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Assessing the Uplift Displacement of Buried Geotechnical Structures in Liquefied ground during earthquakes

○GiChun KANG, Tetsuo TOBITA, Susumu IAI

The 2004 Niigata-ken Chuetsu, Japan, earthquake, more than 1,400 manholes were uplifted. Then, uplifted manholes have become a serious matter because they not only hinder the flow of sewerage systems as a part of lifeline systems but also disturb traffic flow. Despite intensive research efforts in geotechnical earthquake engineering, practical methods to predict the phenomena and estimate the uplift amount of buried geotechnical structures in liquefied ground have not been established yet.

The present research is focused on establishing a practical method to assess uplift displacement of manhole uplift. Then, a simplified method is proposed to estimate the uplift displacement of a manhole and settlement of backfill due to liquefaction. The simplified method is based on the equilibrium of forces acting on a manhole under assumption of no volume change or continuity of liquefied backfill. Forces acting on the manhole are the dead weight of the manhole and the frictional force between the manhole and backfill above ground water table as downward force, and hydrostatic pressure and the uplift force acting on the bottom of the manhole due to liquefied backfill as upward forces. However, the predicted uplift displacement by the simplified method is the maximum uplift displacement and the method is incapable of predicting transient behavior during shaking. To overcome the limitation of the simplified method, the two dimensional finite element analyses as detailed method based on the multiple shear mechanism for soil are carried out and the results are compared with the centrifuge test data. The numerical analysis is conducted for test cases in which the manhole uplift did not reach the maximum amount and was then overestimated by the simplified method. The computed uplift displacements were consistent with that measured in the centrifuge model tests. It indicates that the numerical approach is capable within the limit of small uplift displacements.

In order to verify the application of the simplified method, the method is applied to the case history in Nagaoka city during 2004 Niigata-ken Chuetsu, Japan, earthquake as shown in Fig. 1. As shown in this figure, The simplified method is reasonable to estimate the maximum uplift displacement considering that all the data are plotted within the predicted boundary of the maximum uplift and the numerical analysis as detailed method can be applied to estimation for low magnitude of the manhole uplifts with the various soil/structure/shake conditions as well as transient behaviors of the manholes during shaking.

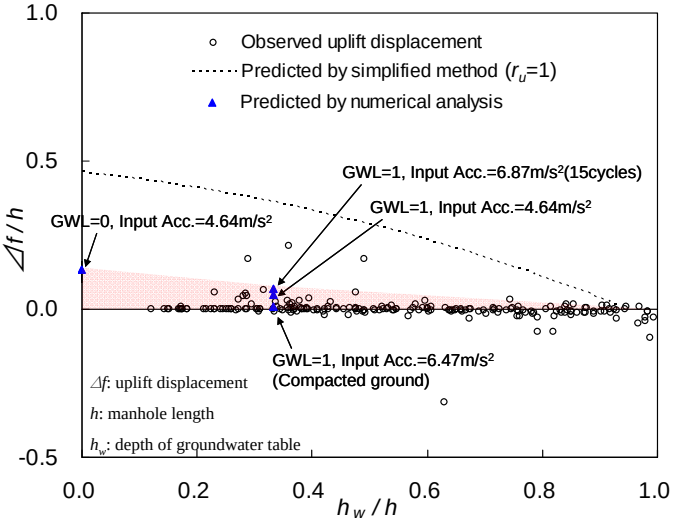

Fig. 1. Predicted uplift of manholes and ones observed in Nagaoka during 2004 Niigata-ken Chuetsu, Japan, earthquake.