Influence of Gelling Time on Permeability and Strength of Ground Improved by Chemical Grouting Method

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ABSTRACT

Since the 1995 Hyogoken-Nanbu earthquake caused serious damage, countermeasures against liquefaction for revetments have been executed rapidly in Japan. A chemical grouting method has been selected as one of them. One reason for this is that the method can be applied without ceasing operation of improved facilities during the improvement work because a set of grouting machines equipped for conducting the method is quite compact. Furthermore, this method has advantages of low vibration, low noise as well as less ground heaving during the construction.

However, in case that an appropriate gelling time of the grout is not set, it is pointed out that construction defects such as poorly-lithified grouting and fractured grouting may happen. It is, therefore, important to decide a proper gelling time for a type of soil at a construction site. Moreover, it is important to grasp how grout material behaves in ground in order to improve the ground properly.

In this paper, the effectiveness of the chemical grouting method against liquefaction is proved from survey results on the Tohoku earthquake damages. And a series of grouting experiments, using one-dimensional and two-dimensional containers, was conducted on model sand grounds grouted with various gelling times of grout materials. In the experiments, in order to examine the dilution of grout material, stereometry and strength test of the grouted specimen, measurement of distributions of silica concentration and pH in the grouted material were conducted. As a result, it was confirmed that the infiltration behavior of the grout material could be visualized using the two-dimensional container, and the dilution of the grout material was observed. In addition, the appropriate gelling time of a sand specimen for the chemical grouting method was discussed.

KEY WORDS: Chemical grouting; Liquefaction countermeasure; Gel time; Permeability of grout; Active silica colloid; Unconfined compression strength; Dilution phenomenon

INTRODUCTION

Survey results on chemical grouted improvement

The Tohoku Earthquake occurred on March 11th 2011. In this earthquake, the maximum acceleration of 2933 gal was observed in Kurihara city in Miyagi prefecture. Liquefaction occurred in many regions from Tohoku to Kanto district. The total area liquefied was 42 square kilometers. The chemical grouting method had been performed in several places along the Pacific coast (Towhata. 2008). A damage survey of the 2011 off the Pacific coast of Tohoku Earthquake revealed the effectiveness of the chemical grouting method as a liquefaction countermeasure.

The port of Sendai was the nearest port to the epicenter of the 2011 off the Pacific coast of Tohoku Earthquake. The distance from the epicenter was 169km, and the maximum acceleration of 2018gal was measured. Takamatsu wharf in Sendai Port had been treated with the liquefaction countermeasure by the chemical grouting method a few years before the earthquake. Fig.1 shows the map of Sendai Port. Cross sections of improved sites are colored in blue, unimproved in red. Fig2 shows a section of the improved ground.

Photo.1 and Photo.2, taken after the earthquake, show damage situations of the improved sites. Except for a little settlement of the apron surface caused by the strong motion, no damage was observed in the improved parts of the wharf. Therefore, the improved parts of the wharfs were operated as usual immediately after the earthquake.

Photo.3 and Photo.4 show unimproved quays adjacent to the improved wharf. The backfills of the quays were liquefied and settled down and the quay walls were tilted and sunk in large amount. By comparing the survey results of the earthquake damages, the efficiency of the chemical grouting method as a liquefaction countermeasure was demonstrated.