Development of Triaxial Compression Test Method for Sandy Soil Containing Supercritical CO₂

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The mechanical properties of soil containing CO₂ are essential to simulate the geomechanical response to geological storage of CO₂ in sub-seabed formations. A method of preparing an artificial sandy soil specimen containing supercritical CO₂, and a drained triaxial compression test method for specimens used in this study, were developed. The triaxial compressive properties of a specimen consisting of sand, water, and supercritical CO₂ were successfully obtained, and the results were found to be quantitatively similar to those of a water-saturated specimen.

INTRODUCTION

It is essential to consider the geomechanical behavior of a CO₂ reservoir to ensure sustainable geological storage of CO₂ in sub-seabed formations, because it may affect the well integrity, the stability of other subsea structures, the occurrence of geohazards (e.g., subsea landslides and seafloor subsidence), and CO₂ storage capacity.

Some papers concerning the numerical simulation of geomechanical response to geological storage of CO₂ have been published. Yin et al. (2012) conducted a hypothetical numerical simulation using a fully-coupled thermal, hydraulic, mechanical, and chemical model to analyze stress and pressure changes in the rock around a borehole during CO₂ injection and showed that thermal and chemical effects have a significant impact on the stress and pressure change around the borehole. Rutqvist et al. (2010) presented the progress in coupled reservoir-geomechanical modeling of CO₂ injection and ground surface deformations to investigate potential causes and mechanisms of the observed uplift at In Salah, Algeria. Comerlati et al. (2006) preliminarily analyzed the geological CO₂ storage in a saline aquifer below the Venice Lagoon by using a fluid-dynamic and geomechanical model, and showed the CO₂ capacity in a selected aquifer and the corresponding surface uplift. Li and Wu (2005) conducted numerical parametric studies on the influence of geological storage of CO₂ on the slip behavior of faults around the injection well and showed that the change in shear stress along the fault surface is sensitive to the variation of the injection pressure and the thickness and spread width of CO₂ plume.

Geomechanical characteristics of a CO₂-containing formation are necessary to numerically simulate the mechanical behavior of the CO₂ reservoir. Some works concerning laboratory tests for geomechanical characterization for a CO₂-containing rock or coal (Mehic et al., 2006; Viete and Ranjith, 2006; Ranjith et al., 2010; Grgic, 2011; Ranjith and Perera, 2011; Liteanu et al., 2012) have been reported. However, there are various layers with different geological characteristics in an expected field of sub-seabeds around Japan, such as soil, soft rock, and hard rock. Thus, the geomechanical characteristics of CO₂-containing soil and of soft and hard rocks are important to assess the stability of sub-seabed formations.

The triaxial compressive property is one of the most important geomechanical characteristics and is often modeled or formulated to numerically simulate geomechanical behavior. This study aims to develop a method of preparing an artificial sandy soil specimen containing supercritical CO₂ and to conduct a drained triaxial compression test on a specimen under environmental conditions similar to those in an expected field of sub-seabed formations around Japan. This study is considered to be the first step in the geomechanical characterization of CO₂ reservoirs.

EXPERIMENTAL METHODS

Apparatus

The testing apparatus used in this study is drawn schematically in Fig. 1. The apparatus is a digital servo-controlled machine with a maximum axial load of 200 kN. The triaxial cell and pipe lines have a maximum pressure of 20 MPa.

A cyclic confining liquid system was used to control the temper-ature and pressure inside the triaxial cell. A temperature-controlled confining liquid was pumped from the outer thermostat bath into the