3d, these houses were built on soft soil deposits.

DAMAGE TO HISTORICAL MONUMENT

At Site X at Prambanan in Sleman district, the Prambanan temple suffered from dropping and tilting of its masonry (Photo 33). At the time of the survey, some parts were under repair. In addition, as shown in Photo 34 several top parts of the fence wall suffered from dropping and tilting as well.



Photo 33. Damage to Prambanan temple at Site X

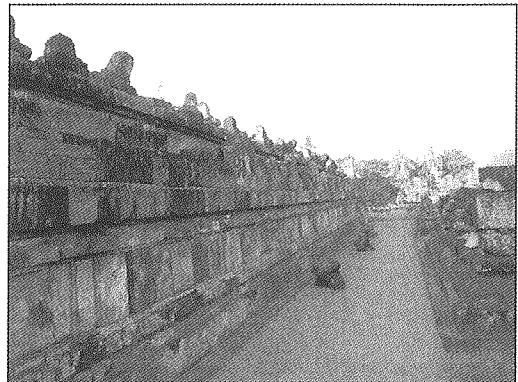


Photo 34. Dropped and tilted masonry of the fence wall of Prambanan temple at Site X

CONCLUSIONS

Results from the present damage survey can be summarized as follows:

Failures from geotechnical point of view and severe damage to buildings spread over the regions from the south part of Bantul district to the southwest part of Klaten district.

By conducting portable cone penetration tests, subsurface soil condition at several sites was investigated.

Liquefaction occurred at several locations, including the Yogyakarta city, the southeast part of Sleman district, and the southwest of the Klaten district. Due to this phenomenon, a number of wells in those areas suffered from plugging.

A large scale landslide occurred at Lepen – Sengir village (Sumberharjo) in Sleman district. In addition, a number of rock falls were observed in the mountainous area, spreading over the region from the south to the northeast part of Bantul district, the southeast of Sleman district, and to the southwest of Klaten district.

A large number of residential and public buildings suffered from severe damage. In addition, the Prambanan temple as a historical monument was damaged as well.

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- Mr. K. Takeya (Java Earthquake Reconstruction Program Advisor, JICA).

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