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Seismic behavior of piled raft with ground improvement supporting a base-isolated building on soft ground in Tokyo

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Abstract

The static and seismic behavior of a piled raft foundation, supporting a 12-story base-isolated building in Tokyo, is investigated by monitoring the soil–foundation–structure system. Since the building is located on loose silty sand, underlain by soft cohesive soil, a piled raft with grid-form deep cement mixing walls was employed to cope with the liquefiable sand as well as to improve the bearing capacity of the raft foundation. To confirm the validity of the foundation design, field measurements were carried out on the ground settlements, the pile loads, the contact pressure and the pore-water pressure beneath the raft from the beginning of the construction to 43 months after the end of the construction.

On March 11, 2011, 30 months after the end of the construction, the 2011 off the Pacific coast of Tohoku Earthquake struck the building site. The seismic response of the ground and the foundation–structure system was successfully recorded during the earthquake, and a peak horizontal ground acceleration of 1.75 m/s^2 was observed at the site of the building. Based on static and dynamic measurement results, it was found that there was little change in the foundation settlement and the load sharing between the raft and the piles before and after the earthquake. It was also found that the horizontal accelerations of the superstructure were reduced to approximately 30% of those of the ground near the ground surface by the input losses due to the kinematic soil–foundation interaction in addition to the base isolation system.

Consequently, the piled raft with grid-form deep cement mixing walls was found to be quite stable in the soft ground during and after the earthquake.

Keywords: Building; Case history; Load sharing; Measurement; Piled raft foundation; Settlement; Seismic loading; The 2011 off the Pacific coast of Tohoku Earthquake

1. Introduction

In recent years, there has been an increasing recognition that the use of piles to reduce raft settlement can lead to considerable economic savings without compromising the safety and performance of the foundation (Poulos, 2001). Detailed investigations of several high-rise buildings in Germany, mainly in Frankfurt, were carried out (Katzenbach et al., 2000; Mandolini et al., 2005). Piled raft foundations have been used for many buildings in Japan, including tall buildings in excess of 150 m in height (Yamashita et al., 2011a).

It has become necessary to develop more reliable seismic design methods for piled rafts, particularly in highly seismic areas such as Japan. Yamada et al. (2001) reported

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a case history of a piled raft, supporting a 12-story building in Osaka, which was monitored before and after the 1995 Hyogoken-Nambu earthquake. Mendoza et al. (2000) reported on the static and seismic behavior of a piled-box foundation, supporting an urban bridge in Mexico City clay, i.e., the response of the soil–foundation system was recorded during the occurrence of two seismic events in 1997, in which the maximum horizontal acceleration of the foundation was 0.31 m/s^2. However, only a few case histories exist on the monitoring of the soil–foundation–structure interaction behavior during earthquakes.

Photo 1. Twelve-story building in Tokyo.

This paper offers a case history of a piled raft with ground improvement on soft ground supporting a 12-story base-isolated building in Tokyo. The foundation type was employed to cope with the liquefiable sand as well as to improve the bearing capacity of the raft foundation on loose sand underlain by soft cohesive soil. To confirm the validity of the foundation design, field measurements were carried out on the ground settlements, the pile loads, the contact pressure and the pore-water pressure beneath the raft, both statically and dynamically, from the beginning of the construction to 43 months after the end of the construction. On March 11, 2011, 30 months after the end of the construction, the 2011 off the Pacific coast of Tohoku Earthquake struck East Japan, and the seismic response of the soil–foundation–structure system was successfully recorded at the site of the building. In this paper, the characteristics of the observed static and seismic behavior of the piled raft with ground improvement are discussed.

In addition, the field measurement results from the beginning of the construction to 27 months after the end of the construction have been reported in a previous paper (Yamashita et al., 2011b).

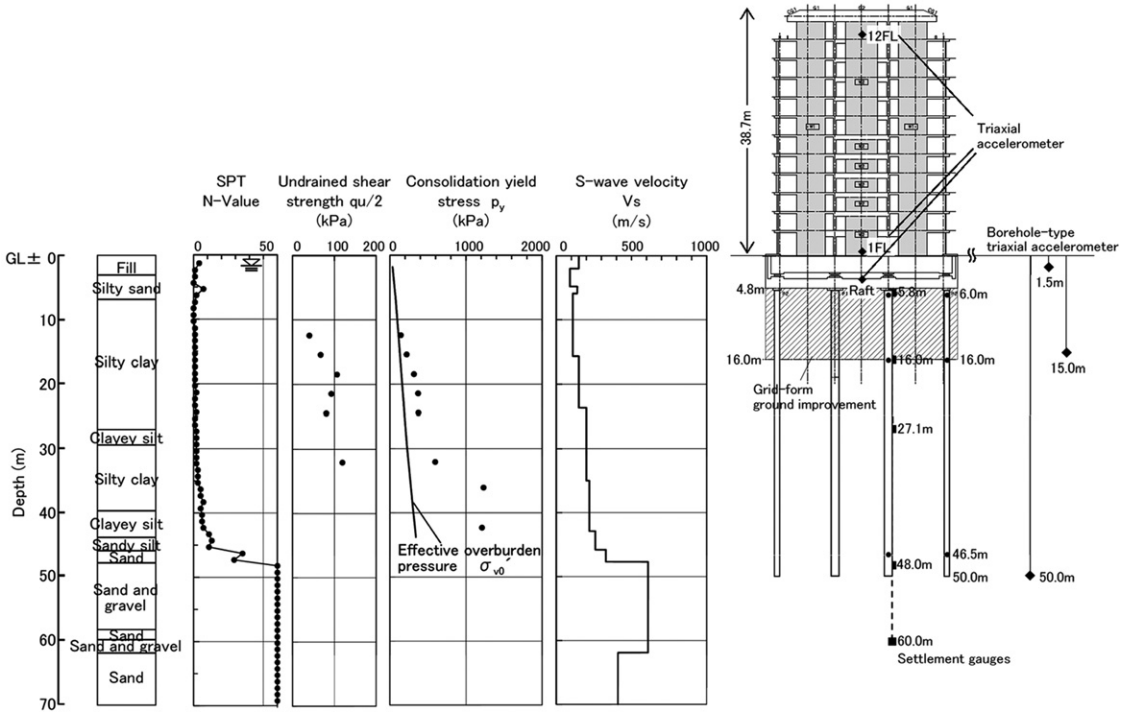

Fig. 1. Schematic view of building and foundation with soil profile.