氏　　名	ホウ　ホウ **PENG Peng**
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学位論文題目	Research on mechanical behavior of geomaterials related to geological repository under different acidic environment and temperature （異なる温度･化学環境下における地層処分に関わる地盤材料の力学特性に関する研究）
論文審査委員	主査　教授　張　鋒 教授　前田　健一 教授　野中　哲也 教授　中野　正樹 （名古屋大学）

論文内容の要旨

Deep geological repository has been adopted for disposal of high-level radioactive wastes (HLW) in Japan. In considering the problem of construction and long-term operation of a deep geological repository, it will work under a coupled thermo-chemical-mechanical condition, due to the heat emitting of the nuclear waste canisters, infiltration of groundwater, swelling of bentonite blocks and mechanical loading of surrounding rock formations. The thermo-chemical mechanical behavior under different acidic environment and temperature of not only the artificial barrier using bentonite-based material, but also of the natural barrier, most of which is sedimentary rock or granite, is definitely important to be investigated both in laboratory tests and modelling.

Firstly, since the lack of verification of geological disposal in these problems in field scope, cement-treated Masado (CTM), as a common cement-mixed geomaterial usually used in ground improvement is focused in this study, as it is despite to face similar thermo-chemical problems of the risk of exposure to environmental changes in acid

conditions and temperature. The influence of the acidic environment and temperature on the mechanical behavior of CTM was systematically investigated by element tests and constitutive modeling. Element tests, including uniaxial compression tests, triaxial compression tests and triaxial creep tests, were conducted under different pH values, temperatures and confining pressures. And all the mechanically tested specimens were also investigated with X-ray fluorescence spectrometry (XRF) analysis to determine the relation between the macromechanical behavior and the microstructure of CTM. Finally, an existing thermoelasto-viscoplastic model was modified to consider the influence of the acidic environment, temperature and confining pressure. In the modified model, substituting for the material parameter representing the stress ratio at the critical state (SRCS) that has a constant value in the original model, four new material parameters are introduced, which can be determined from triaxial compression tests and XRF analysis. By comparing the tested and simulated results of triaxial compression and creep tests, the accuracy of the modified model is confirmed.

Secondly, to verify the numerical method proposed in the works (Zhang & Kurimoto, 2016; Zhang et al., 2019) in estimating the mechanical behaviors of soft rock, heating and loading tests on cave model made of man-made rock were firstly conducted to investigate the basic features of the thermo-mechanical behavior of geological repositories at model scale. Additionally, 2D/3D FEM analyses on the model tests were conducted to simulate the model tests. By comparing the calculated results with the test results, the numerical results can identify various main features of the loading and creep tests, i.e., typical compression failure and thermal dependency.

Thirdly, the tested specimens in triaxial test were investigated with further XRF analysis to determine the distribution of calcium ions. Additionally, 3D finite element analyses were conducted to simulate triaxial tests on CTM under different conditions as a boundary value problem considering the uneven distribution of *Ca* ions, using the proposed thermoelasto-viscoplastic model considering the influence of the acidic environment, temperature and confining pressure. By comparing the calculated results with the test results, the numerical method used in this research offers a satisfactory accuracy to describe the mechanical behavior of CTM in triaxial test under different conditions. The influence of *Ca* ion distribution on the mechanical behavior of CTM was

investigated. In addition, a strain localization within the specimen can be observed.

Fourthly, in this chapter, a new method for preparing the saturated bentonite specimen on normally consolidated state was proposed firstly, based on one-dimensional (1D) compression tests. A series of triaxial compression tests were conducted under various conditions of confining pressure, which was carefully kept the same as compression stress obtained in 1D compression tests. The test results shows a typical mechanical behavior of normally consolidated soil, that relationship between the effective stress ratio and the axial strain is identical and stress paths eventually reach the same critical state line (CSL) under different confining pressure. Therefore, it is shown that the newly proposed specimen preparing method is suitable and can significantly shorten the preparation time than past studies.

According to the abovementioned discussion, the research on mechanical behavior of geomaterials related to geological repository under different acidic environment and temperature and its modeling is comprehensively conducted. It can provide a reference for the practical engineering problems about long-term stability of CTM and bentonite and promote a new theoretical study method for studying the deterioration mechanism of geomaterials related to thermo-chemical problems.