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Liquefaction in the Kanto region during the 2011 off the pacific coast of Tohoku earthquake

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Abstract

The present text is a summary of liquefaction events that occurred in the Kanto Region during the 2011 off the Pacific coast of Tohoku Earthquake, excluding those events in the Tokyo Bay area that are discussed elsewhere. Most liquefaction occurred in the abandoned river channels and former lakes that had been recently filled with liquefiable soils. Noteworthy was the damage to private housing lands and river dikes that had not been well treated against liquefaction risk. Many sites experienced repeated liquefaction after former earthquakes in 1923 or 1987, if they existed in those times. In contrast to the recent liquefaction-prone soils, more-aged sands scarcely liquefied because of what is called the "ageing" effect. The present study analyzed cases in Tokyo area to quantitatively assess the temporal development of ageing so that liquefaction risk in more aged soils might be reasonably assessed. In the appendix, remarks are made of the reliability of air-photo survey in quick detection of liquefaction sites.

Keywords: The 2011 off the Pacific Coast of Tohoku Earthquake; Liquefaction; Site investigation; Earthquake resistance; Deformation; Ageing; IGC: E08

1. Introduction

The gigantic earthquake of $M=9.0$ in Japan caused many kinds of damage that was characterized by a tremendous number over a vast area. Fig. 1 illustrates the area of damage together with the assessed causative rupture zone. Among different kinds of damage, liquefaction was extremely serious in the sense of significant distortion of river levees and subsidence as well as the tilting of private houses, although there were no resulting casualties. Because the causative fault was extremely large in size, liquefaction occurred not only in the Tokyo and the surrounding Kanto

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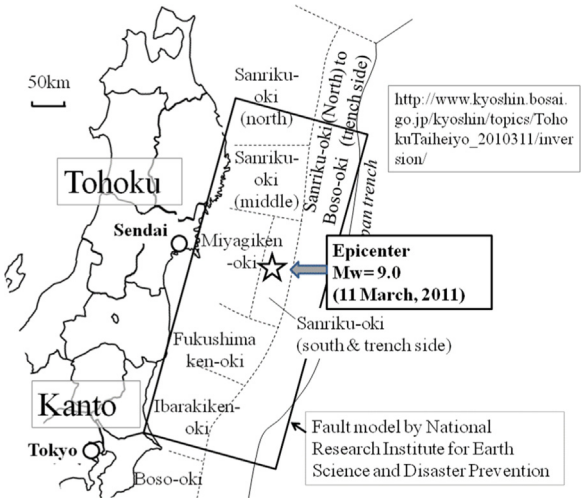

Fig. 1. Causative rupture and seismically affected Tohoku and Kanto Regions of Japan (drawn after National Research Institute for Earth Science and Disaster Prevention).

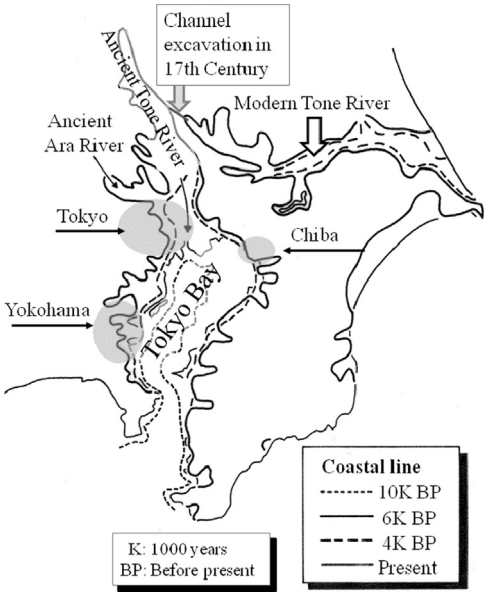

Fig. 2. Ancient map of Kanto Region when there were many bays and lakes.

Region but also in Sendai and Tohoku Region to the north where there are young sandy deposits everywhere. However, most evidence of liquefaction in the coastal area of Tohoku was washed away by the tsunami and limited liquefaction evidence was left behind in river levees and earth-filled valleys in the inland area. Hence, the present paper summarizes and discusses liquefaction evidences only in the Kanto Region.

Immediately after the quake, the Kanto Chapter of the Japanese Geotechnical Society initiated an investigation project on liquefaction in the Kanto Region jointly with the Kanto Regional Development Bureau of the Ministry of Land, Infrastructure, Transport and Tourism. This project aimed to collect as much as possible the available information on occurrence of liquefaction in the region, including locations, photographs, conditions of topography and surface geology, and seismic motion records. Accordingly, the present paper summarizes the essence of the study. It should be noted that in this special issue Yasuda et al. (2012) focuses on details of liquefaction in the man-made islands in the Tokyo-Bay area. Hence, this paper addresses mainly liquefaction in the inland area. Note that detailed study is still going on and the contents of this text are a temporary summary of the information so far obtained.

2. General geography and surface geomorphology of Kanto region

The Kanto Region consists mainly of planar topography with some mountains, terraces, rivers, and lakes. The surface geology/soil conditions in the plain is a product of the Holocene era, during which the sea level rose over 100 m and reached the peak a few thousand years ago, and then lowered a few meters. When the sea level was very low, rivers eroded the land and created valleys; the most important of them was the valley in the eastern part of present Tokyo that was produced by the present Tone River, which formerly flowed into Tokyo Bay. The rising sea level inundated low lands to produce many bays and lakes in the southern half of the region (Fig. 2). Since then those water areas have been filled gradually by sediments, and more recently by human actions, and have become land made of soft deposits. However, lakes and swamps still remain. Finally, the channel of the Tone River was artificially converted to go directly to the Pacific Ocean in the 17th Century in order to prevent flooding in Tokyo as well as to promote the economic development of the region.

3. On the conducted reconnaissance project

After the gigantic earthquake of $M=9.0$ on March 11th, 2011, the Japanese Geotechnical Society and the Kanto Regional Development Bureau started reconnaissance to collect comprehensive information about liquefaction at 184 sites in total. It was initially decided that this joint activity should address objective information that would help liquefaction studies in future. Thus, a detailed interpretation of the damage mechanism was excluded from the project. Further, liquefaction of backfill soil of, for example, sewage pipelines were eliminated from the study because it was not a problem of ground but of construction technology. Note, however, that liquefaction of manmade islands was still included although the size boundary between backfilling and island could not be clearly defined.

Detailed methodology of the study is summarized in what follows:

(1) Investigators visit sites of liquefaction and identify their exact locations. Fig. 3 indicates the sites of liquefaction thus identified. It is therein shown that there are two major groups of liquefied sites: those in manmade islands along