SURVEY ON DAMAGE TO ROADS IN AKITA PREFECTURE CAUSED BY 2008 IWATE-MIYAGI NAIRIKU EARTHQUAKE

Yukika TSUTSUMI[1], Junichi KOSEKI [2], Reiko KUWANO[3], Takashi KIYOTA[4] and Tomonori MIKAMI[5]

ABSTRACT: On June 14, 2008, the main shock of the Iwate- Miyagi Nairiku earthquake with a JMA magnitude of 7.2 hit the mountainous areas in Iwate, Miyagi and Akita prefectures, Japan. Based on a site investigation performed four days after the earthquake, the following damage to roads in Akita prefecture was reported: a road closing caused by slope failure adjacent to a bend of a river, settlement of approach embankments for highway bridges due to large displacement of reinforced soil retaining walls having low stability, a failure of a road constructed by cut and fill, and a large slope failure including road embankment.

Key Words: Iwate-Miyagi Nairiku earthquake, Site investigation, Slope failure, Road embankment, Reinforced soil retaining wall

INTRODUCTION

At 8:43 am on Saturday, June 14, 2008, the main shock of the Iwate-Miyagi Nairiku earthquake measuring a magnitude specified by the Japan Meteorological Agency, M_{JMA}, of 7.2 (JMA, 2008) with an epicentral depth of 8 km struck mountainous areas in Iwate, Miyagi and Akita prefectures, Japan. It caused 13 casualties, 10 missing persons, 451 injuries, 2,352 collapsed houses, and 48 sediment disasters as of November 19, 2008 (Cabinet Office, Government of Japan, 2008). It was pointed out that, on the whole, the number of collapsed houses was smaller, while the number of sediment disasters was larger than the data in the past large earthquakes. Mostly, these severe effects occurred in Oshu city in Iwate prefecture and Kurihara city in Miyagi prefecture.

The authors conducted a site investigation in Akita prefecture on June 18, 2008, four days after the earthquake. This paper briefly summarizes typical results of the investigation, focusing on damage to roads and its possible causes from a geotechnical point of view.

OVERVEIW OF INVESTIGATED AREA

Figure 1 shows location of the investigated area in this report and those of another survey in Iwate and

[1] Technical staff, Institute of Industrial Science, University of Tokyo
[2] Professor, Institute of Industrial Science, University of Tokyo
[3] Associate professor, Institute of Industrial Science, University of Tokyo
[4] Research associate, Tokyo University of Science
[5] Graduate student, Department of Civil Engineering, University of Tokyo

Miyagi prefectures on July 1-2, 2008, which are indicated by dotted rectangles, and epicenters of the main shock and aftershocks that are marked with symbols “X”. In Akita prefecture, there were 21 injuries, 12 collapsed houses and 2 sediment disasters as of July 28, 2008 (Akita prefecture, 2008). Most of them occurred in Yuzawa city that was included as the major investigated area in this paper (Figure 2).

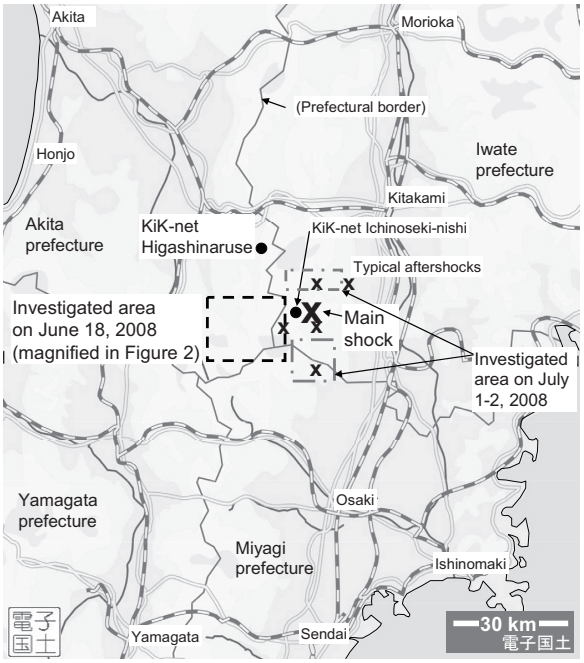

Figure 1. Locations of investigated areas and epicenters of main shock and aftershocks

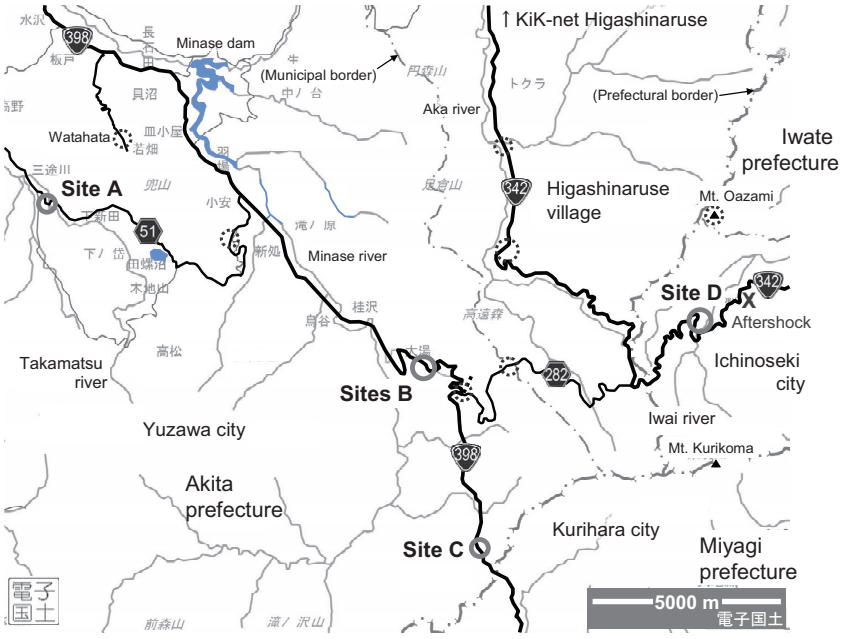

Figure 2. Locations of sites investigated on June 18, 2008

As shown in Figure 2 with solid and dotted circles, 11 sites along national highway route Nos. 342 and 398, and prefectural road Nos. 51 and 282 were investigated in detail. In addition, a site where strong motion seismograph was set by National Research Institute for Earth Science and Disaster Prevention (NIED) along national highway route No. 342 in Higashinaruse village (KiK-net Higashinaruse in Figure 1) was also visited. In this paper, the following typical damage to roads at 4 sites is reported as its representative: a road closing caused by slope failure, settlement of approach embankments for highway bridges, a failure of a road constructed by cut and fill, and a large slope failure including road embankment. The results of the investigation at the other 8 sites and those of another survey in the areas shown in Figure 1 are uploaded to the authors' website in Japanese (http://soil.iis.u-tokyo.ac.jp/Investigations-j.htm).

ROAD CLOSING CAUSED BY SLOPE FAILURE

A north facing slope adjacent to a bend of Takamatsu river at west side of Kurotaki bridge along prefectural road No. 51 (N 39° 1' 22.0" latitude, E 140° 35' 10.0" longitude) failed and the road was completely closed due to collapsed soil and trees as shown in Photo 1 (site A in Figure 2). Inclination of the original slope was about 30 degrees and the dimensions of failed area were approximately 30 m in width and 40 m in length. Figure 3 represents detailed locations of the failed slope in Photo 1, Takamatsu river and Kurotaki bridge. Collapsed soil flowed into the south side of Kurotaki bridge and caused a closure of the river course of Takamatsu river, while no damage to abutment of the bridge on the side of the failure was observed as shown in Photos 2 a) and b). By removing the collapsed soil and trees, prefectural road No. 51 was re-opened under two-way alternate traffic condition on August 7, 2008 (Yuzawa city, 2008).

Photo 1. Slope failure at west side of Kurotaki bridge along prefectural road No. 51 (site A in Figure 2)

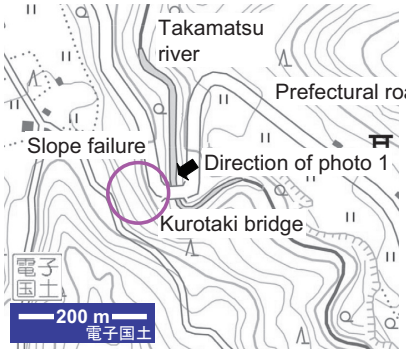

Figure 3. Detailed location of slope failure in Photo 1

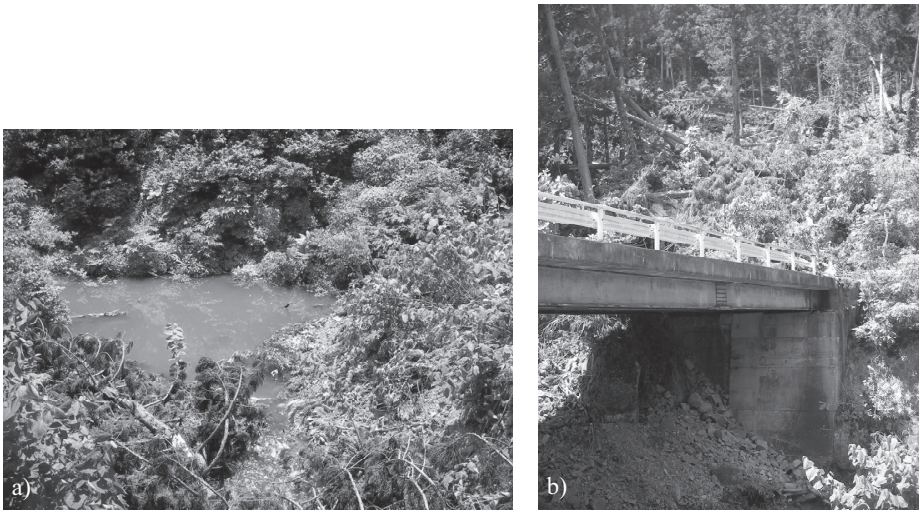

Photo 2. a) River course closure of Takamatsu river due to collapsed soil
b) Abutment of Kurotaki bridge on the side of slope failure

SETTLEMENT OF APPROACH EMBANKMENT FOR HIGHWAY BRIDGE

Settlement of approach embankments for two bridges, Shirakaba bridge and Tochinoki bridge, which are located adjacent to each other along national highway route No. 398 was observed at site B in Figure 2 (N 38° 59' 6.5" latitude, E 140° 42' 2.8" longitude). Photo 3 and Photo 5 show the settlement of approach embankments at east side of Shirakaba bridge and at south side of Tochinoki bridge, respectively.

As shown in Photo 3, the settlement of the embankment for Shirakaba bridge was about 10 cm at the maximum, and it was accompanied by horizontal residual displacement with large cracks formed along the center line of the road with the maximum opening width of about 25 cm. The embankment was supported by a newly constructed gravity type retaining wall which did not suffer any damage and an old reinforced soil retaining wall using horizontal steel strips and concrete skins (so-called "Terre Armee" method) which suffered extensive opening of inclined concrete skins at the top (Photos 4 a) and b)). It can be estimated from the existence of vegetation from the opening that the reinforced soil retaining wall had displaced and its stability had been originally low before the earthquake. Accordingly, the damage to the embankment shown in Photo 3 was possibly caused by large displacement of the old reinforced soil retaining wall that exhibited low stability during the earthquake.

Photo 3. Settlement of approach embankment for Shirakaba bridge
along national highway route No. 398 (site B in Figure 2)

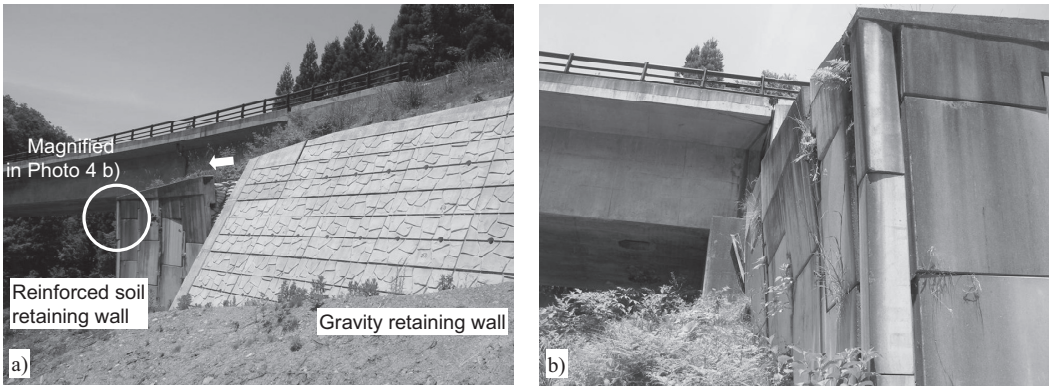

Photo 4. a) Retaining walls supporting approach embankment for Shirakaba bridge
b) Damage to reinforced soil retaining wall in a)

The amount of the maximum settlement of the embankment for Tochinoki bridge in Photo 5 was approximately 20 cm. As shown in Photo 6 a), a reinforced soil retaining wall by "Terre Armee" method having a length of about 30 m supported the embankment. As the retaining wall had already deformed and overhanged largely, additional reinforcement had been executed by using H-shaped steel piles and concrete beams, or tie rod and anchoring at the time of the earthquake. At the foot of the reinforcement concrete beam as indicated in Photo 6 a) with a circle, a crack that was possibly caused due to the earthquake was observed as shown in Photo 6 b). The same type of reinforcement structure was adopted on the opposite side of the embankment, while adding anchoring at the wing of the abutment. Between the reinforcement frame and the wing of the abutment, outflow of backfill soil due possibly to the earthquake was observed as shown in Photo 7. It can be inferred from the above facts that large deformation and displacement of the reinforced soil retaining wall that was under the execution of additional reinforcement work caused the settlement of the embankment with outflow of backfill soil.

Photo 5. Settlement of approach embankment for Tochinoki bridge along national highway route No. 398 (site B in Figure 2)

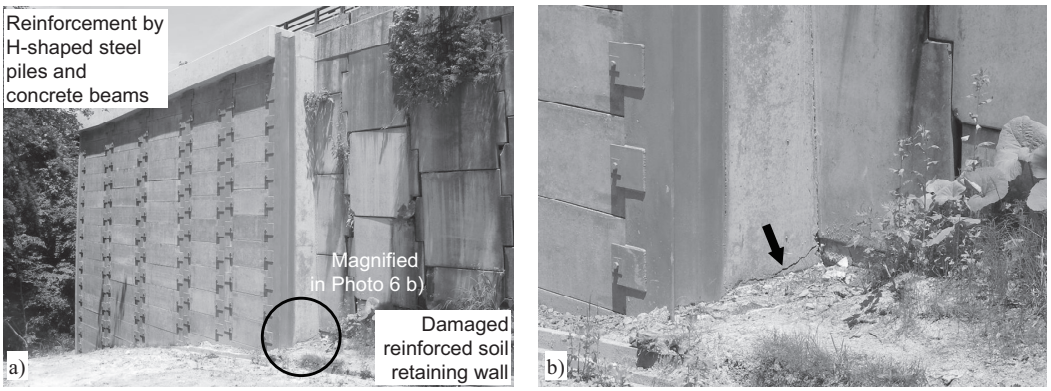

Photo 6. a) Reinforcement of approach embankment for Tochinoki bridge and adjacent reinforced soil retaining wall, b) Crack in reinforcement concrete beam of approach embankment

Photo 7. Outflow of backfill soil between reinforcement frame and original wing of Tochinoki bridge

FAILURE OF ROAD CONSTRUCTED BY CUT AND FILL

As shown in Photo 8, an embankment supported by a gravity type retaining wall along national highway route No. 398 collapsed at around the border between Akita and Miyagi prefectures (N 38° 56' 33.6" latitude, E 140° 43' 4.2" longitude, site C in Figure 2). Due to the collapse of the embankment, a large gap in the pavement was formed with the maximum width of about 30 cm at the center of the road. Photo 9 shows the tilting and settlement at the shallower part of the gravity type retaining wall that was constructed on slope with the maximum height of 4 m. The amount of maximum horizontal displacement at the top of the retaining wall was approximately 50 cm. On the opposite side of the road, cracks were formed in shotcrete on a cut slope as shown in Photo 10.

Photo 8. Collapse of embankment along national highway route No. 398 (site C in Figure 2)

Photo 9. Tilting and settlement of gravity type retaining wall in Photo 8

Photo 10. Cracks in shotcrete on cut slope

LARGE SLOPE FAILURE INCLUDING ROAD EMBANKMENT

As shown in Photo 11, a large slope failure including a road embankment occurred at an east facing slope along national highway route No. 342 in Ichinoseki city, Iwate prefecture (N 38° 59' 43.5" latitude and E 140° 47' 4.2" longitude, site D in Figure 2). The dimensions of the slope failure were about 90 m in width, 290 m in length and the height of the main scarp was about 30 m. A trace of puddle was observed at the surface of collapsed soil that remained at the north part of the slope. Collapsed soil flowed into Iwai river and made the river course closed as shown in Photo 12.

Photo 11. Large slope failure including embankment along National Highway route No. 342 (site D in Figure 2)

Photo 12. River course closure at Iwai river due to slope failure in Photo 11

It was observed that the total volume of collapsed soil was rather small, considering the dimension of the slope failure. Figure 4 shows a result of topographical analysis of slope failures including the one shown in Photo 11 based on aerial photo survey (GSI, 2008). According to the above observation and the relevant analysis results, it is estimated that the lower gentle slope was involved in a slope failure which occurred initially at the upper steep slope with partially deep sliding surfaces as schematically shown in Figure 5.

A section of the national highway route No. 342 between "Sukawa-onsen" and "Shinyu" in Ichinoseki city for a total length of 15.3 km, which included the slope failure explained above, was still completely closed for rehabilitation work as of December 22, 2008 and will be opened in autumn, 2010 (Iwate prefecture, 2008).

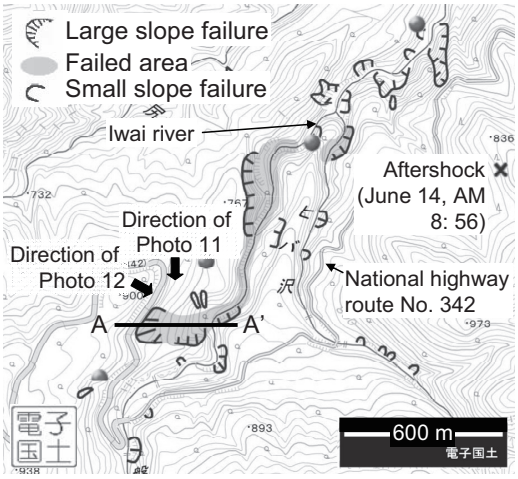

Figure 4. Topographical map including slope failure in Photo 11 (modified from GSI, 2008)

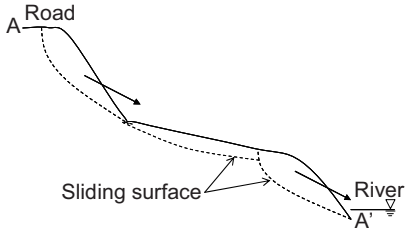

Figure 5. Estimated topography of cross section A-A' in Figure 4

CONCLUSIONS

Based on a site investigation performed four days after the earthquake, the following damage to roads in Akita prefecture was identified: a road closing caused by slope failure adjacent to a bend of a river, settlement of approach embankments for highway bridges due to large displacement of reinforced soil retaining walls having low stability, a failure of a road constructed by cut and fill, and a large slope failure including road embankment.

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