



EFFECTS OF LIQUEFACTION IN KANTO REGION CAUSED BY THE 2011 OFF THE PACIFIC COAST OF TOHOKU EARTHQUAKE

Junichi KOSEKI¹, Yukika MIYASHITA², Jianliang DENG³ and Hiroyuki ARAKI⁴

ABSTRACT: Some case histories surveyed by the authors are reported briefly on effects of liquefaction in Kanto region caused by the 2011 off the Pacific coast of Tohoku earthquake. Extensive liquefaction took place predominantly in reclaimed lands along Tokyo bay areas and river basins, which induced damage to houses, lifeline facilities and river dikes. On the other hand, structures that had been designed considering effects of liquefaction performed in general satisfactorily.

Key Words: Case history, Liquefaction, The 2011 off the Pacific coast of Tohoku earthquake

INTRODUCTION

The geo-disaster caused by the 2011 off the Pacific coast of Tohoku earthquake, Japan is too extensive and widely distributed, and thus its outline and details have not yet been fully revealed.

In view of this, by focusing on liquefaction and its effects on structures, some case histories in Kanto region surveyed by the authors are reported briefly herein.

SAND BOILING

In Kanto region, Japan, as typically shown in **Photo 1**, extensive sand boiling was observed in reclaimed lands along the Tokyo bay areas and basins of several rivers such as Tone, Kokai and Kuji rivers. Refer to **Figure 1** for their locations.

When the residential and industrial areas suffered from sand boiling, as shown in **Photo 2**, the boiled sand covered the ground surface and occasionally caused clogging of drainage facilities. It should be noted that, as shown in **Figure 2**, the samples retrieved by the authors from the sand boiling sites consisted mainly of fine sand to silt particles.

As exceptional cases, a gravelly soil boiled out as shown in **Photo 3** at two sites along the Kokai river located near the border of Ibaraki and Tochigi prefectures.

SETTLEMENT AND TILT OF SUPERSTRUCTURES

Soil liquefaction caused settlement of the ground by not only sand boiling but also re-consolidation of liquefied soil layers due to dissipation of excess pore water pressure. In addition, when there existed

¹ Professor, Institute of Industrial Science, University of Tokyo

² Technical Staff, ditto

³ Post-doctoral Researcher, Geosphere Research Institute, Saitama University

⁴ Graduate Student, Department of Civil Engineering, University of Tokyo

superstructures such as low-story houses with shallow foundations, they suffered from additional settlement due to their self-weight, which was occasionally accompanied by tilt, as typically shown in **Photo 4**.

Considering that the above damage induced serious social problems, future attentions shall be paid on rational measures for existing houses constructed on liquefiable soil layers.

DAMAGE TO RIVER DIKES

Some part of dikes of Tone, Kokai and Kuji rivers suffered from failure, excessive deformation and/or cracking. As typically shown in **Photo 5**, they were frequently accompanied by sand boiling at the foot of the dike, suggesting that liquefaction of subsoil layers and/or submerged part of the dike itself induced the damage.

UPLIFT OF UNDERGROUND STRUCTURES

Underground structures such as sewer pipes and manholes suffered from uplift failure. It was caused by liquefaction of backfill soil and/or original soil layers, as typically shown in **Photos 6 and 7**, respectively.

LATERAL FLOW

Liquefaction-induced lateral flow was observed in river basins at gently-sloped ground (**Photo 8**) and level ground (**Photo 9**) facing a pond or a river. However, as far as the authors know, it did not occur extensively in the areas along Tokyo bay where liquefaction of reclaimed lands was significant.

PERFORMANCE OF DEEP FOUNDATIONS

In the areas where liquefaction took place extensively, there existed structures with deep foundations that had been designed considering the effects of liquefaction, such as viaducts and high-story buildings. As typically shown in **Photo 10**, they performed in general satisfactorily, except for the damage to the connecting pipes caused by the liquefaction-induced settlement of surrounding ground.

Future investigations would be required to review the seismic design of these structures by conducting back-analyses.

SUMMARY

The 2011 off the Pacific coast of Tohoku earthquake caused liquefaction in Kanto region, predominantly in reclaimed lands along Tokyo bay areas and river basins. It induced damage to houses, lifeline facilities and river dikes, among others. On the other hand, structures that had been designed considering effects of liquefaction performed in general satisfactorily. Future attentions shall be paid on rational measures for existing houses constructed on liquefiable soil layers.

ACKNOWLEDGEMENTS

Part of the survey was conducted by the first author in corporation with Taisei Kiso Sekkei Co. Ltd. Valuable information on liquefaction-induced damage was provided by Katori City Office, Chiba Prefecture.



Figure 1. Location of liquefied sites reported in this paper

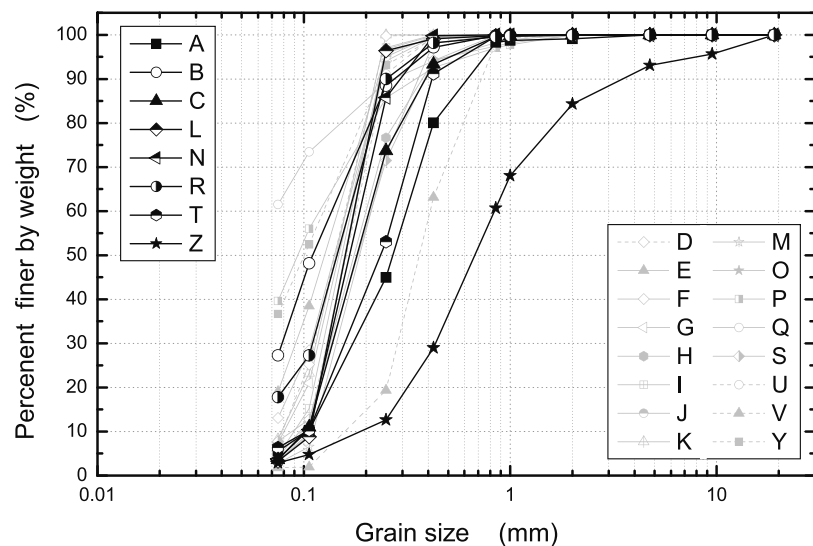


Figure 2. Gradation of samples retrieved from sand boiling sites at Chiba, Ibaraki and Tochigi prefectures

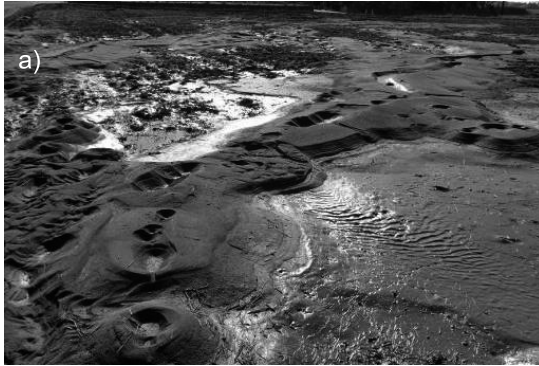


Photo 1. Extensive sand boiling a) at rice paddy in Toride city, Ibaraki prefecture (site C) and b) at back yard of supermarket in Urayasu city, Chiba prefecture (site R)



Photo 2. Boiled sand a) at reclaimed old swamp in Katori city, Chiba prefecture (site L) and b) at reclaimed old pond in Abiko city, Chiba prefecture (sites A and B)



Photo 3. Boiling of gravelly soil at toes of Kokai river dike in Chikusei city, Ibaraki Prefecture (site Z)



Photo 4. a) Tilt of wooden houses and failure of wall in reclaimed land of Urayasu city, Chiba prefecture (site RR) and b) tilt of wooden house at reclaimed old swamp in Itako city, Ibaraki prefecture (site LL)

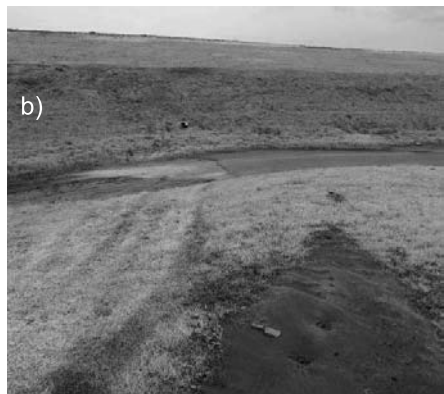


Photo 5. a) Cracking of Tone river dike in Kawachi Town, Ibaraki prefecture (site N) and b) sand boiling at its toe



Photo 6. Uplift of sewer manhole and settlement of backfill soil in Naka city, Ibaraki prefecture (site TT)



Photo 7. Uplift of sewer manhole in reclaimed land of Urayasu city, Chiba prefecture (site R2)

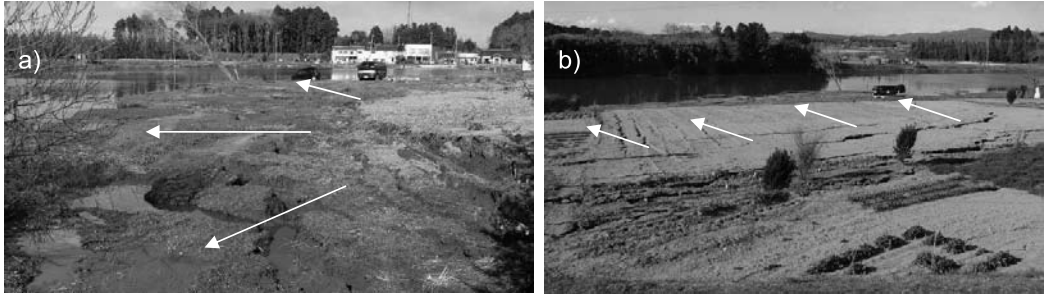


Photo 8. a) & b) Lateral flow of gently-sloped ground along a pond in Hitachi-Oota city, Ibaraki prefecture (site T)



Photo 9. Lateral flow of level ground facing a pond in Katori city, Chiba prefecture (site L2)

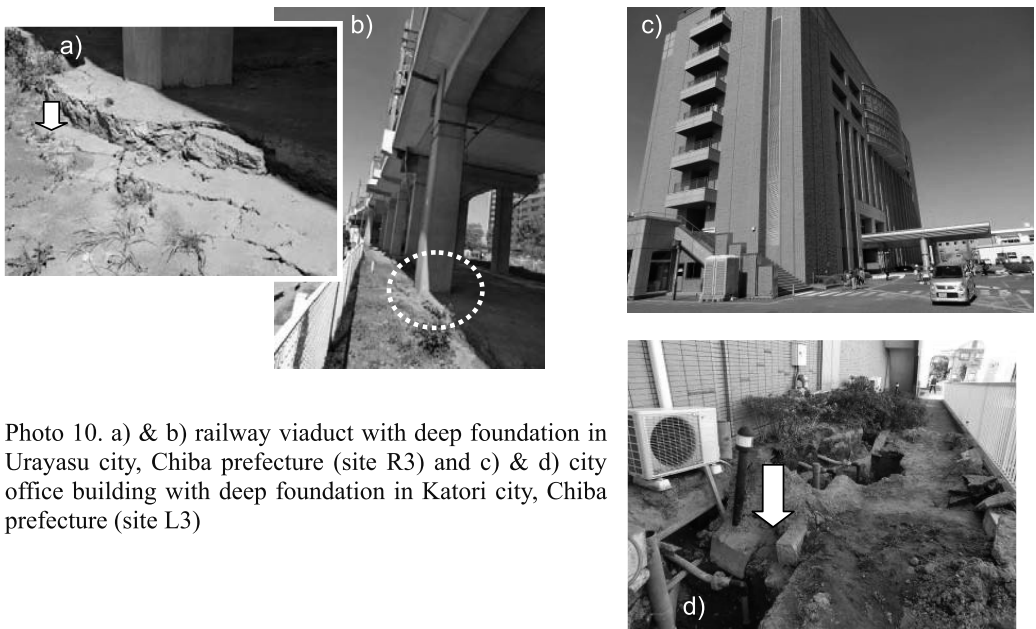


Photo 10. a) & b) railway viaduct with deep foundation in Urayasu city, Chiba prefecture (site R3) and c) & d) city office building with deep foundation in Katori city, Chiba prefecture (site L3)