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学位論文題目	Modeling of hydro-mechanical behavior of unsaturated soils considering finite deformation and its application to unsaturated landslide dam stability （有限変形を考慮した不飽和土の力学特性のモデル化および地すべりダム安定性への応用）
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論文内容の要旨

Generally speaking, most of geomaterials in surface ground are in unsaturated state. The mechanical and hydraulic properties of unsaturated soil are much more complicated than those of saturated soil. When soil in unsaturated state, it is not only the problem that the degree of saturation is less than 1, but also its influence on strength and deformation properties of unsaturated soil. Changes of the degree of saturation sometime may even trigger geological disasters, such as landslides or dam breaks, threating human being and infrastructure. Therefore, it is undoubtedly important to study the hydro-mechanical properties of saturated/unsaturated soil, both in laboratory tests and modelling, especially proposing constitutive model that can rationally describe the soils under saturated/unsaturated states in unified way.

Firstly, a series of systematic element tests were conducted on Masado, a completely decomposed granite and widely distributed in western Japan. The water retention properties of Masado were clarified first, and then oedometer and triaxial compression tests were conducted under various hydraulic/mechanical conditions. Two special loading conditions, i.e., constant suction and constant degree of saturation, were considered in the triaxial tests. From the tests, it is found that the strength and

deformation of Masado are greatly dependent on the interaction between suction, degree of saturation and hydraulic/mechanical loading conditions. The test results can provide a fundamental database, based on which it is possible for us to propose a constitutive model that could precisely describe the hydro-mechanical behavior of unsaturated Masado, taking into consideration the fully coupled water retention characteristics, including not only suction and degree of saturation but also the change of void ratio.

Secondly, based on the results of element tests, a water retention curve (WRC) considering the volumetric change in soil is newly proposed, in which the skeleton and scanning curves of water retention characteristics were assumed to parallel shift in accordance with the change in void ratio. The proposed WRC is then incorporated into an existing saturated/unsaturated constitutive model that regards the degree of saturation and Bishop-type skeleton stress as state variables. The results of the tests conducted on the unsaturated Masado are used to verify the validity of the newly proposed model. The proposed model has a satisfactory accuracy in describing not only the stress-strain relation but also the variations in suction and saturation of the unsaturated Masado under drained/undrained conditions.

Thirdly, unsaturated slope stability around the Three Gorges Reservoir (TGR) under various combinations of rainfall and water level fluctuation (FRWL) is studied experimentally and numerically. Model tests on the slope stability of the TGR area were conducted with a synthetic colluvial material S1 under three different rainfall and FRWL combinations. Additionally, numerical simulations on the model tests were conducted, in which proposed saturated/unsaturated soil constitutive model was selected. By comparing the calculated results with the test results, the numerical method used in this paper offers satisfactory accuracy to describe the various failure mechanisms of the model slopes under different loading combinations. The results of both the model tests and the numerical simulation indicate that in the TGR area during one year of operation, a decrease in the reservoir water level combined with a long weak rainfall is more likely to trigger a landslide than the other combinations studied.

Fourthly, the stability of unsaturated landslide dam (LD) with various materials and internal structures is discussed. A systematic flume test programme was conducted, in which Tangjiashan LD was referenced for model design. Particular attention is paid to the heterogeneities of Tangjiashan LD in material and internal structure. The development of phreatic line in model LD was carefully measured by sensors, including piezometer, water content sensor and tensiometer. Furthermore,

corresponding numerical simulations on the flume tests were conducted using proposed saturated/unsaturated soil constitutive model. It is found from tested and calculated results that deformation of LD materials influences the development of phreatic line in the dam body. In addition, hydro-mechanical behaviours of LD materials and internal structure of LD play an important role in the stability of LD.

According to abovementioned discussion, the research on the modeling of unsaturated soils hydro-mechanical behavior and its application is comprehensively conducted. It can provide a reference for the development of unsaturated soil constitutive model and promote the application of unsaturated soil theory in practical geotechnical engineering problems.

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