

	グ リンリン
氏 名	GU LINLIN
学位の種類	博士（工学）
学位記番号	博第1061号
学位授与の日付	平成28年9月7日
学位授与の条件	学位規則第4条第1項該当 課程博士
学位論文題目	Quantitative Evaluation for the Deformation of Structures Built in Soft Ground Subjected to Dynamic Loads (軟弱地盤に建設される土構造物の動的荷重による変形特性の定量的評価)
論文審査委員	主査 教授 張 鋒 教授 前田 健一 教授 小畑 誠 教授 野田 利弘 (名古屋大学)

論文内容の要旨

In recent years, the research on the multi-phase problems in Geotechnical Engineering has drawn more and more attention, such as unsaturated slope failures caused by heavy rain, liquefaction caused by earthquakes, long-term stability of geological disposal of high-level nuclear waste, and so on. However, the researches are limited, and most of the problems have not been worked out. When the geotechnical disasters occurred, they may cause tremendous loss of life and properties, therefore understanding the mechanism of multi-phase geotechnical disasters are necessary and urgent. In this thesis, the multi-phase problems especially the deformation of structure built on soft ground subjected to earthquake loading and train loading are quantitatively evaluated based on the sophisticated constitutive model proposed by laboratory experiments and field tests.

Firstly, element tests are conducted to investigate the mechanical behavior of Toyoura sand, standard Japanese sand. Actually, confining pressure besides void ratio also influences the mechanical behavior of sand. Finding out if the confining pressure is another state parameter for sand requires laboratory tests at different ranges of confining pressure. There are various laboratory test data at medium and high confining pressure ($\sigma'_{m0} \geq 49 \text{kPa}$), while the test data at low confining pressure ($\sigma'_{m0} \leq 49 \text{kPa}$) are limited. Element tests including undrained cyclic loading tests as well as drained and undrained strain-controlled monotonic loading test under low and normal confining

pressure (5-98 kPa) were carried out to investigate the influence of confining pressure on the mechanical behavior of Toyoura sand in loose and medium dense state. The confining-stress dependency was investigated systematically by test data and data collected under high confining pressures (1-3 MPa). The results show that loose sand under low confining pressure behaves like dense sand under normal pressure when subjected to monotonic loading, on the other hand, when subjected to cyclic loading, the smaller the confining pressure is, the easier the sand is to liquefy.

Secondly, numerical tests based on a sophisticated constitutive model and a soil-water coupled finite element method (FEM code: DBLEAVES) is used to predict the mechanical behavior of real designed dike and the surrounding ground not only liquefaction behavior due to seismic motion but also its post-liquefaction behavior. The dike subjected to two different seismic excitations is numerically simulated. The results show that earthquake affects not only the immediate behavior of dike and the surrounding soils but also their long-term settlement due to post-earthquake consolidation. The enhancement effect of partial ground improvement with permeable injection of cement is also simulated and it is found that the deformation can be reduced to almost half, indicating that the ground improvement is effective, and that the method proposed in this study can provide a quantitative evaluating method for the daily design of geoenvironmental engineering.

Thirdly, the settlement of piled-raft foundation of Shanghai soil subjected to high-speed train loading is considered systematically. There is a case study that railway settled significantly due to cyclic train loading after a one-month trial operation. The settlement of soft soils due to traffic loading can be divided into two parts: a settlement induced by plastic deformation of the soils subjected to undrained cyclic loading, and accumulative consolidation settlement induced by the dissipation of excess pore water pressure (EPWP) after the loading. Numerical simulation was conducted to investigate the mechanism of the settlement of the piled-raft foundation and EPWP of soft soils caused by the cyclic train loading. In order to demonstrate the performance of this numerical simulation, the calculated results were compared with the data recorded in the one-month trial operation and the reliability of the proposed numerical method is confirmed.

Fourthly, in order to decrease the settlement due to high-speed train loading and ensure the safety of train operation, countermeasure by ground treatment is proposed and the reinforcement effect is numerically analyzed. Countermeasures by infiltration grouting method in the bearing layer of pile group and split grouting method in soft clay layer are investigated respectively. It is found that infiltration grouting in the pile bearing layer can increase efficiently the tip resistance of the bearing layer and consequently reduce the settlement greatly. On the other hand, the split grouting method in soft clay layer cannot increase efficiently the frictional resistance between the clay and the pile group and therefore has less effort in reducing the settlement. Because of lack of recorded data after the ground treatment, numerical simulation is also used to predict the long-term settlement and the change in the EPWP during one-year period.

According to the above discussion, the research on the deformation of structures subjected to earthquake loading and cyclic train loading is comprehensively conducted, and it is useful for the development of geomechanics and can provide the theoretical foundation to solve these kinds of engineering problems.