論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Constitutive Modeling of Granular Materials Subjected to Internal Erosion
著者(和文)	WangGang
Author(English)	Gang Wang
出典(和文)	学位:博士(学術), 学位授与機関:東京工業大学, 報告番号:甲第12015号, 授与年月日:2021年3月26日, 学位の種別:課程博士, 審査員:髙橋 章浩,北詰 昌樹,竹村 次朗,笠間 清伸,千々和 伸浩
Citation(English)	Degree:Doctor (Academic), Conferring organization: Tokyo Institute of Technology, Report number:甲第12015号, Conferred date:2021/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

2013.8改訂
Revised August 2013

（論文博士）
(Dissertation Doctorate)

論　文　要　旨（英文）　（800語程度）

Dissertation Summary (approx. 800 words in English)

報告番号 For administrative use only	乙 第　　　　号	氏　名 Name	王　剛 Wang Gang

（要　旨）
(Summary)

Internal erosion occurs when fines are detached under hydraulic force. More fines are washed out with the void growth. The soils become looser and soil strength decreases, which subsequently causes the failure of earthen structures. The objective of this dissertation is to develop a constitutive model of granular materials considering deterioration induced by internal erosion.

To quantify the seepage-induced internal erosion process, several series of seepage tests are investigated. The effects of the initial conditions (i.e., initial fines content, confining pressure, flow direction) on the erosion mechanism are elaborated. It is found that the post-erosion grading curves shift downward in the fines fraction for all seepage tests; soils with higher confining pressure and smaller initial fines content have less loss of fines. When downward or upward seepage flow is applied to soils, the heterogeneity of both fines and voids exists along the seepage direction. A predictive equation of the final fines content considering confining pressure, initial fines content, and flow velocity is proposed. At the same time, a hyperbolic tangent function is employed to estimate the erosion-induced volumetric strain based on the experimental observations. The Post-erosion void ratio is estimated by considering the cumulative fines loss and erosion-induced volumetric strain.

The mechanical behavior of internally eroded soils under the drained and undrained triaxial shearing is largely dependent on the erosion phenomena (suffusion and suffosion), the fines content, and the intergranular void ratio. When suffosion occurs, the drained strength of the eroded soils is smaller than that of the uneroded soils, while the undrained strength of the eroded soils is larger than that of the uneroded soils. This contradiction may be related to the stress state and associated particle rearrangement. When suffusion occurs, the undrained strength of the eroded soils is smaller than that of the uneroded soils when the intergranular void ratio is relatively low. The subloading Cam-clay model can capture the basic features of the original soils under the drained triaxial shearing condition. Thus, the subloading Cam-clay model is selected to predict the mechanical behavior of the soils with suffosion under the drained condition. From the triaxial tests, the angle of shearing resistance at the critical state is found to increase with the final fines content when the final fines content is smaller than the threshold fines content. From the simulation of the drained triaxial tests on the eroded soils, evolutions of key parameters (the slope of the normal compression line and initial stress ratio) with suffosion are quantified. The slope of the normal compression line of the loose soils has a positive correlation with the initial void ratio before shearing. The initial stress ratio of the loose soils decreases with the increase of the initial void ratio before shearing.

The over-consolidation ratio is found to increase with the loss of fines for the eroded loose soils, which indicates that erosion makes the loose soils highly structured condition. This implies that the normal yield surface for loose soils is expected to expand after erosion. However, both peak strength and deviatoric stress at the critical state under the drained condition are smaller for the eroded dense soils, and the volume change characteristic becomes more contractive. This means that the normal yield surface for dense soils is expected to shrink after erosion. Based on these, the subloading Cam-clay model incorporated with the similarity ratio for eroded soils is modified. Key parameters in the modified subloading Cam-clay model are the post-erosion void ratio, the slope of normal compression line, the angle of shearing resistance at the critical state, the similarity ratio of the eroded soils. The determination method of erosion-related model parameters is proposed through experimental results and back analysis of the experimental results.

The modified subloading Cam-clay model can predict the mechanical behavior of the eroded dense soils with different cumulative fines losses under the same confining pressure obtained through both the experiments and the DEM simulation. The similarity ratio of the eroded dense soils (R_{er}) increases with the continuing shearing and reaches to be one finally. And it increases faster with the larger value of the degradation parameter (h_0). Both predictive equations for the seepage-induced erosion and the modified subloading Cam-clay model are employed to simulate the seepage and drained triaxial tests of the loose soils with different initial fines contents under the same confining pressure (two-step calculation). This study on the constitutive model considering internal erosion offers some important insights into the design of the earthen structures subjected to seepage flow.