学位論文の要旨（論文の内容の要旨）
Summary of the Dissertation (Summary of Dissertation Contents)

論　文　題　目
Dissertation title

Numerical Analysis on the Pile Loading in Sand Considering Large Deformation and Particle Crushing

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　　The behavior of piles remains one of the largest sources of uncertainty in geotechnical engineering. Much of the uncertainty is because of a lack of understanding of the physical mechanism that controls the characteristics of deformation, strain and stress in the soil during pile installation and loading. It is hard to estimate the behavior of pile because that soil particles around the pile tip tend to be crushed when the external force exceeds their crushing strength. Another difficulty is to describe the mechanical behavior of structures interacting with soil. Simulating behaviors of the sand crushing and sand-pile interactive region around pile tip provides insight understanding of the pile loading and penetration process. The numerical results will make valuable suggestions to the pile design into crushable soil in practical engineering.

　　The deformation of soil under complex stresses in the soil surrounding the pile tip exhibits typical large deformation behavior. It is important to consider the geometrical nonlinearity caused by the large deformation to establish a model of the actual behavior of the structure. This study aims to implement a thorough numerical analysis on sand behavior around pile considering effects of large deformation and features change of sand crushing.

　　To investigate the mechanical behavior of granular material crushing, the experimental and numerical research of sand particle crushing is conducted respectively. The high compression test apparatus is proposed and three kinds of granular materials are tested to be crushed. The mechanical behavior and crushing ability of three granular materials are analyzed. An elastoplastic constitutive model is employed to represent the mechanical behavior of sand in numerical analysis. Its constitutive tensor is obtained for being integrated with finite element analysis.

　　This study presents a numerical analysis pile loading with different pile tips in sand under three kinds of surcharge pressures. The innovation of this study is that numerical analysis of pile loading is implemented in consideration of both the geometrical and material nonlinearities. The elastoplastic constitutive model and joint element are employed to represent the behavior of sand ground and interactive region. A mixed incremental method for the UL method is integrated with finite element method to solve large deformation problem in this study.

　　The numerical values of normalized bearing stress and displacement is compared with the experimental results. It is found that numerical values by large deformation can improve the prediction accuracy than that by small deformation and agree well with the experimental results. The predicted results show that the distributed shape of the high-level mean stress is ellipse and becomes wider with larger surcharge pressure and displacement. The distributed shape of the high-level deviatoric stress appears firstly near the edge of pile tip and forms the shear band.

The effects of pile tip shape on sand behavior around pile tip are investigated. The axial, radius and circumferential stress and axial, radius and circumferential strain contours around pile tip are displayed. A significant finding is that an underreamed pile with a smaller convergent angle can prevent crack failure on the pile base surface.

Finally, the mechanical behaviors of three selected elements beneath the pile tip at different depths are examined. The predicted relationship between the stress ratio and the deviatoric strain shows that the stress ratio changes for the three elements exhibit nearly the same tendency. The predicted results represent that the volume of element near to pile tip is heavily compressive. The volume of element far from tip slight expands. Such prediction is compatible with deformation of sand in surrounding of pile tip.