GEO-DISASTER REPORT ON THE 2011 TOHOKU-PACIFIC COAST EARTHQUAKE

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ABSTRACT: On March 11th, 2011, the Tohoku-Pacific coast earthquake caused severe damage to the eastern Japan. Authors have made damage surveys on geotechnical problem in south part of Kanto region and Tohoku region. This report briefly summarizes earthquake-induced geo-disasters from the field investigations which were conducted between March 12th and April 18th in 2011.

Key Words: Tohoku-Pacific coast earthquake, Liquefaction, Slope instability, Reconnaissance

INTRODUCTION

The Tohoku-Pacific coast earthquake measuring the moment magnitude Mw of 9.0 (USGS, 2011) hit the east Japan at 2:46PM on Friday, March 11th, 2011. The fault of the earthquake having about 500 km in length in the NS direction is located in the Pacific Ocean off east Japan (Fig. 1). Many coastal areas along Pacific Ocean were destroyed by tsunami, and the number of victims is not yet finalized at the beginning of May. Meanwhile, a large number of geo-disasters (liquefaction of sandy soils and instability of slope and embankment) was caused by the earthquake over a large extent of area in the eastern Japan. In addition, not negligible damages were caused by aftershocks measuring Mw of larger than 7.0 that occurred five times until the beginning of May (Japan Meteorological Agency, 2011).

Since the main shock on March 11th, authors have made damage survey on geo-disaster in the affected areas for several times (Fig. 1). This report summarizes damage aspects that have so far been found by the author's investigations that were conducted between March 12th and April 18th.

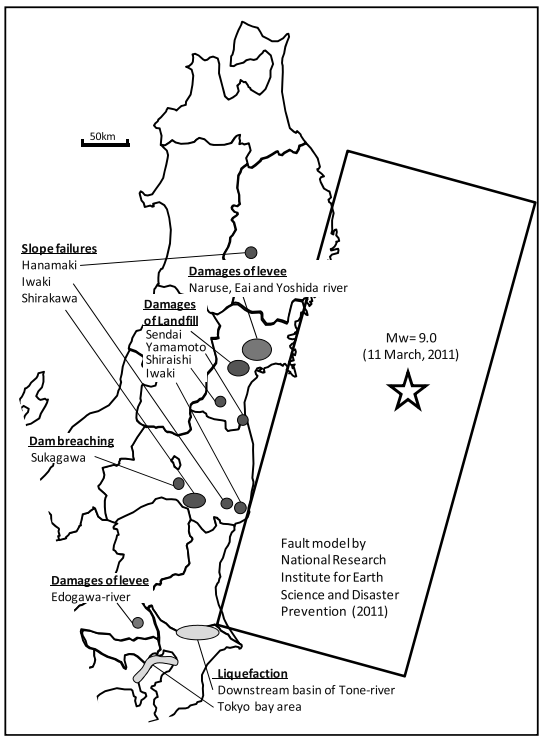

Figure 1 Location of surveyed area and epicenter of Tohoku-Pacific coast earthquake

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LIQUEFACTION-INDUCED DAMAGE IN KANTO REGION

The earthquake-induced liquefaction caused severe damage to residences, buried lifelines. High ratio of occurrence of liquefaction was found in Kanto region, especially, in Tokyo bay area and downstream basin of Tone River which would be linked to the soft subsurface ground and reclamation site.

Photo 1 shows boiled sand, which is an evidence of subsurface of liquefaction, in Shin-Kiba area in Koto-ku, Tokyo. The boiled sand covered street with a thickness of about 30 cm. Photo 2 shows rehabilitation work of sewage line which can be observed at many locations in the areas where liquefaction occurred. The distribution of boiled sand in Shin-Kiba area is summarized in Fig. 2. Large amount of boiled sand and associated damage to the road, buried lifeline and low-rise building could be observed in north part of the area while few evidences of liquefaction were found in the south area.

N35 38.687 E139 49.692
Photo 1 Boiled sand on the street in Shin-Kiba area

N35 38.713 E139 49.944
Photo 2 Rehabilitation work of sewage line in Shin-Kiba area

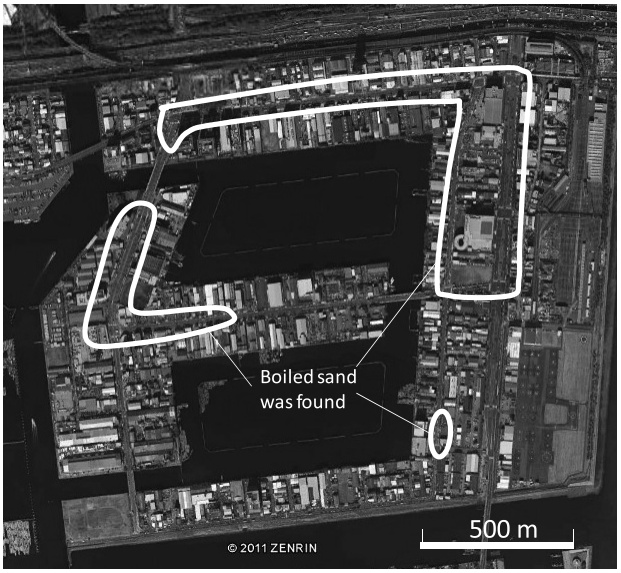


Figure 2 Distribution of boiled sand in Shin-Kiba area. Survey was conducted on 15th May.

Liquefaction-induced damage was found in many reclaimed lands along the coast of Tokyo bay, like Shin-Kiba area, which have been constructed since 1960s. One of the most affected areas by liquefaction was Urayasu city in Chiba Prefecture. Photo 3 shows the differential settlement between the building and ground surface which could cause disconnection of buried lifeline. Liquefaction in reclaimed land caused subsidence of backfill of retaining wall along the river and uneven settlement of many houses as shown in Photos 4 and 5.

Photos 6 and 7 show liquefaction-induced damage to the residential area in Itako city and Kamisu city which are located in downstream basin of Tone River. Photo 8 shows damage of road and buried high-voltage cable. Reportedly, the situation came off badly because liquefaction caused damage to the road followed by tsunami attack. Photo 9 shows water treatment plant in Kamisu city which suffered serious damage due to liquefaction. Before the earthquake, the ground surface in this area was flat. However, floating of buried box culvert and ground subsidence allowed large relative displacement of water pipes, resulting in long-lasting cut of water supply in whole Kamisu city.

N35 38.977 E139 54.811

Photo 3 Differential settlement due to liquefaction in Urayasu city

N35 38.902 E139 54.371

Photo 4 Settlement of backfill of retaining wall along Sakai River in Urayasu city

N35 38.509 E139 53.936

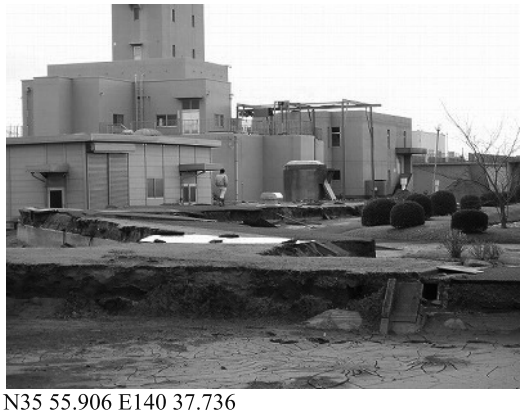
Photo 5 Uneven settlement of house due to liquefaction in Urayasu city

N35 55.712 E140 34.108

Photo 6 Damage of electric poles in Itako city

N35 55.112 E140 38.630
Photo 7 Uneven settlement of houses in Kamisu city

N35 55.488 E140 38.800
Photo 8 Damage of road by Liquefaction and tsunami in Kamisu city



N35 55.906 E140 37.736
Photo 9 Liquefaction-induced damage of Wanigawa water treatment plant in Kamisu city

DAMAGE OF RIVER LEVEE

River levee was damaged by the earthquake at many locations in Miyagi Prefecture. Figure 3 shows damaged points of levees of Eai River, Naruse River and Yoshida River. Although we could not check whole levees of these rivers, we found more than 80 damages to the levee during the survey for three days.

Photo 10 shows damaged levee of Eai River. The levee suffered from large and deep cracking on the crown and slope. Photos 11 and 12 show significantly destroyed levees of Naruse River. They exhibited slope failure and lateral spreading, respectively. Liquefaction of levee body and/or foundation ground would be one of the causes for damages. As shown in Photo 13, boiled sand from the levee body was observed which may link to the slope failure behind it.

Damage of river levee was observed in other areas. Photos 14 and 15 show distortion of Edogawa River levee that are located in Saitama Prefecture. These damages were associated with occurrence of liquefaction because boiled sand was found on the failed slopes.

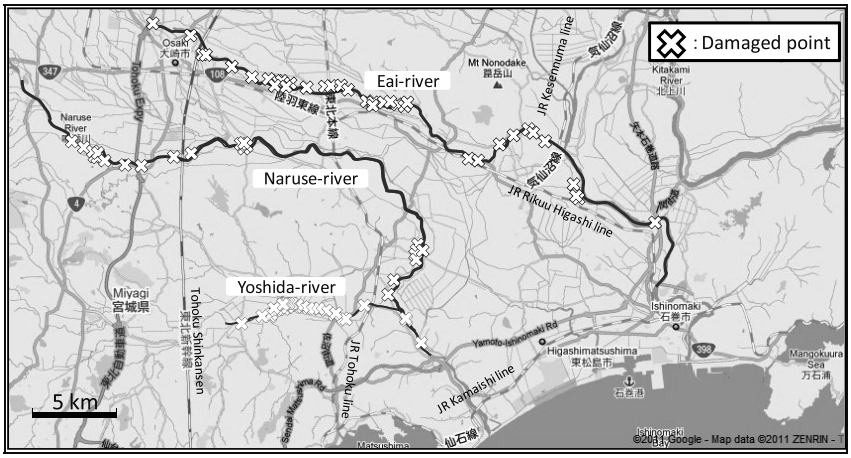


Figure 3 Distribution of damage of levees of Eai River, Naruse River and Yoshida River in Miyagi Prefecture

N38 33.903 E141 01.933

Photo 10 Damage of levee (Eai River)

N38 31.810 E141 00.311

Photo 11 Damage to levee (Naruse River)

N38 32.223 E140 53.233

Photo 12 Levee suffered from lateral spreading (Naruse River)

N38 31.705 E140 54.128

Photo 13 Liquefaction-induced damage of levee (Naruse River)

N36 05.313 E139 46.829

Photo 14 Liquefaction-induced damage of levee (Edogawa River)

N36 05.116 E139 46.607

Photo 15 Liquefaction-induced damage of levee (Edogawa River)

SLOPE INSTABILITY IN TOHOKU RESION

Natural slope failure and distortion of earth fills occurred at many locations in Tohoku region. In the area of Sendai city that is largest cities in Tohoku region, there are many artificial earth fills for housing estate that suffered from serious damage. Figure 4 is map of Sendai city showing locations of developed residential land in hill areas where damages were detected during our survey.

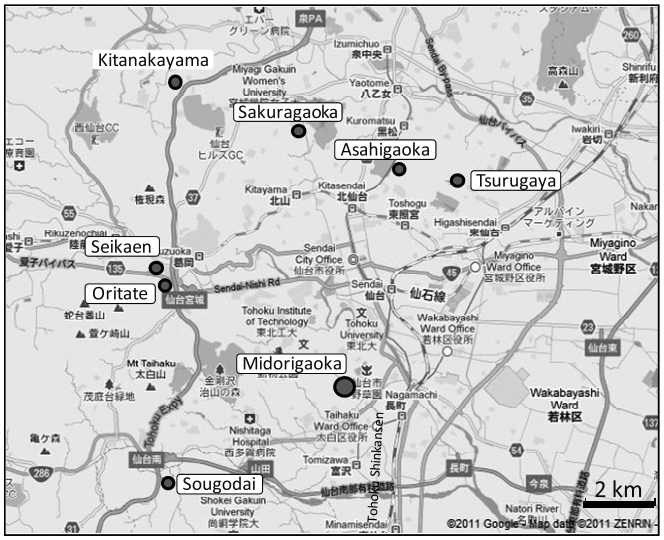


Figure 4 Locations of damaged earth fill for housing estate in Sendai city

Photo 16 shows damage of artificial earth fill in Midorigaoka, Sendai city. This earth fill failed during the 1978 Miyagiken-Oki earthquake at the same location. After the earthquake in 1978, steel pipe piles were installed at toe part of the slope as a countermeasure construction against further distortion of the earth fill (Photo 17), and the land had been used for public garden. Fortunately, therefore, damage to residences in this area was not severe despite large deformation of ground.

Slope failure of earth fill occurred in Kita-Nakayama, Sendai city. Sliding slope towards the toe is remarkable as shown in Photo 18. This failure killed one person who was on the road at the foot of slope.

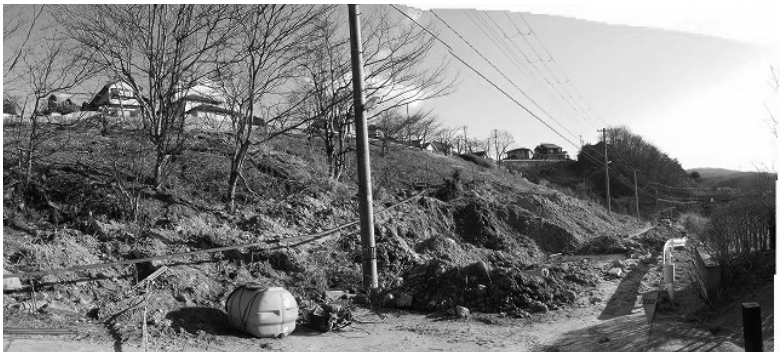
Photo 19 shows damage of road and house on the earth fill in Oritate, Sendai city. Although this area survived the 1978 Miyagiken-Oki earthquake, significant distortion of subsurface ground occurred during the earthquake this year. During the construction of this area in 1970s, cut-and-fill work was carried out, and significant earthquake-induced damage could be found only in a fill part. In addition, further ground deformation occurred during aftershocks. Photo 20 was taken at the same location as Photo 19 three weeks after, and it seems that the crack opening between road and house developed.

N38 13.984 E140 52.021

Photo 16 Damage of artificial earth fill in Midorigaoka, Sendai city

N38 13.986 E140 52.026

Photo 17 Countermeasure work was carried out in Midorigaoka after 1978 Miyagiken-Oki earthquake



N38 19.003 E140 48.640

Photo 18 Slope of earth fill failed in Kita-Nakayama , Sendai city

N38 15.593 E140 48.430

Photo 19 Ground deformation could be found on the earth fill in Oritate, Sendai city (March 31st 2011)

N38 15.593 E140 48.430

Photo 20 Further ground deformation due to aftershocks could be found in Oritate, Sendai city (April 18th 2011)

Damage of artificial earth fill was observed in other areas of Tohoku region. Photos 21 and 22 show failures of earth fill that are located in Yamamoto-cho, Miyagi Prefecture. Significant damage could be found only in a fill part, similar to the one in Oritate, Sendai city, as mentioned above. It should be noted that geosynthetics reinforced soil retaining wall that can be seen right side in Photo 22 was maintained intact while next unreinforced slope failed completely.

Photo 23 shows a huge slope failure in Iwaki city, Fukushima Prefecture, which occurred during aftershock on April 11th. As shown in Photo 24, the failure caused the foot of slope to uplift of about three meters.

Photo 25 shows breaching failure of Fujinuma earth dam in Sukagawa city, Fukushima Prefecture. The discharged water reportedly rushed into downstream village, destroying many houses and killing eight people. It could be found that the toe part of dam failed towards the reservoir which may be responsible for subsidence of the dam body and thus water-overtopping.

N37 57.291 E140 52.939

Photo 21 Slope failure in developed land in Yamamoto-cho

N37 57.367 E140 53.171

Photo 22 Reinforced soil retaining wall survived the earthquake while normal slope failed

N37 00.015 E140 47.508

Photo 23　Slope failure occurred due to aftershock in Iwaki city

N36 59.985 E140 47.553

Photo 24　The failure of Photo 22 caused the foot of slope to uplift significantly.

N37 18.149 E140 11.678

Photo 25　Breaching failure of Fujinuma earth dam in Sukagawa city

Photos 26, 27 and 28 show natural slope failures caused by the main shock on March 11th, in north of Shirakawa City, Fukushima Prefecture. Back in Aug. 27, 1998, this area, an upstream reach of Abukuma River, was ravaged by a torrential rain. The rain was reportedly responsible for more than 1000 slope failures in this 10km-by-10km area of row-raised mountain terrain. They are mostly found in Early Pleistocene non-alkaline pyroclastic flow volcanic rocks. The fact indicates a potential risk of that slopes that have suffered hidden cracks in the earthquake would slide during either an upcoming rainy season in June or summer/autumn typhoon seasons.

Photo 26 and 27 show the toe part and overall of landslide respectively. 13 people were killed in the debris. Photo 28 shows landslide which occurred near Tohoku Shinkansen railway tunnel. Soil mass reaches around the south mouth of tunnel.

N37.137829, E140.217354

Photo 26　Landslide in Hanokidaira, Shirakawa area, Fukushima prefecture.

N37.137779, E140.219116

Photo 27　Overall landslide: width 110m, length 205m and height 31m

N37.173364, E140.239052

Photo 28 Landslide in Kitanoiri, Shirakawa area, Fukushima prefecture
: width 50m, length 300m and height 60m.

SUMMARY

The authors conducted damage survey after the 2011 Tohoku-Pacific coast earthquake in eastern Japan. The results from the survey can be summarized as follows:

Significant liquefaction occurred in many reclaimed lands along the coast of Tokyo bay and downstream basin of Tone River in Kanto region. It caused severe damage to residences, buried lifelines and levees. There is still risk of repeated liquefaction during aftershocks remaining. A number of natural slopes and artificial earth fills for housing estate in Tohoku region suffered earthquake-induced damage. The whole picture of the damage caused by the earthquake was not clarified. There are still many geotechnical problems for reconstruction and rehabilitation work remaining. It is necessary to further watch the slope behaviour during aftershocks to come and the rainy season.

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REFERENCES

USGS (2011): http://earthquake.usgs.gov/earthquakes/recenteqsww/Quakes/usc0001xgp.php
Japan Meteorological Agency (2011): http://www.jma.go.jp/jma/en/2011_Earthquake.html
National Research Institute for Earth Science and Disaster Prevention (2011):
http://www.bosai.go.jp/e/international/110318/110318.html