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Recent Earthquakes in Japan

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RECENT EARTHQUAKES IN JAPAN

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ABSTRACT

The paper presents highlights of case histories during earthquakes in Japan in 2003. One is a river embankment of the Naruse river in Northern Miyagiken, in which the earthquake with Richter magnitude 6.2 caused failure. A particular interest in this case history is the timing of the earthquake and failure; the earthquake was coincided with the oncoming risk of flooding, with the river suffering a high water level due to continuous raining for three days before the earthquake. This warns us not to disregard the low probability event of combined risks that pose high consequence. The other case history is a gravity quay wall in Kushiro port, Hokkaido, in which the earthquake with Richter magnitude 8.0 caused minor damage. Of a particular interest in this case history is the performance of a quay wall with backfill treated with cement for solidification, which suffered settlements in the order of 0.5m. Other quay walls in the vicinity treated with densification and gravel drains suffered no damage. The investigation is under way with respect to the difference in the performance of these quay walls.

INTRODUCTION

Two case histories during earthquake in Japan in 2003 are reported in this paper. One is a failure of a river embankment due to an earthquake, coincided with the continuous rainfalls for three days before the earthquake. The other is a gravity quay wall with backfill treated with cement for solidification that suffered settlements in the order of 0.5m. The report is preliminary, containing only those of preliminary data available at the time of writing, and does not include detailed analyses or investigations.

NORTH MIYAGIKEN EARTHQUAKE (M=6.2)

The North Miyagiken earthquakes were a series of earthquakes with epicenters located at Northern part of Miyagiken consisting of the following:

a) July 26, 2003 0:13 M=5.5
b) July 26, 2003 7:13 M=6.2
c) July 26, 2003 16:56 M=5.3

Figure 1 shows the epicenteral area of 2003 North Miyagiken earthquake, located at a pacific side of Northern Japan near Sendai city. Focal depths of the earthquakes were about 10km. The main shock occurred at 7:13. Earthquake motions recorded at Ishinomaki site, located about 10 km east of the epicenter, through K-net station is shown in Fig. 2, together with an earthquake motion recorded at May 26, 2003 earthquake (M=7.0). The failed river embankment at the Naruse river was located about 10km west of the epicenter.

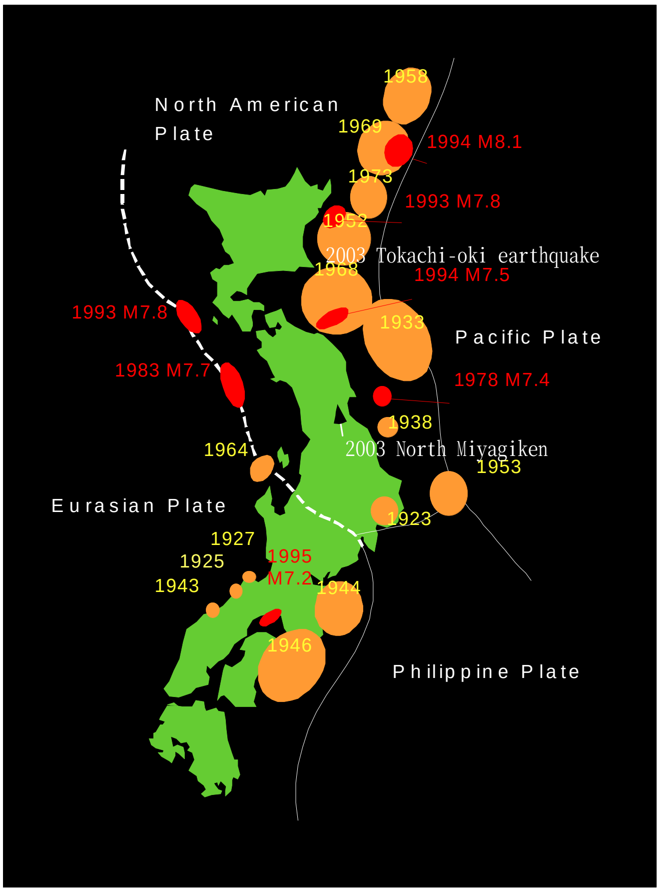

Fig. 1 Earthquakes around Japan, and epicenters of 2003 North Miyagiken (M=6.2) and Tokachi-oki (M=8.0) earthquakes

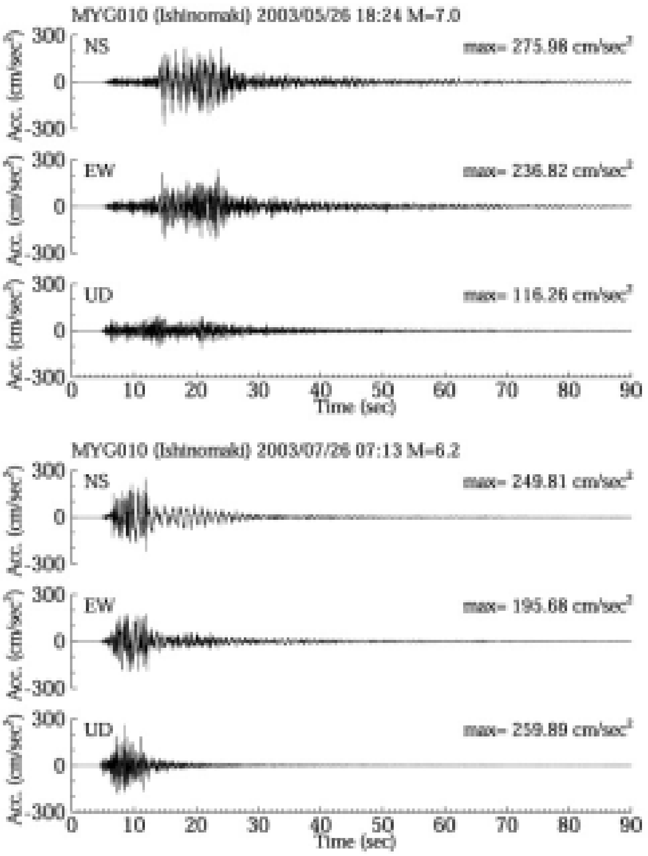

Fig. 2 Earthquake ground motions at Ishinomaki, about 20 km from the failed river embankment at the Naruse river, during May 26 (M=7.0) and July 26 (M=6.2) earthquakes (K-net)

Figure 3 shows typical damage to the embankment at the Naruse river. A particular interest of this case history is the timing of the earthquake occurrence. It was coincided with the continuous rainfall for three days before the earthquake. As shown in Fig. 4, the continuous precipitation in the order of 1 to 5 mm/h for three days indicates that cumulative rainfall was in the order of 150 to 200mm when the earthquake hit the area. The water level was over the specified level, above the elevation of flooding area, and approaching toward the warning level.

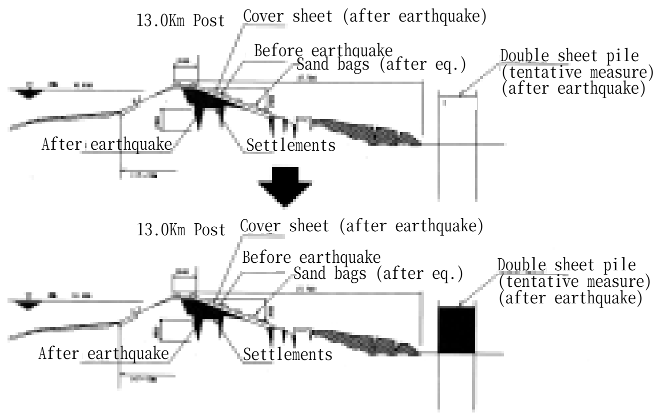

Fig. 3 Cross section of the failed river embankment and tentative measure for restoration (after Tohoku Construction Bureau, MLIT)

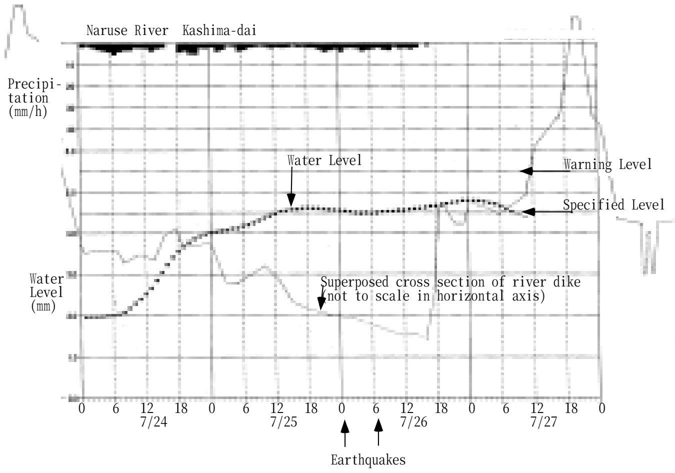

Fig. 4 Water level, rainfall, and the warning and specified water levels at the Naruse river (After Tohoku Construction Bureau, MLIT)

In typical design of river embankment, coincidence of earthquake occurrence and heavy rain is not considered. This is because the combined probability of the occurrence of both phenomena is very small. However, the case history obtained here suggests that the low probability event may not be easily neglected when the combined risk poses a very high consequence. This is especially true when the river embankment is located in the vicinity of residential area as shown in Fig. 5.

Fig. 5 Residence in the vicinity of the failed river embankment at the Naruse river

2003 TOKACHI-OKI EARTHQUAKE (M=8.0)

River Embankment Failure

More significant failures and liquefaction occurred at the river embankments in Tokachi area during 2003 Tokachi-oki earthquake. These failures were widely reported by the mass media after the earthquake because they were wide spread and easily recognizable. Major cause of damage was the liquefaction of foundation soils. Some of the photos are shown in Fig. 6.

Fig. 6 Damage to embankment at the Tokachi river (After Hokkadio Development Bureau)

Fig. 7 Sand boils at the toe of an embankment

After the earthquake, a run-up of a tsunami occurred along the Tokachi river. There was no serious damage or flooding due to the tsunami. However, the incidence of the occurrence of a tsunami run-up immediately after the earthquake suggests that the failure of embankment should be design not only for potential flooding due to rainfall but also for a possible tsunami run-up after the earthquake especially for the river mouth area and in the vicinity.

Fig. 8 Traces of tsunami run-up along the Tokachi river

Performance of Gravity Quay Walls

Less remarkable but more of a particular interest in the profession of geotechnical engineering may be the performance of gravity quay walls at Kushiro port.

Figure 9 shows earthquake motions record at the Kushiro port. The peak ground surface acceleration was about 0.5g.

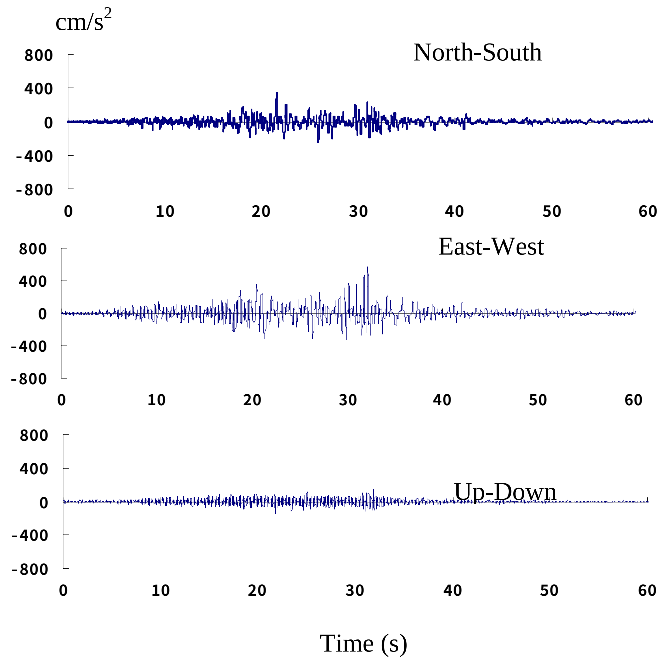

Fig. 9 Earthquake ground motions recorded at Kushiro port during 2003 Tokachi-oki earthquake (After Port and Airport Research Institute)

Figure 10 shows a cross section of a quay wall with backfill soil treated with cement for solidification. The backfill soil was silt dredged from the nearby sea bottom. The cement was mixed for solidification using an in-situ plant before filling. Cement added were 80 to 110kg/m^3 for achieving unconfined compression strength in the average of 400kN/m^2. Due to the earthquake, the backfill soil settled about 0.5m. There was no evidence of liquefaction in the cement treated zone.

Damage was minor or non to the quay wall having the similar cross section but with backfill treated by sand compaction piles or gravel drains.

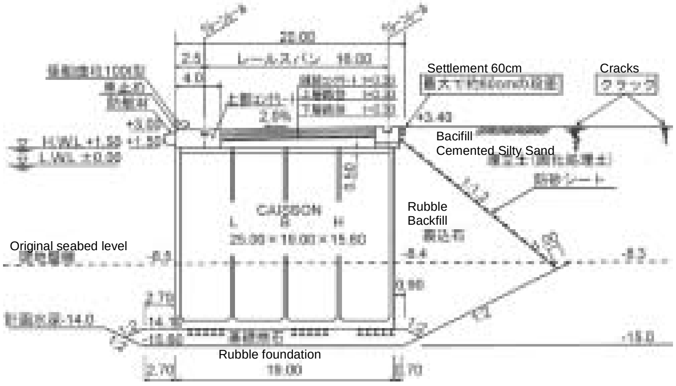

Fig. 10 Cross section of a gravity quay wall at Kushiro port with backfill treated with cement for solidification (After Hokkaido Development Bureau; Port and Airport Research Institute)

The difference in the performance of these quay walls attracted a keen interest among geotechnical engineering profession. Various speculations have been made. Pseudo static analysis typically results in the smaller displacement when the stiffness of some portion of the soil-structure system is increased. Due to the dynamic response of a system, stiffening of one portion of system might not always results in the stiffness increase in the overall system. Highly non-linear nature of a system may also contribute to a complex response of a system. In particular, unbalanced stiffness distribution in the system may result in strain concentration to a remaining soft portion, thus casing unfavorable deformation in the system.

Another possibility speculated is the effects of stress history. The quay walls having backfill soil improved with sand compaction piles and/or gravel drains were constructed before 1993 Kushiro earthquake and underwent the stress histories due to 1993 Kushiro-oki (M=7.8) and 1994 Hokkaido-Toho-oki (M=8.1) earthquakes. The PGA recorded at Kushiro port at these earthquakes were 0.3g and 0.2g, respectively. Due to these stress histories, it might be possible that the backfill stones and foundation gravels may be sufficiently strengthened by obtaining the more solid particle contacts between the gravel particles. The backfill soil improved by sand compaction piles and gravel drains might also become more stable than the initial state immediately after the sand compaction piles or gravel drains installation. On the other hand, the quay walls having backfill treated with cement for solidification were constructed in 2002 just before the earthquake. There was none in the stress history in these quay walls before the 2003 earthquake.

Currently all of these discussions remain at the speculation stage. There were not fully backed up by the numerical or physical model testing. A study is on-going, some of which could be reported verbally during the conference.